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Regional Forest Resource Accounting: A Northern Alberta Case Study Incorporating Fire and Price Risk

by

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Abstract

This study develops a forest resource account for a region of public forestland in northern Alberta. The account includes both commercial and non-commercial uses of the forest. Non market forest services considered include recreational activities, resource use for subsistence, biodiversity maintenance, and carbon sequestration. The implications of incorporating risk in resource accounts are also considered in this study. The findings show that in the boreal forest where forest fire is the dominant form of disturbance, fire risk plays such an important role in determining income flows over time, that the value of this risk needs to be considered in forest resource accounts. As suggested by Brekke (1997) and others, a sustainability rule that requires that the *expected value* of income flows be non-declining over time is more reasonable in this setting than the standard rule of non-declining income or consumption.

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Chapter 1 Introduction

1.1 Introduction

In 1992, many of the world's governments came to a consensus on the goal of sustainable development at the United Nations Conference on Environment and Development (i.e. the Earth Summit) and among other things, agreed to adopt some common principles of forest management. Since 1992, there has been increasing emphasis on promoting sustainable development including sustainable forest management (SFM). Particularly in Canada where the majority of timber harvesting occurs on public lands, the management of forestry practices in a way that considers the importance of non-timber values has become a social objective. In general, forest management is not considered sustainable unless there is a balance between timber harvesting and the protection of non-timber values. However, the appropriate tools for attaining this objective have not been agreed upon and in many cases there is no means in place for assessing whether forestry practices are sustainable.

In Alberta, the Department of Environmental Protection has recognized the need to incorporate the objective of sustainable development in its policies. The Alberta Forest Legacy is the Alberta Government's implementation framework for SFM. This framework was created to ensure that Alberta's forests

> "...are capable of providing us with diverse social and economic benefits today and tomorrow, while at the same time retaining the ecological vibrancy that has made it such a special part of our lives and our landscape" (AEP 1998d p. 1).

The framework outlines the guiding principles needed to meet this objective. Among other things, the framework recognizes the importance of quantifying social values and monitoring performance in relation to sustainability indicators. Overall, the framework "challenges us to look at a broader landscape, and to blend consideration of all resource values, measurable and perceived, when making our management decisions" (AEP 1998d p. 1). Natural resource accounting can assist the government and forest users in meeting these challenges.

Natural resource accounting is a potential tool for assessing the socioeconomic sustainability of forestry practices. The contributions of resource accounting to policy assessment and planning are quite well established. In the area of forestry, several countries (most notably Sweden) have attempted to augment the contribution of timber production to national income with the production of value from other forest assets and services. However, resource accounting at finer resolutions is not common. The formulation of a resource accounting framework that generates useful information regarding the sustainability of regional development in the context of a forest ecosystem is the problem investigated in this study.

1.2 General Problem and Previous Research

Resource accounting has been the focus of both theoretical and empirical research for several years. Several countries have developed national scale resource accounts. The accounts have proven to be useful tools in policy and planning analysis and have given countries an indication of whether resource use is sustainable.

National level forest resource accounts have been developed as part of larger resource accounts and as separate initiatives. Vincent and Hartwick (1997) give a comprehensive list of forest resource accounting applications as of 1997. Despite numerous applications at the national level and a few at sub-national scale, forest resource accounting at the regional level is a new initiative.

Although not all resource accounting systems incorporate future wellbeing, those that do are generally based on simple growth models that assume agents have perfect foresight. This assumption allows the welfare or income measure to be based solely on current information. However, as numerous authors have pointed out, full knowledge of future conditions is not a realistic assumption in many cases (see for example, Brekke (1997)). Recent papers have dealt with the theoretical implications of relaxing this assumption, however, empirical investigations of the issue are limited.

This study will create a regional resource accounting system for a forested region in northern Alberta. Many of the complexities of resource accounting at this finer resolution parallel those of resource accounting at the national level, however, constraints and challenges unique to the regional and forestry context are also dealt with throughout the study. As in the national context, once established the framework has the potential to be a valuable management tool that can be used as the basis of modeling and simulations aimed at assessing the impacts of a variety of different environmental and economic conditions. In addition, the maintenance of the system over time can help a company or resource manager to track the implications of operational changes and the socioeconomic sustainability of its practices.

Since future income flows from the case study region are characterized by fire and price risk, the perfect foresight assumption does not apply. Although, not formally incorporated into the accounting system or net income measure for the region, the implications of these forms of risk are empirically investigated. Simulations incorporating the stochastic nature of these forms of risk, illustrate how consideration of risk is required when assessing the sustainability of the activities in the case study region.

1.3 Objectives

This study aims to advance the existing literature related to resource accounting and illustrate how regional forest resource accounts can provide valuable information to forest resource managers. The objectives of the study are threefold. The first objective is to develop a resource accounting framework for a forested region in northern Alberta. The second objective is to use this case study as a vehicle for identifying the usefulness of resource accounting at the regional level and to identify some of the complications and difficulties that are unique to the regional and forestry context. Finally, this study aims to investigate the role of risk in resource accounting and its influence on the use of resource accounts for assessing sustainability using the case study as an illustration.

1.3 Outline of Study

This study will begin with a discussion the development of natural resource accounting and a review of applications of resource accounting at the regional level and the creation of resource accounts specifically for forest resources. The next chapter will review the objectives of resource accounting and then focus on the use of resource accounting as a tool in sustainable welfare measurement. The fourth chapter will provide a description of the case study including a description of the region and the forest values that will be included in the accounting system. Chapter 4 will also provide estimates of the value of the components of the accounting system and discuss how particular values were attained and any inherent biases. Chapter 5 will build on the basic accounting framework by investigating the influence of fire and price risk on the realization of future income flows in the region. The final chapter will provide summarizing remarks, conclusions and comment on the limitations of the study. Recommendations and avenues for future research will also be discussed.

Chapter 2 Background

2.1 Introduction

Dissatisfaction amongst economists and researchers from other fields with the use of GDP or GNP as an indicator of a country's progress and aggregate welfare led to calls for adjustments to this measure of national income. The field of resource accounting was initiated by those that felt that conventional national accounting inadequately reflected the effects of environmental degradation and of natural capital depletion on national welfare. Therefore, at its conception, resource accounting was focused at the national level. However, there have been a few attempts to develop resource accounts at the regional level. There have also been a number of studies and national initiatives that focus specifically on the development of forest resource accounts.

2.2 The Contribution of the Environment to Welfare

The environment contributes to social well being in a number of ways. The environment can be considered a form of natural capital as opposed to human-made or produced capital. As with other forms of capital, natural capital creates a flow of services that are used by humans. Natural capital can affect human wellbeing indirectly when resources or environmental services are used as inputs in production. Dasgupta *et al.* (1994) point out that

> ...if the relevant production units are included in the national accounts, then changes in the flow of current services are measured by conventional GNP; a change in the quantity of one service will affect the operating surplus and the operating surplus is accounted for in the value added of the production unit. This means that indirect uses will already be reflected in the current SNA [System of National Accounts], if the relevant production units are included (p. 122).

The flow can also "directly affect human well-being, as exemplified by clean air, recreational opportunities and food gathering" (Dasgupta *et al.* 1994 p. 122). Environmental degradation that accompanies the use of natural resources can be seen decreasing the positive benefits provided by the flow of environmental goods and services such as clean air and water. These benefits are not accounted for in conventional accounting procedures such as the System of National Accounts (SNA).

Therefore, the current flow of environmental services can affect human welfare directly and indirectly. However, the size of the stock of natural capital is also important because current changes in the stock of natural capital affect the future flow of services provided by the environment and therefore have implications for the welfare attained in future periods. In other words, "...the well-being of future generations are reflected in the stock of assets the current generation is leaving to the future. If we are interested in the well-being of future generations, we should obviously include the net changes in the productive assets in the accounts" (Dasgupta *et al.* 1994 p. 126). Such stock effects are generally associated with the depletion of non-renewable resources; however, in theory, changes in the stock of all forms of natural capital both renewable and non-renewable should be included. Conventional calculations of net national product (NNP) account for stock effects that result from the running down or depreciation of human-made capital through a capital consumption allowance which is subtracted from gross national product (GNP). However, there is no equivalent depreciation charge made to account for natural capital depletion.

2.3 Resource Accounting at the National Level

In the words of Repetto (1989), the current SNA "reflects the Keynesian macroeconomic model that was dominant when the system was developed" (p. 1). At the time of its development in the 1930's, most economists were preoccupied by the business cycle and persistent unemployment. In general, Keynesian economists were not concerned with natural resource scarcity. The accounts focused on the need to measure the total demand for outputs of produced commodities so that the economy could be fine-tuned to avoid unemployment and inflation. Although gross domestic product (GDP) and GNP derived from this system may be useful for these purposes (although even this has been disputed); they were also used for other purposes including as welfare measures (Mäler 1991).

The origin of the SNA is likely an important reason why the contribution of natural resources to production and economic performance are not well represented in the system. As discussed above, natural resources are not treated like other tangible assets. In the words of Solorzano (1991), "the national accounts thereby create the illusion of income development, when in fact, national wealth is being destroyed. Economic disaster masquerades as progress" (p. 1).

Recognition of these deficiencies in the SNA combined with the emergence of the sustainability issue has stimulated "concern about problems with national income accounting conventions in relations to their treatment of the interconnectedness between economic activity and the natural environment" (Common 1995 p. 194). The product of this concern has been the proposal of a number of adjustments to the conventional national accounting framework. The revision and adjustment of the national systems of accounts for these purposes is referred to as resource accounting (or sometimes environmental accounting or less frequently green accounting or environmental asset valuation).

Today, there appears to be widespread consensus that the national accounts need to be modified at least with respect to the way in which environmental stocks and flows are recorded (Pearce 1992). However, there is no such consensus regarding the best and most practical way to adjust the national accounts. As a result, many different frameworks for developing resource accounts have been suggested and many different methods for valuing resource depletion and environmental degradation are used in these frameworks. However, all the systems have been developed with a common goal of improving information regarding the link between economic activity and natural resources and the environment. With the growing emphasis on sustainable development that does not comprise the environment or the welfare of future generations, modification of the SNA seems inevitable. (Additional information regarding national level resource accounting initiatives is provided in Appendix I.)

2.4 Regional Level Resource Accounting

Resource accounting at finer resolutions is a less common initiative, however, where undertaken it has been proven to be a useful framework for summarizing economic activity and incorporating important environmental benefits and losses. Prudhan and Lonergan (1992) develop a resource accounting framework for the Vancouver Island region. They also briefly review the status of regional level resource accounting at the time. They note that the French patrimony accounts and the System for Integrated Environmental and Economic Accounting (SEEA) include provisions for developing accounts at a finer spatial resolution and that "Gilbert and Hafkamp (1986) discuss the potential for regional resource accounting applications" (p. 21). The observation of Prudhan and Lonergan (1992) that the "development of a sub-national, sub-provincial accounting focus has not been a dominant theme in the literature" continues to apply. However, there have been some empirical studies that estimate environmentally adjusted income levels for specific regions or resource industries. For example, Swedish economists including Hulkrantz have developed resource accounts for the Swedish forests.

2.5 Forest Resource Accounting

The first Canadian application of resource accounting is the Alberta timber account compiled by Anielski (1994). The study is part of a broader resource accounting initiative lead by Alberta Treasury and Alberta Environmental Protection, to develop resource accounts for oil and gas, coal, agricultural soils, forests, carbon, and water. Anielski uses the methodology recommended by the United Nation's guidelines for incorporating natural resource and environmental capital accounts into the traditional SNA. However, Anielski makes no attempt to include non-market values in the forest account. An earlier study by Balasubramaniam (1992) which makes use of Anielski's preliminary data does make an attempt to incorporate non-market values but the scope is limited to recreational values.

Hulkrantz (1992) "outlines an extension of the national account of income from forest resources in Sweden 1987, incorporating changes in timber inventories, production of non-marketed timber and non-timber goods, and depletion or improvement in vital environmental stocks such as soil nutrients, biodiversity and carbon sinks" (p. 283).[1] The paper focuses on environmental stocks and non-marketed forest products but does not attempt to value all environmental services provided by the forest.[2] The components of income generated from non-marketed forest resources that Hulkrantz does attempt to value include fuelwood consumption, berries, mushrooms, and meat from hunting. The annual change in carbon storage, biodiversity, exchangeable base cations, and reindeer forage within the forest is also valued. Hulkrantz uses a variety of different valuation methods dependent on the data available. Some of these methods are more theoretically justifiable than others and will be discussed in subsequent sections.

Adger *et al.* (1995) estimate the total economic value (TEV) of Mexico's forests. Although not undertaken with the intention of devising an accounting system, the exercise involves estimating the value of a number of non-market forest benefits including tourism and recreation, non-timber forest products, carbon storage, watershed protection, option value, and existence value. As in Hulkrantz (1992), Adger *et al.* (1995) use a number of different methods for valuing these non-market services.

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[1] Hartwick (1990) and Mäler (1991) are the basis of the capital theoretical framework used by Hulkrantz.
[2] Use values associated with recreation activities are not included. Hulkrantz (1992) argues that "the introduction of recreational values is clearly inconsistent with the way leisure and work are accounted in the current national account" (p. 286).

Several other countries have also developed forest resource accounts; however, much of the work is not reported in academic journals or other published media. Vincent and Hartwick (1997) provide a bibliography of forest resource accounting applications that includes both published and unpublished documents and reports.

2.6 Summary

Dissatisfaction with the lack of incorporation of the contribution of the environment to welfare in conventional income accounting sparked the development of resource accounting. The development and application of RA was initially focused at the national level but a small number of regional and forest resource specific RA systems have been developed in recent years. By developing and applying a regional level accounting system for a forest products company, this study will make a significant contribution to the existing literature. The formulation of this system so that it provides a consistent measure of the region's sustainable income and the investigation of the sensitivity of this measure to risk will be an even more valuable undertaking.

Chapter 3 Resource Accounting Frameworks and Methodologies

3.1 Introduction

As noted in chapter 2, there have been few applications of resource accounting systems at the industry or regional level. However, despite the change in spatial resolution the main objectives of resource accounting are the same. Therefore, the theory and empirical work associated with resource accounting at the national level can be used as a guide.

As noted in Dasgupta and Mäler (1991), there have been a number of proposals in recent years to modify conventional national income accounting practices to incorporate environmental and natural resources. These frameworks are reviewed in a number of sources. Peskin (1991), Peskin and Lutz (1993) and Dasgupta *et al.* (1994) describe some of the resource accounting frameworks that have been applied by government agencies and researchers.

The discussion below will focus on the link between resource accounting and the assessment of sustainability. After reviewing theoretical work related to sustainable welfare measurement in a resource accounting framework, the various methods that exist for calculating the resulting index will be discussed. The limitations of the use of the framework will also be identified. The way in which these limitations will be addressed within the case study will also be discussed.

3.2 Objectives of Resource Accounting

Resource accounting systems have developed with a variety of objectives in mind. Many national level resource accounting systems aim to adjust conventional income accounting aggregates to arrive at a more defensible welfare measure. In other cases, resource accounting has been more focused on assessing environmental and resource policies (see for example Repetto (1989) and Sadoff (1995)). Particularly at the regional level, resource accounting systems may also play a role in assessing the sustainability of current practices (see for example Anielski (1991)) and be used to simulate the implications of future practices and economic or environmental conditions.[3]

The content and organization of the accounts is dependent on which of these objectives the accounts have been constructed to address. For example, in some cases resource accounting frameworks focus on the compilation of physical data representing the stock and flow of resources (Peskin and Lutz 1993). However, if the objectives of the system include the adjustment of accounting aggregates, then it is necessary to express information in monetary terms as well. Based on this delineation, resource accounting systems can be considered to take either a physical or monetary approach.

3.2.1 Physical and Monetary Accounting

As noted by Dasgupta *et al.* (1994), "resource accounting in physical terms avoids the complexity of transforming resource use into monetary terms" (p. 133). The physical resource "accounts can be linked to the conventional economic accounts through the use of ratios (or input-output coefficients) that express units of energy or material use per unit

[3] As will be discussed in subsequent chapters, the use of resource accounting systems for these purposes requires a number of assumptions.

of production or sales" (Peskin and Lutz 1993 p. 148). Therefore, physical accounts can be useful tools for revealing economy-environment interactions.[4]

One of the disadvantages of physical resource accounting is that aggregation is difficult due to the lack of common units of measurements (Peskin and Lutz 1993). As noted above, if the objectives of the RA system include the adjustment of conventional accounting aggregates and the assessment of the sustainability of income over time, as are two of the objectives of this study, then physical changes need to be expressed in monetary terms. By using various methods to estimate monetary values, monetary approaches allow the calculation of adjusted accounting aggregates (i.e. green NNP).

However, lack of consensus regarding the appropriate methods for estimating monetary values and how these values should be integrated into conventional accounting systems has led to the development of a number of different methodologies. Some researchers have focused primarily on how to value the flow of environmental goods and services and others have focused on how to account for the stock effects associated natural resource depletion.[5]

3.3 NRA as a Tool for Assessing Sustainability

It was noted above that resource accounting systems can aid in revealing the sustainable or unsustainable nature of existing policies and activities. To date the link between welfare measurement, national income accounting and sustainability concepts has mainly been investigated by supporters of present value maximization, namely Weitzman, Dasgupta, and Mäler, and recently reviewed in Aronsson, Johansson and Löfgren (1997). Their findings will be discussed in the next section.

3.3.1 From Income Measurement to Sustainable Welfare Measurement

As noted earlier, one of the driving forces behind the development of resource accounting, particularly monetary resource accounting, was the search for a more defensible welfare measure. However, even before the emergence of resource accounting, researchers have been searching for a meaningful welfare concept. In this regard Weitzman (1976 p. 156) notes that:

> "As Samuelson convincingly argued, the rigorous search for a meaningful welfare concept leads to a rejection of all current income concepts and ends up with something closer to a "wealth-like magnitude", such as the present discounted value of future consumption".

However, Weitzman also argues that all current income concepts do not necessarily need to be abandoned in the search for an appropriate welfare measure. He demonstrates that "the welfare justification of net national product is just the idea that in theory it is a proxy for the present discounted value of future consumption" (p. 156).[6] Such findings have led

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[4] Norway is an example of one country that has chosen to limit its efforts to physical resource accounting.

[5] Some literature has also addressed the organization of the resulting values into a consistent accounting structure or merging them into the current SNA but this work is not particularly relevant to the current study.

[6] According to Weitzman (1976), "net national product is what might be called the *stationary equivalent* of future consumption, and this is its primary welfare interpretation" (p. 160).

researchers such as Hartwick (1990) to comment that "NNP is the best welfare measure we have under standard national accounting procedures" (p. 291).

But what exactly is NNP? In addressing this question Weitzman (1976) demonstrates that NNP function is just the current value Hamiltonian[7] along an economy's optimal growth path. NNP can also be conceived of as the annual pay-off from the economy's capital stock (Hanley *et al.* 1997). Another more intuitive description is that NNP is "the largest permanently maintainable value of consumption" (p. 159). Therefore, part of the welfare justification for NNP is that it captures the importance of dynamic considerations since it is derived from the intertemporal optimization of an economy's growth. Of course, as in most intertemporal optimization problems assumptions regarding the future are required.

It would seem that NNP is an appropriate foundation for the calculation of a welfare measure that incorporates environmental degradation and natural resource depletion. Under this presumption, Weitzman's "capital theoretic treatment of the national accounts" has been extended to incorporate exhaustible (Solow 1986), renewable and environmental resources (Hartwick 1990) and to arrive at a measure of 'green' (or 'environmentally adjusted') NNP.[8] The importance of dynamic considerations in national accounting which is stressed in Weitzman's work is also the foundation of the RA frameworks developed in Maler (1991), Dasgupta and Maler (1990) and Dasgupta *et al.* (1994). These frameworks "use an optimal growth model to study the most important characteristics of an accounting framework" (Dasgupta *et al.* 1994 p. 120) and "how a proper environmentally adjusted national product should be calculated" (Dasgupta *et al.* 1994 p. 118). The work of these authors parallels the work of Weitzman (1976) but concentrates more heavily on the implications for consistently incorporating the environmental sector in the calculation of NNP.

Dasgupta and Mäler (1991) argue that a RA framework should be derived from economic theory of resource allocation, otherwise the aggregate welfare measures generated will not have a specific interpretation. This sentiment is echoed by the following comment in Kristrom (1995 p. 168):

> "Without basing our systems on welfare economics theory, we run the risk of assembling information that is inherently useless... Measurement without theory is as dangerous in resource accounting as it is elsewhere".

Kristrom argues that this is significant because for systems that are not based on any "supporting theory, we cannot tell what an increase or decrease in our indicator signifies" (p. 165).[9]

Other RA frameworks also address "...the importance of dynamic considerations in national accounting, particularly with respect to the representation of consumption over time as being the true measure of an economy's "wealth"" (Faber and Proops 1991 p. 215). Faber and Proops (1991) argue that the "appropriate valuation of the stocks and

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[7] The current or present value Hamiltonian is the objective function in a dynamic optimal control problem. For an introduction to optimal control theory as it relates to welfare measurement see Chapter 2 of Aronsson *et al.* (1997).

[8] Weitzman's approach is considered to be capital theoretic because he assumes that capital if the source of all economic growth. His broad notion of capital allows this assumption to be realistic.

[9] In addition, Kristrom (1995) argues that "Mäler's work provides a consistent system of accounts that avoids the many risks of double-counting that plague other approaches" (p. 166).

flows of the natural world must be an intertemporal valuation, if they are not to add to the problems of national accounting" (p. 214). They concur with Samuelson and Weitzman that consumption over time is the true measure of an economy's wealth. However, Faber and Proops develop a RA framework "by using an input-output framework and a neo-Austrian model of intertemporal production" (p. 215). They note that the application of the resulting model is likely to be impractical and "that alternative institutions and conventions have to be developed to measure and value the scarcity of the services provided by the ecosystem" (p. 214).

Peskin has developed an accounting framework "based on a neoclassical economic theory that treats environmental assets as if their contribution to economic activity were similar to that of conventional, marketed assets" (Peskin and Lutz 1993 p. 146). The resulting "...accounting structure has the input-output form of the conventional consolidated income and product account with several modifications" (Peskin and Lutz 1993 p. 146). Peskin (1989, 1991) describes the conceptual foundations of this framework and Grambsch *et al.* (1993) describes the result of an empirical application of the framework. Peskin (1989) suggests that in order to minimize the cost of expanding the national accounts, the framework should closely adhere to the accounting structure of the existing national income and product accounts. Such a feature may be of importance for the integration of RA with the existing national income accounting activities but not for the development of a RA system at the regional level where there is no previous income accounting structure in place.

3.3.2 NNP and Sustainable Development

Mäler and other supporters of discounted utilitarianism argue that Green NNP can be used to assess whether or not an economy is following a sustainable path. In support of this, Mäler (1991) re-states Weitzman's interpretation of NNP and relates it directly to the concept of sustainable development. In the words of Mäler (1991 p. 126),

> "the present discounted sum of today's current-value Hamiltonian is equal to the maximum present discounted value of the flow of social well-being. Thus the current-value Hamiltonian is the maximum sustainable flow of social well-being".

Furthermore, Mäler (1991) notes that the green NNP measure that he derives represents "the maximum consumption that can be allowed if future consumption should be prevented from decreasing" (p. 11). Or in other words, it is a measure of sustainable income in utility terms since it represents the maximum current utility that can be sustained forever.[10]

Assuming that Green NNP is a measure of sustainable income, sustainable development *might* be defined as following a development path which never allows Green NNP to fall. This definition implies that sustainable development is construed in terms of non-decreasing utility over time.

[10] It should be noted that, as Kristrom (1995) points out these conclusions are limited to the specifics of the model used. In other words, NWM is more correctly a measure of *sustainable income from the components included in the welfare function* used in the model. If significant aspects of human welfare (i.e. crime and education) are not included then NWM will not be a true measure of sustainable welfare.

A recent Environmental Economics textbook by Hanley *et al.* (1997) recognizes Green NNP as an indicator of sustainability and describes some of its features. They suggest that Green NNP is a good measure of sustainable development

> "...when all elements of NNP are valued in terms of the current economic situation, ...when this is true in a forward-looking sense too (prices reflect future scarcity); and third, when all depreciation of natural capital is similarly adjusted for as well" (Hanley *et al.* 1997 p. 434).

They note that if the total capital stock (man-made plus natural) increases and/or technology improves then green NNP can increase over time (Hanley *et al.* 1997). However, if green NNP falls then this indicates that "society's sustainable level of income is falling too" (p. 434).

Hanley *et al.* (1997) also comment on how a sustainable path can be attained. As noted above, in order to ensure that the overall productive capacity of the economy is not reduced, the total stock of capital must be maintained. They advocate the Hartwick rule:

> "...each year, reinvest the Hotelling rents (price minus marginal cost) from an optimal non-renewable resource extraction plan in new natural or man-made capital" (Hanley *et al.* 1997 p. 434).

3.4 Calculation of Green NNP

Although presented from a national perspective, the NRA frameworks developed by researchers following in the footsteps of Weitzman (1976) act as the most theoretically justifiable guide to the calculation of a sustainable welfare measure at the regional level (assuming that PV optimality is accepted as justifiable). For example, Kristrom (1995) argues that "Mäler's work provides a consistent system of accounts that avoids the many risks of double-counting that plague other approaches" (p. 166). However, as admitted by Mäler (1991) they tend not to thoroughly address the implementation issues associated with such frameworks.

Mäler (1991) derives the Green NNP function for a simplified economy using an optimal growth model and then discusses the components of the resulting function as they relate to welfare measurement. Green NNP can be obtained from conventional NNP[11] by subtracting the wage bill for raw labour, adding the value of flow services provided by the environment, and deducting the value of input goods used to enhance the stock of environmental assets. The value of current environmental damage as valued by households and the value of the degradation of resource stocks with a price reflecting future value of the stock should also be netted out.

The calculation of Green NNP requires that appropriate accounting or shadow prices be used to value the components of the accounting system including resource depletion, and the flow of environmental services and environmental damage. This requires collection of physical data on flows and opening and closing stock levels for the accounting period and the estimation of accounting prices.

[11] Conventional NNP includes the consumption of marketed goods, public expenditures and the value of the net change of human-made capital.

3.4.1 Estimating Accounting Prices

Dasgupta (1995 p. 124) defines the accounting price of a resource as "the increase in the maximum value of aggregate well-being if a unit more of the resource were made available costlessly. (It is a Lagrange multiplier.) Accounting prices are, therefore, the differences between market prices and optimum taxes and subsidies". For the case of the optimizing economy, Dasgupta notes that the optimization process enables the estimation of accounting prices which can be used even for an economy that is not at its optimum.

Dasgupta also suggests that accounting prices can be "estimated from the prevailing structure of production and consumption (and not from the optimum)" (p. 125). Dasgupta (1982) explains that "one may use the gradient of the social welfare function at any state of the economy as a system of accounting prices at that state... It follows that under these circumstances one may regard social discount rates as social rates of indifferent substitution of the numeraire between adjacent dates even when the economy is far from the optimum" (p. 103). This procedure is analogous to the 'gradient process' or hill climbing method used in social cost benefit analysis to reach an optimum when the net benefit function is considered to be convex. The method uses "the rate and direction of maximum increase in social welfare - the gradient of the (net) social benefit function - wherever the economy happens to be at. And one ought to use the gradient as the set of accounting prices at that point for evaluating marginal projects" (p. 53).

Unfortunately, even if the prevailing structure of production and consumption can be used as a basis, the estimation of accounting prices is not a simple task. For private goods the market price must be adjusted for distortions such as subsidies. There are also many other goods for which no market exists and therefore no market price exists. There are a number of techniques available for estimating 'non-market' benefits and losses (see Freeman 1993). However, the cost and complexity of more theoretically sound techniques often makes their use impractical for the purpose of resource accounting. This has caused researchers to use a number of different estimation procedures depending on data availability and other circumstances.

Several of the most common valuation techniques used in the RA literature to estimate the accounting or shadow prices associated with resource depletion and environmental degradation are discussed below. Some of these methods are rather *ad hoc* and some are inconsistent with the type of RA frameworks that have been formerly discussed. This results from the fact that there are number of RA frameworks that have been developed that are not based on the type of wealth-like or dynamic concept of welfare discussed above, in fact, some are not based on economic theory at all.

3.4.1.1 Valuing the Depletion of Natural Resources

The two most commonly discussed and used methods for deducting the value of resource depletion from the SNA are the user cost and depreciation approaches.

The user cost approach is "based on the premise that the consumption of natural capital should not be included as value added in national income" (p. 32). When natural resources are depleted, the revenues include not only value added but also a component of capital consumption or user cost. User cost can be viewed as the amount of future income that is no longer available due to the current use of the natural resource (Sadoff 1995).

Appendix II outlines the calculation of user cost for non-renewable and renewable resources.

Whereas the user cost approach focuses on the discounted value of forgone future income, the impetus behind the depreciation approach is that income should be adjusted to account for the re-investment necessary to maintain economic productivity after natural capital is depleted. The method of depreciation suggested is the same as the procedure currently used to depreciate human-made capital. The method requires that the amount by which natural assets are depreciated in an accounting period be subtracted from the revenues generated by the resource depleting activities.

As reviewed by Hanley *et al.* (1997; pp. 436-439), Hartwick (1990) discusses exactly how to calculate natural capital depreciation.[12] According to Hartwick (1990), for the case of non-renewable resources, the Hotelling rents (or economic rent or residual value), which correspond to the product of the net annual change in the stock of the resource (new discoveries - annual production) and price minus marginal extraction cost, should be deducted from NNP.[13] For the case of renewable resources, an analogous adjustment factor is used by Hartwick. "Hartwick models the introduction of renewables into the system by including a term in the utility function to represent... [the annual harvest]" (Hanley *et al.* 1997 p. 437). Hartwick shows that the optimal deduction from NNP is the product of the net change in the resource stock and the ratio of marginal utilities (marginal utility of harvest/marginal utility of consumption of other goods) minus marginal harvesting costs. In a competitive market, the ratio of marginal utilities is equivalent to the market price.

Hartwick's rules for calculating the depreciation of resources can be summarized in mathematical terms:

Non-Renewable Resource Depreciation (D_n):

$$D_n = [P - MC][D - R] \qquad (1)$$

where P = market price of the resource;

MC = marginal cost of extraction;

D = new discoveries of the stock; and,

R = the current flow (extraction) of the non-renewable resource (Hartwick 1990).

Renewable Resource Depreciation (D_r):

$$D_r = \left[U_E / U_C - MC \right] [G - H] \qquad (2)$$

where U_E / U_C = marginal utility of harvest divided by marginal utility of consumption of other goods;

MC = marginal cost of harvesting;

G = growth of the stock; and,

H= the current flow (harvest) of the renewable resource (Hartwick 1990).

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[12] Mäler (1991) notes that the Hartwick's approach is essentially the same as the one that he presents. However, Hartwick provides a more clear and stepwise guide to the appropriate calculation of shadow prices for the depletion of different types of natural resources.

[13] As Hanley *et al.* (1997) note, this assumes that "all inputs/outputs are valued at their correct shadow prices" (p. 436).

The relative merits of the user cost and depreciation approach have been discussed in the literature (see Sadoff 1995 and Prudhan and Lonergan 1992). Neither method appears to be clearly superior in terms of practicality and data requirements. However, the depreciation approach is consistent with the concept of Green NNP as a measure of sustainable income and as discussed in a subsequent section, it appears more amenable to the incorporation of uncertainty and risk associated with future streams of income which will be a component of this study.

3.4.1.2 Valuing Environmental Flows

Several methods for valuing environmental non-market goods and services and environmental degradation have been suggested and applied in resource accounting literature. Some researchers suggest using the defensive expenditures, which refer to expenditures undertaken by individuals or firms to decrease the impact of environmental damages, as an estimate (Mäler 1991). This valuation method has been criticized for a number of reasons. First, defensive expenditures are only an accurate measure of individuals' willingness to pay (WTP) in limited circumstances. Second, defensive expenditures may include both final and intermediate expenditures since household defensive expenditures are generally final expenditure and firm's defensive expenditures are generally intermediate expenditures. Therefore, deleting defensive expenditures from national expenditure in an attempt to adjust for environmental damage would "break the equivalence between factor incomes and expenditures that is fundamental to conventional accounting" (Pearce 1992 p. 16).

The avoidance cost or restoration cost method calculates the cost of restoring the environment to a pre-defined environmental quality level. An example may be valuing the societal loss from acidification of a lake by calculating the cost of liming the lake to return it to its former pH. However, as with defensive expenditures, restoration costs may not accurately reflect individuals' WTP. Using this method may lead to significant overestimates of the true value of environmental quality changes.

Hueting (1991) advocates the use of environmental functions to represent the various uses of the environment in production and consumption. "When the use of an environmental function conflicts with the use of another or the same function, either in the present or future, loss of function occurs" (p. 198). Hueting argues that in order to derive shadow prices for environmental functions demand and supply curves for these functions must be constructed. Hueting suggests that the supply curve can be "constructed by estimating the costs of measures need to prevent the loss of function" (p. 199) and therefore, the supply curve can be referred to as the 'elimination cost curve'. Hueting argues that the construction of the demand curve is a much more complicated matter and suggests that it is usually not possible. As an alternative Hueting (1991) proposes that physical standards for the sustainable use of environmental functions be defined, the measures necessary for meeting these standards be determined and finally the cost of instituting these measures be estimated. Considering recent advances in the area of non-market demand estimation, it seems that the estimation of these demand curves is now likely to be feasible in many cases, however the practicality in terms of cost is likely to the limiting factor.

A similar method that has been suggested for estimating the monetary value of environmental damages is to use the "politically determined willingness to pay". This method assumes that there are politically determined environmental goals and uses the annual costs of achieving these goals as a proxy of the public's WTP. A criticism of this method is that explicitly set environmental goals rarely exist and when they do they often change over time.

Possibly the most theoretically justifiable but most expensive method to elicit willingness to pay is by using direct methods such as contingent valuation methodology or indirect methods such as the travel cost method and hedonic price models (see Freeman (1993) for a review of these techniques). Although extensive use of these methods is likely to be impractical, where these methods have been used to estimate WTP for other research purposes in the area, they might be used to value some aspects of environmental quality changes. In addition, benefits transfer may allow estimated models of WTP for specific non-market goods and services in other areas to be used to estimate WTP for the same goods and services in the area under consideration.

There is no consensus regarding the appropriate method for valuing environmental service flows and environmental degradation. The choice of method involves a trade-off between theoretical consistency, cost, and practicality. An assessment of these trade-offs has lead researchers to different conclusions regarding the appropriate methods to use.

3.5 Complications in Welfare Measurement using Green NNP

The measurement aggregate welfare and the determination of whether or not current practices are sustaining welfare are complicated by a number of factors. These complications are related to the implied sustainability concept, limitations in the comprehensiveness of components included in the calculation of Green NNP and other assumptions underlying the interpretation of Green NNP as a measure of sustainable welfare. A brief explanation of how these complications will be addressed in this study will be given.

3.5.1 Sustainability Concepts

Most definitions of sustainable development include an intertemporal component through reference to concern for the welfare of future generations or the level of utility over time. Underlying the work of Weitzman (1976) is the belief that sustainable development can be defined as non-decreasing utility (welfare) over time. Dasgupta, Mäler, Hartwick and many other economists feel that the concept of sustainability can be adequately addressed and analyzed using growth theoretic tools that were introduced to resource economics in the 1970s (Howarth 1997). They essentially suggest consumption or income levels over time are the true indicators of welfare and that society's intertemporal concerns will be adequately addressed if it strives to maximize the present value of future utility (welfare). The ethical implications (see for example Goulder and Kennedy 1997) and other aspects of this definition of sustainability are not accepted by all economists.

A number of economists are opposed to the idea that present value optimality is the correct way to reflect society's intertemporal concerns and "a number of practitioners have pointed out the inadequacy of discounted utility for analyzing sustainable growth"

(Chichilinisky 1997 p. 485). For example, Pezzey (1997) argues that "the axioms underlying present valuation maximization are ethically arbitrary, and refuted by empirical psychological data" (p. 463). As a result, a wide range of axioms has recently been suggested as possible constraints on societies' goals for distribution over time (Howarth 1997; see for example Chichilinisky 1997). Pezzey (1997), on the other hand, argues that there is more of a "*preference for sustained development*" as opposed to societal support for sustained development as an overriding constraint" (p. 762, emphasis within). Assuming that this is true this leads to the question of "whether "preferences for sustainability" can be built into a well defined IWF [intertemporal welfare function] which people maximize" (Pezzey 1997 p. 461).

Another division in thought regarding sustainability has lead to the concepts of weak and strong sustainability. Weak sustainability assumes that "...[hu]man-made and natural capital can be fully substituted...", whereas strong sustainability assumes that substitution between the two types of capital is limited (Serôa da Motta 1994 p. 23). Supporters of strong sustainability argue that public policies should aim to maintain the physical stock of natural assets (Pezzey 1997).

The welfare measure resulting from the resource accounting frameworks developed by Dasgupta, Mäler, Hartwick and their colleagues assumes that weak sustainability applies. However, if the physical stock of natural assets is available, it can easily be determined whether or not the criteria for strong sustainability are being satisfied.

3.5.2 Limitations in Calculating Green NNP

If Green NNP is to represent aggregate welfare it should include all components of welfare. Therefore, ideally, a resource accounting system, whether national or regional in scope, should include all stocks and flows that contribute to welfare including such abstract components as changes in human capital and the value of ecological services such as the air purification performed by trees.[14] Unfortunately, this is an unrealistic task due to the difficulties and/or cost involved in quantifying some of the determinants of welfare. For these reasons, empirical applications of resource accounting tend to focus on the most significant components of welfare and those components for which there is physical and monetary data available. The result is an incomplete but improved measure of welfare. Furthermore, the index of sustainability, green NNP, generated by the accounting system must be interpreted according to the components that are included in the system. For example, in this case, the value of green NP can only be used to assess whether the income generated by the components included in the accounting system is being sustained.

3.5.3 Relaxing the Assumptions

A recent book by Aronsson, Johansson and Löfgren (1997) reviews issues related to the use of a national product related welfare measure (Green NNP as it has been referred to thus far in this study) and sustainability. Much of the book is dedicated to the review of recent literature that demonstrates how the welfare interpretation of NNP is highly dependent upon a number of assumptions. The book also discusses the implications of relaxing these assumptions.

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[14]See chapter 5 of Aronsson, Johansson, and Löfgren (1997) for a review of how the value of human capital might be included.

Weitzman (1976), Mäler (1991) and others use a simple Ramsey Growth Model to derive their results. Generally, the model assumes that: the economy is perfectly competitive; externalities do not occur; the dynamics of the economy are essentially time-autonomous with social utilities discounted at a constant rate (stationarity or time invariance assumption); capital is homogenous; and, agents have perfect foresight, therefore, there is no uncertainty regarding the future. As noted earlier, use of such a model assumes that present value maximization in an adequate framework within which to assess sustainability.

If the assumptions of the Ramsey Growth Model are met then all information required to measure welfare is available in current market data and the current value Hamiltonian represents the present value of future utility or the static equivalent of welfare. In other words, "given that the economy follows the optimal path, welfare measurement does not require knowledge of what this path will look like in the future" (Aronsson, Johansson, and Löfgren 1997 p. 32). However, as Aronssom, Johansson and Löfgren (1997) (and Hung (1993)) point out, if these assumptions are altered, the welfare measures derived by Weitzman (1976) and Mäler (1991) no longer apply and welfare measurement is complicated by the need to consider more than just current market data.

Recognizing this, a number of researchers have investigated how relaxing the assumptions of absence of externalities, time-autonomy, capital homogeneity, and perfect foresight will alter the expression for NNP.

Aronsson, Johansson, and Löfgren (1997) (and Aronsson and Löfgren (1993)) consider the case of externalities. They show that if external effects exist then market data no longer reflects socially optimal decisions and "the observed resource allocation does not maximize social welfare and is, therefore, insufficient as a basis for welfare analysis" (p. 1). In other words, if resources are not allocated optimally and the economy is not on its optimal path, "utility NNP is not a static equivalent of welfare" (p. 13).[15] Aronsson, Johansson, and Löfgren (1997) show that the national product related welfare measure needs to be augmented with a term that captures the "present value of the marginal externality along the competitive path" (p. 56) and such information requires knowledge of the future path of the economy. However, neither Aronsson, Johansson, and Löfgren (1997) nor Aronsson and Löfgren (1993) suggest how one could go about estimating the shadow prices or the marginal values needed to calculate these adjustments.

Similar results are found for different forms of time dependence (Aronsson and Löfgren 1995; Aronsson *et al.* 1997). Regardless of whether the time dependence of welfare is exogenous or endogenous, a static equivalent of welfare does not exist because "anticipated technological and environmental change will effect future consumption possibilities (and thus future utility) meaning that neglect of these changes may bias the estimation of the true economic welfare" (Aronsson and Löfgren 1993 p. 2). Aronsson and Löfgren (1993) show that to avoid this bias the present value of anticipated marginal technological progress (regress) or environmental change should be included in Green NNP.

[15] However, as we might expect, if a dynamic optimal tax and transfer system is implemented so that externalities are internalized over time then "the Hamiltonian will represent the appropriate measure of welfare" (Aronsson and Löfgren 1995 p. p. 321).

Chapter 6 of Aronsson, Johansson, and Löfgren (1997) discusses the relationship between sustainable development and Green NNP. They show that the assertion that the maximum sustainable utility level corresponds to the value of the Hamiltonian along the optimal path does not hold if capital is hetergeneous. "The conclusion is that the appropriate measure of income at time *t* is, at best, a static equivalent of future welfare, but it is not an indicator of whether or not the present consumption level can be, or will be, sustained" (Aronsson, Johansson, and Löfgren 1997 p. 160).

Of particular interest in this study is the assumption related to perfect foresight. The implications of relaxing this assumption are discussed in Mäler (1991), Dasgupta (1995), Aronsson and Löfgren (1995) and Aronsson, Johansson, and Löfgren (1997). Maler and Dasgupta (1990), Dasgupta (1990), Hung (1993), Aronsson and Löfgren (1995) and Aronsson *et al.* (1997) have mathematically illustrated how different types of uncertainty can be incorporated into national product related welfare measures. Hung (1993) nicely summarizes the findings of this literature related to welfare measurement under uncertainty. Hung (1993) suggests that "two principles should be retained; first, the NNP must contain a component that reflects explicitly the cost of risk bearing; and second, all items in the estimate of NNP are to be evaluated in terms of contingent (rationally anticipated) values" (p. 388).

Clearly, relaxing the assumptions of the simple Ramsey Growth Model results in national product related welfare measures that are considerably more complicated to use for actual welfare calculations. It is therefore not surprising that there have been very few attempts to account for the resulting complications in resource accounting applications. An exception is Weitzman and Löfgren (1997) which presents a method for accounting for labour-augmenting technological change in their estimate of Green NNP for the US economy.

3.5.4 Dealing with the Complications

Obviously, it would be a difficult if not impossible task to develop a resource accounting system that provides a perfect measure of welfare or sustainability. The subsequent case study will attempt to quantify as many of the different values that are derived from the environment and resources in the region as possible given the time and financial restraints of this project. The case study will focus on those stocks and flows that are of the greatest significance to the public and will build a resource accounting system that will be most useful to industry and government as a management tool.

Recognizing the limitations of the resulting measure as an indicator of welfare and sustainability, it will be referred to as a net income measure. It is also recommended that the accounting system be supplemented with a monitoring program that includes other qualitative social and ecological indicators that together with net income will give a broader picture of the level of social welfare in the region.

It is also recognized that using the resulting net income measure to assess the sustainability of regional activities relies upon the validity of the assumptions underlying the growth model used to derive the welfare measure. Chapter 5 of this study investigates the influence of uncertainty regarding future conditions on the evolution of the case study's net income over time and the interpretation of changes in net income. The importance of considering the risks associated with future environmental and market conditions in the region is illustrated and the practical implications are discussed.

3.6 Summary

Depending on the objectives of the resource accounting system, the accounts may consist of physical and/or monetary data on flows and stocks. Of particular interest in this study is the use of resource accounting system to estimate welfare and evaluate whether existing policies and activities are sustainable. The theoretical foundations for the use of resource accounting for these purposes suggest that Green NNP can be used as a measure of sustainable welfare and various methods have been proposed for calculating the components of Green NNP.

The use of Green NNP as a measure of sustainable welfare is not without problems. Green NNP is derived based on one particular definition of sustainability which although supported by many economists is not without controversy. In addition, the inclusion of all components that affect welfare renders the calculation of Green NNP impractical. Finally, the interpretation of Green NNP as a measure of sustainable welfare is dependent upon a number of assumptions which are not likely to apply in all cases. When the assumptions are relaxed, the adjustments required are often difficult to estimate empirically. This case study recognizes the general implications of these complications on welfare measurement and provides a more specific empirical investigation of the influence of fire and price risks on the flow of income from the case study region.

Chapter 4 Case Study: A Forest Management Area in Northern Alberta

4.1 Introduction

This portion of the study will develop a resource accounting system for a region of public forestland in Alberta. The majority of the deciduous and some of the coniferous trees in the area have been allocated to the forest products company, Alberta Pacific Forest Industries Inc. (Alberta-Pacific), under specific terms and conditions that have been laid out in their Forest Management Agreement (FMA). Quota holders also harvest coniferous timber which is used to produce lumber in various sawmills in the region. It is of interest to the Alberta government and the public, who are the owners of the land, whether or not the income that is derived from the environment and resources in this region is sustainable. Since many aspects of the management of this land have been entrusted to Alberta-Pacific, the sustainability of income flows from the region reflects on the suitability of the company's practices and whether or not they are in the best interest of the public, both current and future generations.

A resource accounting system for the region would act as a useful tool in assessing the suitability of forest management practices and lend insight into how these practices might be improved upon. The accounting system may also be used to monitor the impacts of changes in forest management regimes on the region's socioeconomic sustainability.

This case study will attempt to quantify several different values that are derived from the environment and resources in the region. The study will focus on those stocks and flows that appear to be of greatest significance to the public. However, information and data availability also determine which forest benefits the study quantifies.

Selection of the components of the resource accounting system requires knowledge of how forested lands contribute to welfare as well as which forest services play a significant role in the study region. Following a review of the various services that forests provide, the composition and use of resources in the study region and the important aspects of Alberta-Pacific's operations will be discussed. Following this, the components that will be included in the accounting system will be identified. The final section will deal with the actual valuation of the identified components including the estimation of activity levels and WTP. Wherever possible sources of bias are discussed and WTP estimates from more than one source are compared in order to identify a reasonable range of values.

4.2 The Contribution of Forestland to Welfare

Forestlands serve as a source of wood fibre that is used to make a variety of products including paper, construction materials, and furniture. However, forests also provide society with a number of 'non-timber' goods and services, many of which have been mentioned in earlier sections. Non-timber goods include items such as berries, medicinal plants, wildlife species and other goods that are generally not traded on markets.

Adamowicz (1992) divides non-timber services into three broad categories: user services; non-user services; and environmental control services. User services refer to "services provided by forest land which support activities by individuals" (Adamowicz 1992 p. 6). User services can be the source of consumptive or non-consumptive value.

The activity is a source of consumptive value if, as with hunting and fishing, a resource is consumed and thereby removed from the ecosystem. Non-consumptive value is associated with activities such as birdwatching and hiking that do not remove resources from the ecosystem. Adamowicz (1992) notes that "both the quantity and quality element of these recreational experiences are important components of non-timber value" (p. 6).

Forests also provide services that are not directly derived from consumption of resources or participation in activities within the region. These non-user (or passive use) services include existence and bequest values associated with the maintenance of biodiversity and habitat for endangered species. Since any individual can hold these values, their estimation tends to be very difficult. The final category of non-timber services, environmental control services, result from the forest's role in preserving watershed functions, purifying air, detoxification and decomposition of wastes, erosion control, and stabilization of atmospheric carbon levels (Myers 1997). The value of these services is also very difficult to estimate.

4.3 Case Study Specific Framework

4.3.1 Case Study Area

The resource accounting system is developed for an area in northeastern Alberta currently managed by Alberta-Pacific Forest Industries Inc. (Alberta-Pacific). Figure 4.1 depicts Alberta-Pacific's FMA. As noted earlier, Alberta-Pacific only has rights to some of the timber within the FMA boundaries. In Alberta, the administrative unit used to assign harvesting rights and determine annual allowable cuts is the forest management unit (FMU). There are a total of 21 of these units wholly or partly within the FMA. A portion of the coniferous timber on a number of the FMUs was allocated to quota holders, before 1993, when the Alberta-Pacific FMA was established. Therefore, timber from the FMA is used to produce lumber in area sawmills, as well as in the production of pulp by Alberta-Pacific.

The overlapping tenure in the region creates some difficulty in creating timber accounts since some FMUs are only partly within the FMA boundaries. There are cases where a quota holder harvests according to a coniferous AAC based on the entire FMU but Alberta-Pacific harvests deciduous timber from only part of the FMU. This creates a difficulty in determining whether the appropriate region to consider in the accounts should be limited to the FMA boundary or include the entire area of the 21 FMUs that are at least partially within the FMA.

The portions of FMUs which are outside Alberta-Pacific's landbase but within FMA's outer boundary are often referred to as 'doughnut holes' and are visible in Figure 4.1. Since most of these areas are swampy and boggy and road access is limited, their contribution commercial forestry production is not large. However, these areas provide other services including carbon sequestration and biodiversity maintenance.

Since one of the objectives of this study is to develop a management tool for industry, Alberta-Pacific in this case, the accounts were developed using the outer FMA boundary. However, doughnut holes are included partly for practical reasons, since data required for the estimation of other components of the accounts are more easily collected for a continuous landbase. Another reason is that these areas provide important non-timber services to the region. The case study region is illustrated in Figure 4.2.

Figure 4.1
Map of Alberta-Pacific's Forest Management Agreement

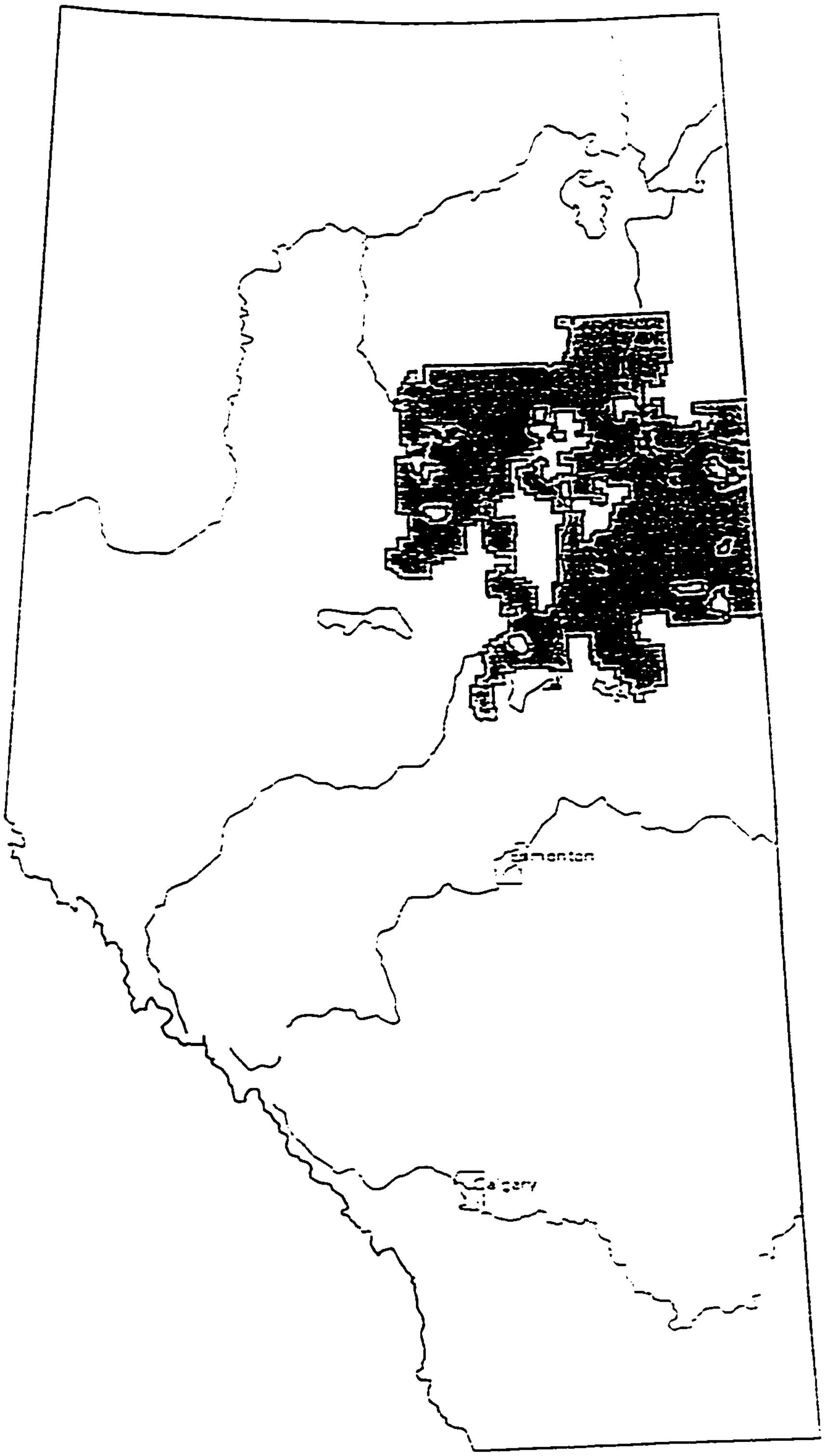
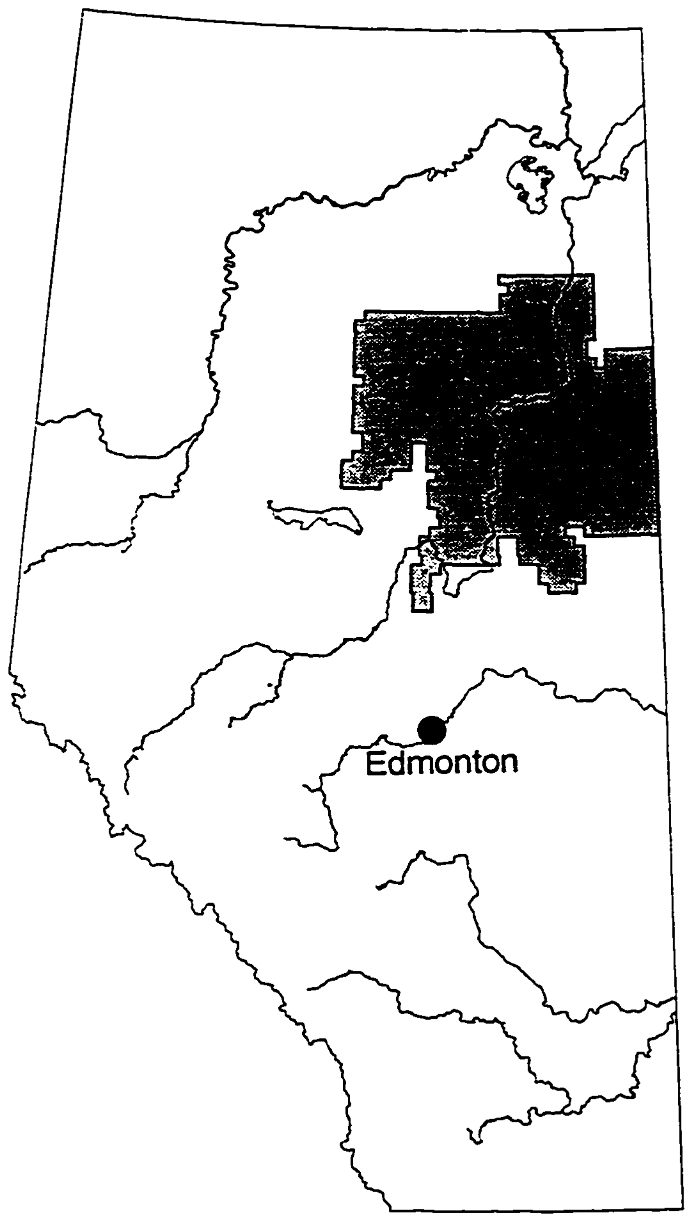


Figure 4.2
Map of the Case Study Region



The total area of the case study region is about 6.8 million hectares (6,806,156 ha). The FMA comprises about 6.138 million hectares (6,138,726 ha) and the doughnut holes within the FMA amount to about 667,000 ha (667,430 ha).[16] (The area consists primarily of Boreal Mixedwood Forest (Alberta-Pacific 1996b). The area "...is bounded on the south by agricultural settlement and the major towns of Athabasca, Boyle, and Lac La Biche. The city of Fort McMurray falls within the outer boundary of the FMA as do a number of communities and Indian reserves including Janvier, Conklin, Sandy Lake, Heart Lake, Gregoire Lake, Fort McKay, Peerless Lake, Trout Lake, Calling Lake, and Chipewyan Lake. Just outside the FMA are the Beaver Lake, Namur Lake and Wabasca reserves and the settlements of Red Earth, Plamondon, Wandering River, Smith, Atmore, Grassland, Buffalo Lake and Kikino" (Alberta-Pacific 1996b p. 23).

Alberta-Pacific employs approximately 1,100 people in total: 440 people in the mill and 660 people in the woodlands operations (Alberta-Pacific 1996b p. 8). Quota holders also employ residents of the area within local sawmills or in positions associated with harvesting and transportation activities.

There are also non-renewable natural resource industries operating in the region which do not rely on the existence of the forest ecosystem. Most of these industries are associated with the extraction of fossil fuel reserves. As noted in Alberta-Pacific (1996b p. 23), "Oil and gas activity is prevalent which creates jobs and business opportunities relating to tar sands, oil extraction, gas and oil exploration, resources development and pipeline work... Oil company roads, wellsites and pipelines are common in many areas and seismic lines criss-cross virtually all of the FMA".

In addition to forestry, there are a number of commercial activities in the area which rely directly upon the existence and state of the mixedwood forest including guiding, outfitting, fishing and trapping and associated tourism activities. As noted in Alberta-Pacific's Detailed Forest Management Plan (DFMP), "A number of guide-outfitters work in the area and the FMA is completely covered with registered traplines... [and] Several large lakes, rivers and streams provide recreational and some commercial fishing opportunities" (Alberta-Pacific 1996b p. 23).

Therefore, despite the presence of other industries,[17] a large amount of employment income within the region's communities is dependent on the forest in some way. However, as noted in the previous section, the forest is more than a source of cash income; there are many other values associated with forest resources. This area is no exception.

For many of the region's First Nations inhabitants,[18] the forest plays an essential role in their physical and cultural well-being. In addition to providing the resources which are used for subsistence, the forest also has cultural importance because it resources serves as the setting for the practice of activities associated with their traditional lifestyle (Alberta-Pacific 1996b p. 23). Native peoples in the area also utilize the forest as a source of food including meat, berries and mushrooms, as a source of

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[16] The area was estimated as 666,239 ha using forest inventory and a few assumptions regarding portions of FMUs lying outside the FMA. A second estimate of 668,621 ha was made with the aid of a GIS map obtained from Alberta-Pacific. The average of these estimates is reported.

[17] For example, there is also a small number of grazing leases in the area, which were present before the FMA was established.

[18] There are a number of Indian reserves within the FMA. See Table A9, Appendix III for a list of First Nations in the area and their populations.

materials for creating native crafts and as a source of plants that can be used for medicinal purposes (Alberta-Pacific, pamphlet).

Value is also derived from recreational activity, both consumptive and non-consumptive, within the area. As in other forested regions of Alberta, recreational hunting and fishing are popular outdoor activities. The area also serves as the setting for non-consumptive recreational activities such as camping, hiking, birdwatching, and wildlife viewing. "Lakes, rivers and streams provide the focal points and much of the recreational potential currently recognized in the FMA" (Alberta-Pacific 1996b p. 106). Alberta-Pacific (1996b) notes that wildlife and nature viewing are increasing in popularity and there is increasing "interest in "self-taught" opportunities such as interpretative trails (near communities) and brochures" (p. 106).

The value of recreational experiences in the area is influenced by the quality of the surrounding environment and the presence of wildlife. Non-use values are also influenced by state of the ecosystem and its components. However, in the case of non-use or passive use values the beneficiaries do not necessarily use the area in any way. Their existence values are associated with the habitat services that the forest provides for a variety of flora and fauna. For example, people may attain satisfaction from knowing that a threatened species like the woodland caribou, inhabits the area or that the biological diversity or 'biodiversity' of the area overall is being maintained or enhanced.

The FMA serves as habitat for a wide variety of wildlife species. The FMA provides breeding habitat for 190 species of birds (30 resident and 160 migratory) and serves as a foraging and staging area during migration for another 42 species. In total, there are about 22 species of ducks and grouse that are hunted on the FMA (Alberta-Pacific 1996b p. 39). A number of ungulate species inhabit the FMA including "moose, woodland caribou,[19] white-tailed deer, mule deer, elk and bison" (Alberta-Pacific 1996b p. 42). Significant aesthetic, subsistence and recreational hunting values tend to be associated with these species especially moose.

4.3.2 Alberta-Pacific's Operations

In 1993, the Alberta Government entered into a Forest Management Agreement (FMA) with Alberta-Pacific. This agreement gave Alberta-Pacific the harvesting rights to the majority of the deciduous and some of the coniferous trees in the area. However, only about one quarter of the FMA is actually available for Alberta-Pacific to harvest. About 59% of the area consists of wetlands, 11% of the area was previously allocated to coniferous quota holders, and 5% of the area represents buffers on streams and the ecological benchmark area in the northwest portion of the FMA (Liege River - 340,000 hectares).

The FMA includes a number of specific terms and conditions to which the Company must adhere. Among other things, Alberta-Pacific was required to construct a state-of-the-art pulp mill where the timber harvested by the Company would be processed into pulp.

Alberta-Pacific's pulp mill is located 52 km (by road) northeast of the town of Athabasca and 69 km west, northwest of Lac La Biche (Alberta-Pacific 1996b). The

[19] "Woodland caribou have disappeared from much of their former range in Canada due to various pressures. Sport hunting of caribou in Alberta ended in 1981 due to concerns over declining populations" (Alberta-Pacific 1996b p. 44).

Alberta-Pacific mill produces softwood and hardwood pulp in separate production runs. About 80% of Alberta-Pacific's mill production consists of hardwood bleached kraft pulp and the other 20% is softwood pulp (Alberta-Pacific 1996a). If run at capacity, the annual mill requirements are about 2,658,000 cubic meters (1.1 million cords of wood) resulting in the production of about 530,000 cubic meters of pulp (Alberta-Pacific 1996a).

The mill "...use[s] chlorine dioxide in place of chlorine as a bleaching agent" (Alberta-Pacific Forest Industries Inc. 1996 p. 18). This allows the company to market its pulp under the label ECF (Elemental Chlorine Free). "[The] pulp is marketed worldwide, with consumption to date being approximately 40% North American, 40% Asian (Korea, Japan, Taiwan) and 20% European" (Alberta-Pacific 1996b p. 15-16).

There are both atmospheric emissions and effluent discharges associated with the pulping process. Wastewater from the pulping process undergoes activated sludge effluent treatment before being discharged into the Athabasca River. The treatment system, which removes between 95 and 99.9% of the characteristic pulp mill wastes, has allowed to the mill to operate well within its license limits (Alberta-Pacific 1996b p. 11).

Steam, carbon dioxide, sulfur dioxide, nitrous oxides and small amounts of other chemicals discharged are also by-products of the pulping process. Associated with these emissions is an odour that may be offensive to those nearby. "In order to control the odour from the mill, a non-condensable gas collection system and extensive chlorine dioxide scrubbing equipment have been installed on various stacks at the site" (Alberta-Pacific 1996b p. 12). To date, the Company has operated below the allowable discharge level for TRS (total reduced sulfur) and has not exceeded the allowable discharge for SO_2 (sulfur dioxide) (Alberta-Pacific 1996b). However, the mill does occasionally experience problems that result in odours that can be detected by area residents (Alberta-Pacific 1996b p. 12).

In terms of its harvesting activities, Alberta-Pacific is in a period of transition in that it is moving from traditional 2 (or 3) pass harvesting and sustained yield management to what the Company calls "ecosystem management". Alberta-Pacific believes that ecosystem management is an important component of sustainable forest management (SFM). According to Alberta-Pacific (1996a p. 9), "this is a management strategy which attempts to replicate the effects of natural disturbance patterns within the forest" and its objective is "to reduce the risk to the forest ecosystem by developing strategies that will maintain biodiversity" (Alberta-Pacific 1996b p. 6). Since fire has historically been the major source of disturbance in the area, Alberta-Pacific has undertaken a research program that focuses on the development of "harvest methods that more closely replicate the effects that fire might have on the forest" (Alberta-Pacific 1996a p. 9). "Harvesting following an ecosystem management approach, should approximate the historical structure and pattern of vegetation at the regional, landscape and stand levels" (Alberta-Pacific 1996b p. 35).

Although, the Company determines where and how its allowable cut will be harvested, the Company itself does not harvest timber. There are about 13 logging companies contracted by Alberta-Pacific to harvest its timber. Harvesting equipment operators are trained on how to harvest timber in a way that is consistent with ecosystem management (Alberta-Pacific 1996a).

The mill's fibre supply originates from a number of different sources. The majority of the mill's fibre supply (approximately 71% in 1997) consists of the deciduous timber harvested by Alberta-Pacific's logging contractors.[20] In addition, the Company purchases about 18% of its fibre supply from other sources including sawmills, industrial users (i.e. oil and gas companies), agricultural land owners who clear land for commercial purposes, and private woodlot owners. The fibre purchased from sawmills is generally in the form of chips, which are byproducts of sawmill operations. The remaining 11% of the fibre supply includes deciduous timber growing on predominantly coniferous which is harvested by companies with coniferous harvesting rights who then ship the trees to Alberta-Pacific. Although Alberta-Pacific anticipates that their fibre supply will be broken down as indicated, in reality, fibre derived from these sources varies from year to year depending on factors such as the prevailing weather and the price of pulp relative to sawlog and chip prices.

Alberta-Pacific is involved in a number of different programs aimed at protecting the forest environment. The company "has entered a Fire Protection Agreement with the Province of Alberta. The Company's role in this agreement is primarily preventative through employee training and awareness programs" (Alberta-Pacific Forest Industries Inc. 1996 p. 17). The Company is also involved in the suppression of insect and disease and cooperates with Land and Forest Services in this regard. In addition, the Company's bio-monitoring program ensures that the state of the environment, including receiving water quality, air quality and the characteristics of groundwater and soils on lands surrounding the pulp mill site, is monitored on a regular basis (Alberta-Pacific 1996b).

The Company also conducts research focusing on the ecological and socioeconomic implications of its activities. Some of these studies are requirements of Alberta-Pacific's FMA, however, the Company is also involved in other research projects, such as this one, in cooperation with the University of Alberta and the Sustainable Forest Management Network Centres of Excellence.

4.3.3 Important Stocks and Flows in the Case Study Area

The above description of the study region reveals that the forest contributes to welfare in many different ways. The following is a list of those components for which values will be determined and included in the resource accounting system:

Commercial Forestry

1) Commercial timber harvest;
2) Changes in timber and human-made capital;

Non-Timber Services

User Services

1) Other Commercial Uses – commercial trapping and fishing activity;
2) Recreational Use - hunting, fishing and camping;

[20] Not all timber harvested by Alberta-Pacific is processed into pulp. As part of its FMA, Alberta-Pacific is permitted to harvest incidental conifer (spruce of pine trees growing in the aspen forest). However, Alberta-Pacific must "offer it for sale to the local sawmill industry on reasonable terms and conditions" (Alberta-Pacific 1996a p. 8). The incidental confer may be sold to one of 13 sawmills that operate within the FMA or to a sawmill in the Lac La Biche or Smith area (Alberta-Pacific 1996a).

3) Subsistence resource use by aboriginal peoples including wood harvesting, hunting, fishing, trapping, and food gathering and use of other forest materials for making crafts or for use in traditional medicine;

Non-User/Passive Use Services

1) biodiversity maintenance

Environmental Control Services

1) Carbon sequestration.

This list is not comprehensive since, as mentioned earlier, it would be extremely difficult and expensive to quantify all the services provided by the forest. However, the components included in this list appear to be the most significant values derived from the forest and those that will be most significantly affected by the Company's forest management decisions. The potential range of values associated with forest services not explicitly valued will be discussed in general terms.

4.3.4 Derivation of Net Income Measure[21]

Ideally, an expression for the net income of the study region should be derived mathematically using the same techniques as Mäler (1991), Dasgupta (1995), and Dasgupta *et al.* (1994). This section outlines the procedure for deriving the net income measure for this region; however, the details are suppressed since they can be found elsewhere. One of the purposes of this exercise is to identify the assumptions required to arrive at the net income measure.

The optimization problem is to maximize the welfare of the region over time, assuming that the important components of welfare are those listed above. Another objective is to formulate an index that can be used along with other information to assess socioeconomic sustainability. The application of a growth model to the problem requires a number of assumptions. It is assumed as in Dasgupta and Mäler (1990) and Mäler (1991) that the economy is perfectly competitive, externalities do not occur, the dynamics of the economy are essentially time-autonomous with social utilities discounted at a constant rate (stationarity assumption), the future is known with certainty and capital is homogenous.[22] For the moment, it assumed that divergences from these assumptions are minor and would not have a significant effect on the net income measure for this region. In the next chapter the implications of uncertainty regarding future conditions will be examined.

The remainder of this section closely follows the procedure and description used by Dasgupta and Mäler (1990) to derive NNP for a hypothetical economy. Some details are modified to correspond to the case study regional economy. However, to avoid unneeded complexity most the expressions are left in aggregate and generalized form. The generalized form of the NNP expression is used to identify how specific components of the regional economy should be incorporated into the net income measure.

In the following discussion, the variables that are used are:

Y = aggregate output;

C = aggregate consumption of output from the market economy;

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[21] As noted earlier, the term net income is used to describe the accounting aggregate resulting from the resource accounting application because the term NNP applies to national level income measures.

[22] As noted earlier, Mäler's model also assumes that present value maximization is an adequate framework within which to assess sustainability.

L = labour effort (measured in work hours);
L_1 = labour effort used to generate aggregate output;
L_2 = labour effort used to enhance the growth of the timber stock;
L_3 = labour effort used to harvest timber;
K_1 = human-made capital;
K_2 = environmental capital (clean air and water and other environmental stocks);
K_3 = forest (timber) capital;
K_4 = defensive capital;
X = timber harvest used in the production of pulp and lumber;
S_1 = timber harvested for the purposes of direct consumption through subsistence activities;
Z = the flow of environmental goods and services;
P = pollution;
R = rate at which pollution damage is mitigated; and,
Q = expenditure on defensive capital.

In this simplified model of the regional economy, there are two environmental stock resources, K_2 and K_3. Clean air and water and other environmental stocks are valued directly. There is also a flow of environmental goods and services. Timber harvest is used in the production of pulp and lumber and for the purposes of direct consumption through subsistence activities.

Labour effort, human-made capital and timber harvest generate output, Y, according to the following aggregate production function:

$$Y = F(K_1, L_1, X) \tag{3}$$

where X is timber input. For the case study region, Y, would represent all production from the commercial forestry (pulp and lumber), commercial fishing trapping sectors.

The rate of timber harvest requires labour effort, which is influenced by the size of the timber stock. Therefore,

$$X = N(K_3, L_3). \tag{4}$$

Although not revealed by equation (4), several characteristics of the timber stock influence harvest levels. Many of these characteristics vary from stand to stand. Besides the stand's volume, species mix, distance from road access, distance from the mill, topography, and other variables influence harvesting costs.

The rate at which the forest regenerates, $M(\cdot)$, can be enhanced by labour effort. Timber growth also depends on a number of other factors, which are not explicitly modeled but are discussed later in the text.

Dasgupta and Mäler (1990) also consider the implications of pollution that decreases the quality of the environmental stock and diminishes the flow of environmental amenities. They assume that society can invest in defensive capital, K_4 (i.e. effluent treatment technology). The amount of pollution is dependent on the amount of defensive capital and the level of output. Therefore,

$$P = A(K_4, Y). \tag{5}$$

Society can also "mitigate the damages to the flow of environmental amenities by expending a portion of final output, at rate R" (Dasgupta and Mäler 1990 p. 30). The following represents the resulting flow of amenities:

$$Z = J(R, P). \tag{6}$$

For the case study region, the flow of amenities from the environmental stock includes services such as carbon sequestration, biodiversity maintenance, and provision of subsistence resources other than timber. The environment also provides a setting for recreational experiences.[23]

As with the timber stock, the remaining environmental stock also regenerates itself. Similarly to Dasgupta and Mäler (1990), it is assumed that the potential regeneration rate is dependent on the stock of timber and is denoted $G(K_3)$; however, the emission of pollutants, $A(\cdot)$, decreases the regeneration rate.

The dynamics of the economy can be expressed in terms of the following equations:

$$\frac{dK_1}{dt} = F(K_1, L_1, X) - C - Q - R \tag{7}$$

$$\frac{dK_2}{dt} = G(K_3) - A(K_4, F[K_1, L_1, X]) \tag{8}$$

$$\frac{dK_3}{dt} = M(L_2) - X - S_1 \tag{9}$$

$$\frac{dK_4}{dt} = Q \tag{10}$$

$$X = N(K_3, L_3) \tag{11}$$

$$Z = J\{R, A(K_4, F[K_1, L_1])\} \tag{12}$$

The general form of the function, W, representing the current flow of aggregate wellbeing is:

$$W = W(C, S_1, Z, K_2, L_1 + L_2 + L_3) \tag{13}$$

where C is aggregate consumption. All arguments of $W(\cdot)$ have a positive influence on wellbeing except total labour effort ($L_1 + L_2 + L_3$) which has a negative influence. If the control variables $(C, S_1, Z, K_2, L_1, L_2, L_3)$ are selected to maximize (13) at each date, then the current-value Hamiltonian of the optimization problem is:

$$\begin{aligned} V = {} & W(C, S_1, Z, K_2, L_1 + L_2 + L_3) + p[F(K_1, L_1, X) - C - Q - R] + \\ & q[G(K_3) - A(K_4, F[K_1, L_1, X])] + r[M(L_2, \bullet) - N(K_3, L_3) - S_1] + \\ & sQ + v[J\{R, A(K_4, F(K_1, L_1, X)) - Z\}] \end{aligned} \tag{14}$$

where p, q, r and s are the shadow prices of the four capital goods, K_1, K_2, K_3 and K_4 respectively, and v is the imputed marginal value of the flow of environmental amenities.

The correct expression for NNP can be derived from equation (14). In the words of Dasgupta and Mäler (1990 p. 31), "it [NNP] is the linear support of the Hamiltonian along the optimal programme". As in Dasgupta and Mäler (1990), the expression for NNP is simplified by denoting the vector of all non-price arguments in the Hamiltonian function along the optimal program at any given date as O^*. Therefore,

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[23] Mäler (1991) assumes that, at the optimum, the marginal utility of time spent recreating is equal to the wage rate; therefore, the value of recreational activities falls out of the NNP equation. This assumption is not applied in this case. Instead, it is assumed that on the margin the value of recreational activities exceeds the opportunity costs of not spending the time working. This seems to be a reasonable assumption considering the many distortions in the labour market including fixed work weeks, minimum wages, etc.

$$O^* = \left(C^*, S_1^*, Z^*, Q^*, R^*, K_1^*, K_2^*, K_3^*, K_4^*, L_1^*, L_2^*, L_3^*\right). \tag{15}$$

Taking the Taylor series expansion around O^* reveals that the linear support of the Hamiltonian is

$$V(O^*) + W_c C^* + W_{S_1} S_1^* + W_Z Z^* + W_{K_2} K_2^* + W_L\left(L_1^* + L_2^* + L_3^*\right) + p dK_1^*/dt + q dK_2^*/dt + r dK_3^*/dt + v dK_4^*/dt \tag{16}$$

where W_C is the partial derivative of W with respect to C, etc. For evaluating a marginal project[24] the constant term, $V(O^*)$, is irrelevant and can be left out of the final expression for NNP.[25] Therefore, in an optimizing economy NNP measured in wellbeing numeraire is:

$$NNP = W_c C + W_{S_1} S_1 + W_Z Z + W_{K_2} K_2 + W_L\left(L_1 + L_2 + L_3\right) + p dK_1/dt + q dK_2/dt + r dK_3/dt + v dK_4/dt. \tag{17}$$

Dividing the expression by W_C causes NNP to be expressed in aggregate consumption numeraire. Dasgupta and Mäler (1990 p. 33) stress that "all resources and outputs are valued at the prices which sustain the optimum programme".

Expression (17) illustrates the general information needed to estimate regional NNP. The equation shows that NNP is the sum of the goods and services consumed in the region and the change in capital stocks valued at their optimal shadow prices less the shadow value of work effort.

More specifically, the equation indicates that measurement of net income requires the quantities of good and service flows (C, S_1, Z) and stocks which are valued directly (K_2). The change in quantity of all capital stocks (dK_1/dt, dK_2/dt, dK_3/dt, dK_4/dt) that occurs within the time period (generally one year) is also needed. The shadow values corresponding to these quantities (W_C, W_{S1}, W_Z, W_{K1}, p, q, r, v) must also be estimated. Finally, shadow value of work effort, W_L, which is assumed to equal the wage rate, and the total amount of work effort (hours) are required.

The shadow values associated with goods and services that are consumed directly correspond to the marginal utility associated with consuming one more unit of the good or service. Mäler (1991) shows that for market goods, under optimality conditions, this marginal utility is market price less the marginal cost of inputs. The cost of inputs includes labour. This explains the presence of the fifth term on the right hand side of equation (17). For non-market goods, the shadow value represents the marginal net value associated with consumption of the good or service; therefore, the marginal cost of inputs should also be factored out.

The final four terms in equation (17) represent the depreciation (appreciation) of human-made, timber, environmental and defensive capital as valued by their shadow prices. Hartwick's method for estimating capital depreciation was outlined in section 3.4.1.1 can be used to estimate the value of these terms.

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[24] According to Dasgupta and Mäler (1990), a marginal project is a perturbation to the optimal program and can be expressed as a series of vectors (i.e. dC, dZ, dL_1, dL_2, dL_3, dK_1/dt, dK_2/dt, dK_3/dt, dK_4/dt).

[25] As discussed in (Mäler 1991 p. 7), this term "reflects the wealth of the society". When the economy is on an optimal trajectory the constant is equivalent to the "total return on all capital at time t" (p. 12). The value of this term will not be estimated in this application. The estimation would require determining the value of all human and natural capital stocks.

For the sake of simplicity, many details of the regional economy are not included in the above derivation. Instead of using the aggregate production function, production functions for the specific sectors (pulp, lumber, and commercial fishing and trapping) of the market economy could be included. In conjunction with this, the aggregate consumption good, C, could be divided into consumption of commercial timber products (pulp and lumber), and commercial fishing and trapping production. This would alter the NNP expression in that instead of the aggregate consumption variable, C, and shadow price, W_C, variables representing the consumption of products from these sectors would appear along with their associated shadow prices.

Other details were included for illustrative purposes but are not considered in the case study. The model above includes pollution control technology as a form of capital and considers the damage imparted by the flow of pollution. The case study does not consider these factors. The shadow prices associated with changes in defensive capital and pollution damage are difficult to determine. Furthermore, water and air pollution does not appear to be a significant concern in the region. For these reasons, the case study assumes that the value of changes to pollution control technology and pollution damage are not significant. However, the validity of these assumptions may be questionable. The expression for NNP illustrates how these aspects of the economy could be incorporated.

Note that equation (9) models timber growth as depending on labour effort and the existing stock of timber. However, in this study the method used to determine timber growth indirectly uses several different variables. Yield tables provided by Alberta-Pacific are used to determine timber growth in the region in 1996. These yield tables are constructed based on characteristics such as species composition, age class, forest type, stand location, etc. Therefore, if the function $M(\cdot)$ could be explicitly defined it would include these type of variables.

The expression for NNP suggests that changes in the environmental stock, K_2, be valued at an appropriate shadow price. Essentially, the indirect effect of changes in all stocks on future flow values should be considered. In the study region there are many flow values that are dependent on environmental stocks. For example, trapping output is influenced by the stock of furbearers, fishing output is dependent on the stock of clean water, and the value of recreational experiences is dependent on the stock of wildlife species. Theoretically, the net income measure for the region should consider these type of interactions. However, in most cases, the quantitative relationship between flow values and stock changes is not known. For this reason, these types of stock effects are not considered here. However, it should be noted that maintaining the resource account over time and combining the results with ecological data may allow such stock and flow relationships to be estimated.

As discussed earlier, in theory, the measurement of Green NNP, or net income in this case, over time can be used to determine whether development is sustainable. Assuming that the assumptions used to derive the measure are correct, if net income decreases from one year to the next then this would indicate that the flow of income or welfare from the components included in the measure are not being sustained over time. However, as discussed in chapter 3, the assumptions may not hold and therefore, conclusions regarding sustainability must bear this in mind.

4.4 Component Value Estimation

The equation for net income outlines the quantitative information required to estimate the various components of the forest resource account for this region. Each component of the accounting system must be quantified in physical terms and then an appropriate shadow price must be determined. Both of these steps may pose difficulties. First, with the exception of commercial timber harvesting, the levels of activities in the region are not well documented for the FMA region. Secondly, since most of the components except timber are non-market goods, the monetary value of these activities is not directly available from market data and a shadow price must be estimated by some method. Even determining the value of harvested timber and changes in timber stock is not straight forward since in Alberta there is no market for logs and the price of standing timber is set by the government using administrative methods.

The data sources and valuation methods used in this study are outlined in the following sections. Where applicable, methods used in previous studies to determine the value of timber and the value of non-market forest services are discussed.

4.4.1 Commercial Forestry

In terms of quantifying the contribution of commercial timber harvesting to overall welfare in the region the resource accounting system will contain both a flow and a stock component. The flow component will record the physical amount of annual harvest and then attach a monetary value to these physical quantities. Similarly, the stock component will estimate the annual physical change in the stock of standing timber and then estimate of the monetary value of this physical change in the standing timber stock.

Physical data was obtained from Alberta-Pacific and Alberta Environmental Protection. The annual timber harvest should be known approximately. Changes in the physical stock of timber, however, are estimated since forest inventory data are not available on an annual basis and the most recent inventory data available is for 1990. As exemplified by Anielski (1994), stock levels can be imputed using estimated timber growth rates, harvesting data, insect and fire removal data and data on reforestation activities.

The more difficult task will be converting these physical values to monetary values. In the resource accounting framework being used in this study, both the flow and stock changes should be valued using a value estimate that reflects the value added from timber production which should in turn be equivalent to timber economic rent.[26]

Hultkrantz (1992) suggests that "marginal rents (price per unit of a resource less the marginal cost of extraction/harvesting) should be used in assessing the value of a change in a natural resource stock" (p. 289) which corresponds exactly to the rule that Hartwick prescribed for calculating the depreciation factor for renewable resources (see Section 3.5.3). The difficulty, however, often lies in the determination of economic rent since a competitive market price for the standing timber and accurate estimates of marginal harvesting costs may not exist.

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[26] Hultkrantz (1992) does not use timber economic rent to convert both physical flows and stock changes to monetary values because he includes labour income as a component in the NNP since this is consistent with current national income accounting conventions. In this study, labour income is not included as a component of NNP since as the work of Mäler (1991) demonstrates that theoretically it should not be included as a contributor to welfare.

In some areas, log markets exist, therefore a corresponding market price exists that can be used to value standing trees if the market is relatively competitive leading to an undistorted price. This is often the case in Europe and the United States where many forests are privately owned. However, in Alberta log markets do not exist because most timber harvesting occurs on public lands where the forest management regulations require the harvesting company to also construct a mill (pulp or saw) where the timber is processed. For the use of the publicly owned timber, the provincial government charges the company 'stumpage fees'.

"Stumpage is timber in unprocessed form as it is found in the woods" (Davis 1966 p. 380). Historically, the government, using an administrative process, has set stumpage fees. The extent to which these fees reflect the true value of the stumpage has been questioned by numerous academics. The issue is further complicated by the fact the government collects 'fees' from the companies in other forms including corporate income taxes and socially beneficial constraints on operations that increase the company's costs (Anielski 1991).

Anielski (1991) attempts to determine how well government administered stumpage fees approximate the true value of the stumpage. The absence of a stumpage market means that there is no explicit stumpage price; however, the implicit value of stumpage can be derived by indirect methods. Anielski (1991) uses two different methods to estimate forest economic rents in Alberta: a residual valuation approach, and; a value added approach. Anielski's results show that "...for the years 1979 to 1990 the Alberta government captured, on average, between 29.2 per cent of the total forest rents (using residual valuation rents) and 37.5 per cent of rents from primary forest industry manufacturing through indirect taxes, such as stumpage pricing" (Anielski 1991 p. 116).[27] This suggests that the use of government administered stumpage fees to estimate the economic rent of the timber stock changes would provide a very conservative (if not biased) measure of value.

Anielski's economic rent estimates appear to provide a less conservative measure (although their accuracy is very difficult to verify) of stumpage value and have already been used for this purpose in two resource accounting applications. Balasubramaniam (1992) uses the rent values from the residual valuation approach in the development of a provincial level forest resource account and Anielski (1994) also uses the rent values in the development of a timber account for Alberta.

It should be noted that in Anielski's calculations of economic rent using the residual valuation approach average costs are used instead of marginal costs as prescribed by Hartwick (1990). There is some debate as to whether the substitution of average costs for marginal costs introduces bias into the economic rent estimation. This issue is addressed in Hultkrantz (1992) and Hartwick (1990). Hartwick (1990) argues that using average costs will lead to an overestimate of resource depreciation. Hulkrantz (1990), on the other hand, suggests that, in circumstances where there is heterogeneity in timber quality and transportation costs "it may be reasonable to use average net conversion value" (p. 290). Due to difficulty in determining marginal costs of production on public

[27] Anielski (1991 p. 119) also finds that "when the total of all indirect and direct taxation by all levels of governments (provincial, federal and municipal) are considered, an average [of] 70 per cent (residual valuation) to 90 per cent (value added) primary forest industry rents were collected".

land in Alberta, it will be assumed that average variable costs per unit are approximately equivalent to marginal costs per unit in aggregate.

For purposes of comparison, the 1996 harvest and change in the timber stock for the study region will be valued using both the government administered stumpage fees and economic rent estimates.

4.4.1.1 Timber Account

The timber account is divided into a coniferous (softwood, i.e. white spruce, black spruce, and jack pine) and deciduous (hardwood, i.e. aspen, balsam poplar and birch) account. Within the coniferous account Alberta-Pacific and quota holder production are separated in most cases so that their relative contributions can be easily identified.

4.4.1.1.1 Initial Stock Levels

Using forest inventory data the 1996 timber volume and annual growth for the region were determined. Table 4.1 provides a summary of this information. Information is provided based on the gross landbase and the net landbase. The gross area covers the entire area whereas the net landbase includes only the are that is considered merchantable. The net area excludes areas that are considered non-productive because they are sparsely forested, have been intentionally set aside for other potential uses (i.e. protection), or required as buffers around waterbodies. (For a more detailed description of Alberta-Pacific's net landbase see Table A1, Appendix III).[28] Note, however, that the values are slightly different since they are based on an older version of the forest inventory data).

Table A2 provides similar information for all the FMUs including the portions lying outside the FMA boundaries. Note that the total net volumes and growth listed in Table 4.1 are not much lower than those in Table A2, indicating that only a small amount of productive area falls within the portion of the FMUs lying outside the FMA boundaries.

Table 4.1
1996 Forest Inventory Data (m^3)

Landbase		*Species*	*FMA*	*Doughnut Holes*	*Total*
Gross	Volume	Deciduous	301,543,560	10,765,567	312,309,127
		Coniferous	215,446,644	10,121,952	225,568,596
	Total		516,990,204	20,887,519	537,877,723
	Growth	Deciduous	3,189,485	122,946	3,312,431
		Coniferous	3,302,066	61,148	3,363,214
	Total		6,491,551	184,094	6,675,645
Net	Volume	Deciduous	256,008,952	9,204,945	265,213,897
		Coniferous	141,962,824	6,806,087	148,768,911
	Total		397,971,776	16,011,032	413,982,808
	Growth	Deciduous	2,806,162	54,032	2,860,194
		Coniferous	1,763,759	65,997	1,829,756
	Total		4,569,921	120,029	4,689,950

Based on 15+/10 cm utilization
FMA stands for Forest Management Area.

[28] Tables A1-A10 referred to in this chapter are contained in Appendix III.

Over the course of a year, this stock level changes due to additions in the form of growth and deletions in the form of harvest. Other factors that influence the stock of growing timber include fires, insects or disease and temporary or permanent removal of FMA land for other uses such as well sites or seismic lines.

4.4.1.1.2 Removals from the Timber Stock

Harvest

Alberta-Pacific supplies its mill with wood harvested from FMA land and with purchased deciduous and coniferous logs and chips. These logs and chips are purchased from coniferous quota holders or private woodlot owners. Table 4.2 provides a breakdown of the allocations to the woodyard in 1996. Although Alberta-Pacific had planned to use only about 7% purchased fibre in 1996, the actual amount of purchased deciduous logs was quite high in 1996. However, when weather and other factors make delivery of FMA wood impractical or too expensive, the Company will defer the hauling of this wood and supplement the mill's fibre requirements with additional purchased logs or chips. This was the case in 1996 (Baker 1998).

Table 4.3 shows Alberta-Pacific's 1996 production levels. Comparing the allocations to the woodyard to the production levels suggests that the composition of the fibre allocated to the woodyard can differ quite significantly from the fibre that is actually processed by the mill. This is due to the fact that logs and chips are stockpiled for varying amounts of time before being processed into pulp. This is particularly true of coniferous timber since only a limited number of days each year are allocated to the production of softwood pulp.

Table 4.2
Alberta-Pacific's Allocations to Woodyard in 1996

	Source	*Actual (m^3)*	*Budget (m^3)*
Deciduous	Harvest from FMA	**1,149,619**	**1,988,618**
	Purchased logs	645,986	155,873
	Purchased chips	0	0
	Total	1,795,605	2,144,491
Coniferous	Harvest from FMA	**71,453**	**71,455**
	Purchased logs	5,333	6,253
	Purchased chips	0	0
	Total	76,786	77,708
Total		1,872,391	2,222,199

Source: Alberta-Pacific records

Table 4.3
Alberta-Pacific's 1996 Pulp Production Levels

	Production Figures		*Woodlands Operations*
	Pulp (ADMT)	*Wood Input (m^3)*	*Allocations to Woodyard (m^3)*
Hardwood	397,150	1,946,035	1,795,605
Softwood	48,822	286,097	76,786
Transition	6,388	31,812	
Total	452,360	2,252,753	1,872,391

Conversion factors used: 4.9 m^3/ADMT for HBKP, 5.86 m^3/ADMT for SBKP, 4.98 m^3/ADMT combined (from Alberta Pacific's 1997 DFMP)
Source: Alberta-Pacific 1996c

The figures in the above tables can also be compared to Alberta-Pacific's AACs listed in the Company's detailed forest management plan (April 1997 draft) are approximately 1,973,000 m^3 for deciduous timber and 424,800 m^3 for coniferous timber. The budgeted deciduous FMA harvest level corresponds closely to the AAC. The coniferous harvest FMA harvest level, on the other hand is much lower than the AAC. Furthermore, generous estimates of the mill's wood requirements for coniferous timber from all sources are listed at 357,000 m^3.

For the purposes of the resource account, a decision must be made as to which figures to use as the basis for calculating the flow value from the region and determining the change in the timber stock. Unfortunately, the actual physical amount of timber harvested from the FMA is not available. The amount of wood allocated to the woodyard could be used but it would not give an accurate indication of the actual change in the growing stock. The other options are to use the planned or budgeted values, the amount of harvest inferred by the 1996 production levels or to use the use the AACs assuming that in any one year the Company would not deviate from them significantly. The problem with using the amount of harvest inferred by the 1996 production levels is that it is not obvious how to determine what amount fibre input originated from the FMA.

In the interest of developing the account based on a typical year, it was decided that where possible the AAC would be used. Since the budgeted amount of deciduous harvest was very close to the AAC, the ACC was used. However, the coniferous AAC is significantly higher than even the total mill requirements which include purchased chips and logs. Therefore, the wood requirements of 357,000 m^3 less the budgeted amount of 6,253 m^3 for purchased logs and chips (350,747 m^3) was used. This figure is also in closer agreement with AACs for 1998 provided by LFS (Bokola 1998).

If the Company maintains the resource accounting system, it is suggested that they develop a means of estimating the actual amounts of deciduous and coniferous timber harvested each year.

Fire, Insects and Disease

It is assumed that the main disturbance within the region is fire and that, at least in recent years, insects and disease have not had significant impacts. The Land and Forest Services (LFS) Division of Alberta Environmental Protection keeps a database of fires which occur throughout the province and areas burned in a specific region could be determined by manipulating this database, however, this would not be a simple process. Furthermore, LFS were unable to provide the structure of the database. Alberta-Pacific also monitors forest fire activity, however, does not keep detailed information unless there are significant impacts on its productive landbase.

For these reasons, the actual area or volume of timber lost to forest fire in 1996 was not available. However, information related to the frequency and impact of forest fires in an area approximately 8.6 million ha in size that encapsulates the study region is provided in Armstrong (1998). This information will be also be used in chapter 5 to characterize future forest fires in the study region Armstrong finds that the annual area burned and the annual burn rate (or fire risk) appear to fit a lognormal distribution. Armstrong's study suggests that the median burn rate of the case study region is about 0.006296%. Assuming that 1996, was a fairly typical year suggests that about 0.006296% of the stock, or 16,698 m^3 of merchantable coniferous timber and 9,367 m^3 of merchantable deciduous timber would have burned.

Land Use Conversion

Changes in Alberta-Pacific's land base that result from oil and gas activity are monitored and tabulated by Ever Green Land Use Consulting. Permanent withdrawls include roads, and wells, and temporary withdrawls include seismic lines. Although Ever Green was unable to provide area change figures for 1996, they were able to provide the total timber damage receipts for 1996 and average per hectare payments for 1997. Using this information, the change in land base that occurred in 1996 was estimated to be 3322.94 hectares in permanent withdrawls and 927.37 hectares in temporary withdrawls. Using the average amount of merchantable volume per hectare on Alberta-Pacific's landbase (397,971,776 m^3 / 6,138,726 million ha = 64.8 m^3/ha), this amounts to a loss of about 275,420 m^3. Of this total, about 64.3 % or 177,173 m^3 is deciduous and the remaining 35.7% or 98,247 m^3 is coniferous. Where practical, this salvage timber would have been purchased by Alberta-Pacific and processed into pulp.

Land use changes occurring within the doughnut holes are not monitored by Alberta-Pacific and were not available. Land use changes occurring on these areas are not included, however, it is anticipated that this omission is not significant.

4.4.1.1.3 Additions to the Timber Stock

Annual growth adds to the volume of merchantable timber on the FMA. The amount of growth occurring in 1996 was approximated using AVI data and yield tables. The resulting estimates of annual growth for coniferous and deciduous timber are listed in Table 4.1.

4.4.1.1.4 Physical Account

The information given in the above sections related to timber stocks and additions and removals for 1996 is used to generate Alberta-Pacific's 1996 timber account (Table 4.4). The next section will derive the economic rent estimates necessary to develop the corresponding value account.

Table 4.4
1996 Timber Stock Account

	Deciduous (m^3)	*Coniferous (m^3)*
Opening Stock	265,213,897	148,768,911
Removals		
Alberta-Pacific Harvest	-1,973,000	-350,747
Quota Holder Harvest		-984,595
Land Use Changes	-177,173	-98,247
Fire/Insect/Disease	-16,698	-9,367
Additions		
Growth	2,860,194	1,829,756
Closing Stock	265,907,220	149,155,711
Net Change in Stock	693,323	386,800

4.4.1.1.5 Economic Rent Estimation

Pulp Production

Although Anielski (1991)'s estimates of economic rent have been used in two previous resource accounting studies, for a number of reasons, Anielski's estimates for pulp production were not used in this study (see Tables A3 and A4). First, Anielski approximates economic rent as the difference between price and average total costs. Anielski's reasons for including average fixed costs were related to the focus of his analysis. He argued that for the purposes of government taxation aimed at rent capture, a more long-run rent concept should be used. For the purposes of this analysis, it was thought the more conventional use of average variable costs to approximate marginal costs would be more appropriate. Fixed costs are incorporated separately through an estimate of the depreciation of human made capital. Second, in order to calculate economic rent, Anielski required predictions of the price of hardwood and softwood kraft pulp. The predicted prices are significantly different than the prices that actually materialized in 1996. Third, when compared to Alberta-Pacific's financial data, Anielski's estimates of costs seem somewhat inflated.[29] This may be because Anielski's estimates were calculated before the completion of Alberta'a newest hardwood pulpmills, DMI and Alberta-Pacific. Both the DMI and Alberta-Pacific mills use more advanced technology and require less labour input. Furthermore, more recent cost estimates were available.

Risek (1995) provides a comparison of costs for bleached softwood kraft mills in different areas of the world based on a 1994 survey by Price Waterhouse. Although Alberta is not included in the comparison, the costs listed for mills in the Interior of British Columbia are given in Table 4.5.[30]

[29] Alberta-Pacific's actual costs were not used for confidentiality reasons.
[30] Risek (1995) also gives a historical review of costs across regions which shows that in 1990, the total delivered costs (before depreciation and interest expenses) of mills in the interior of BC was $560. This value corresponds more closely to Anielski (1991)'s estimate of $581 in 1990.

Table 4.5
Variable Costs of Softwood Pulp Mills in Interior BC (1994)

Cost Category	*Cost (US$1994 per tonne)*	*Cost (CDN$1994 per tonne)*
Wood (stump to mill)	148	208
Purchased Power	30	42
Chemicals	44	62
Labour	77	108
Materials, maintenance and mill administration	40	56
Total mill level costs	386	542
Corporate and sales expense	9	13
Delivery	81	114
Total delivered costs	476	668[a]

[a]Total is different than sum of costs due to rounding.
Source: Risek (1995 p. 310)

Although it is an older study than Risek (1995), Reinhardt (1994) provides an estimate specific to Alberta in his case study of Alberta Pacific Forest Industries. His estimate of the variable costs of hardwood pulps in Alberta is listed in Table 4.6. Transportation costs are excluded as are fixed costs such as financial and administration costs and depreciation. On average his estimate is $290.5 in 1996 dollars.[31] This estimate is significantly lower than the mill level costs estimated for interior BC by Risek (1995). The largest differences being in wood, and labour costs. Geography and climate may provide wood costs advantages in Alberta compared to BC. Alberta-Pacific also employs relatively few people compared to many mills suggesting that its labour costs may be closer to those estimated by Reinhardt (1994). Energy costs are also likely to be lower in Alberta than BC. Overall, the difference in costs seems possible but is difficult to confirm without more specific information.

Table 4.6
Mill Level Variable Costs of Hardwood Pulp Mills in Alberta (mid 1992)

Cost Category	*Cost (US$1992 per tonne)*	*Cost (CDN$1996 per tonne)*
Wood (stump to mill)	80-120	101-152
Purchased Power	20	25
Chemicals	40	51
Labour	30	40
Packaging and other operating costs	40	51
Total	210-250	266-316[a]

[a]Total is different than sum of costs due to rounding.
Source: Reinhardt (1994 Exhibit 11, p. 29)

[31] Canada/US exchange rates and annual average Canadian Producer Price Index, GDP are listed in Table A10.

A general idea of Alberta-Pacific's costs can also be obtained from Crestbrook Forest Industries Annual Report. Since, in 1996, Crestbrook owned 40% of the Alberta-Pacific Joint Venture, the company reported its share of Alberta-Pacific's costs and revenues in the consolidated financial statements provided to its shareholders. With this information and an estimate of 1996 production (452,360 ADMT), the approximate cost of sales (hardwood and softwood combined) for Alberta-Pacific was determined to be about $372/ADMT (Table A5). However, besides variable costs of production, this estimate may include some minor fixed costs (such as holding and protection fees, environmental resources budget, etc.). An additional $18/ADMT is associated with administration services bringing the total mill level costs to $390.

Based on the above information related to costs, as a lower bound, the average of Reinhardt (1994)'s estimated range of costs–$290.5–and, as a higher bound, the estimate obtained from Crestbrook's financial statements–$390–will be used in the estimation of economic rent. Since only delivered prices were available, it is also necessary to consider the costs associated with transporting the pulp from the mill to the point of sale. Risek (1995)'s estimate of the corporate and sales expense and delivery costs for mills in interior BC are assumed to provide a reasonable estimate of similar costs in Alberta. When these costs are added to the mill level costs, the range of total variable costs is $417.5 to $517.

The 1996 prices of Hardwood Bleached Kraft Pulp (HBKP) and Softwood Bleached Kraft Pulp (SBKP) were obtained from Ron Dunnigan of Land and Forest Services, AEP (see Table A6). AEP uses market prices from *Pulp and Paper Week* to calculate stumpage fees.

In Table 4.7, the estimates of average variable costs and average prices are used to estimate the economic rent associated with production of pulp in the region.

Table 4.7
1996 Economic Rent Estimates: Pulp Production (1996$)

Pulp Type	*Scenario*	*Average Pulp Price ($/ADMT)*	*Total Average Variable Costs ($/ADMT)*	*Economic Rent ($/ADMT)*	*Economic Rent ($/m³ wood input)*
HBKP	Low	695.40	517.00	178.40	36.41
	High	695.40	417.50	277.90	56.71
SBKP	Low	763.57	517.00	246.57	42.08
	High	763.57	417.50	346.07	59.06

HBKP and SBKP stand for Hardwood Bleached Kraft Pulp and Softwood Bleached Kraft Pulp.
Pulp production to wood input conversion factors used: 4.9 m^3/ADMT for HBKP, 5.86 m^3/ADMT for SBKP, 4.98 m^3/ADMT combined (from Alberta Pacific's 1997 DFMP)

It should be noted that the rent estimates in Table 4.7 do not include fixed costs such as debt financing and loan payments. However, discussions with Alberta-Pacific's administrative staff suggest that these costs represent a substantial share of total annual costs and are comparable in size to annual human-made depreciation. This suggests that the large capital costs associated with pulp mill construction and start-up remain significant determinants of the Company's financial position for many years. Therefore, although the above rent estimates indicate that pulp production provided net benefits in 1996, these benefits come at the expense of significant capital outlays which are now considered sunk costs.

Lumber Production

Anielski's estimates of the costs associated with sawmill production in Alberta are thought to be more accurate than his estimates for pulp production, therefore they are used in the estimation of economic rent associated with quota holder harvest. However, Anielski includes stumpage fees estimate of the average variable costs (AVC) of production. Since we are concerned with the full value of rent regardless of the recipient, government or Company, stumpage is netted out of AVC. According to Anielski (1991 p. 49), "the average or standard regulation stumpage fee on softwood is $0.70 per cubic meter... [and] can vary from $0.18 to $1.23 per cubic meter". It is not obvious exactly what value in this range Anielski used therefore the standard rate of $0.70 is netted out of his 1991 estimate of AVC before converting them to 1996 dollars.

In Table 4.8, 1996 lumber prices are combined with Anielski's cost estimates (converted to $1996) to arrive at an estimate of the economic rent associated with lumber production in the region.

Table 4.8
1996 Economic Rent Estimate: Lumber Production

Lumber Price	*Residue Income*[a]	*AVC*	*Rents (S$/Mfbm)*	*Rents ($/m³ wood input)*[b]
478.32	33	250	261.32	60.89

[a] Residue Income is the income resulting from the sale of chips and shavings.
[b] Conversion factor for lumber output to wood input is 0.233 Mfbm/m³ as listed in Anielski (1991 p. 178)
Sources: Lumber price: Random Lengths in USDA (1997); costs Anielski (1991)

4.4.1.1.6 Monetary Account

The estimated economic rent estimates represent the shadow prices required to value the flow and stock component of the timber account. The flow component consists of Alberta-Pacific and quota holder harvest for the purposes of pulp and lumber production. The stock component refers to the change in the volume of merchantable timber over the period.

Using the volume of harvested timber and the economic rent estimates from the above tables, the net value of pulp and lumber production is determined in Table 4.9. A range of values associated with low and high rent estimates is given.

Table 4.9
1996 Flow Value of Pulp and Lumber Production

		Low Estimate			High Estimate		
		Rent ($/m³)	Harvest (m³)	Value (1996$)	Rent ($/m³)	Harvest (m³)	Value (1996$)
Pulp	HBKP	36.41	1,973,000	71,836,930	56.71	1,973,000	111,888,830
	SBKP	42.08	350,747	14,759,434	59.06	350,747	20,715,118
Subtotal			2,323,747	86,596,364		2,323,747	132,603,948
Lumber		60.89	984,595	59,951,990	60.89	984,595	59,951,990
Total				233,144,718			325,159,886

HBKP and SBKP stand for Hardwood Bleached Kraft Pulp and Softwood Bleached Kraft Pulp.

The value of the change in timber stock is determined in Table 4.10. Since both Alberta-Pacific and quota holders operate in the region, for the purposes of valuation the change in coniferous stock must be divided amongst future pulp and lumber production. The change in coniferous stock is allocated according to the proportion of coniferous harvest represented by Alberta-Pacific and quota holders in 1996 which is listed in Table 4.4.

The stock changes are valued using the method advocated by Hartwick (1990). Hartwick's method corresponds to the valuation procedure that implied when an optimal control or growth framework is used to derive NNP. However, as discussed in chapter 3, not all resource accounting practitioners use this method.

Table 4.10
Value of the Change in the Merchantable Timber Stock in 1996 (1996$)

	Change in Stock	Product	Rent Estimate ($/m^3)	Value Low	Value High
Deciduous	693,323	HBKP	36.41-56.71	25,243,890	39,318,347
Coniferous	386,800				
Alberta-Pacific (26.3%)	101,728	SBKP	42.08-59.06	4,280,714	6,008,056
Quota holder (73.7%)	285,072	Lumber	60.89	17,358,034	17,358,034
Total				46,882,638	62,684,437

HBKP and SBKP stand for Hardwood Bleached Kraft Pulp and Softwood Bleached Kraft Pulp.

Note that the above valuation assumes that current rent estimates represent the capitalized value of a marginal change in the stock resource. However, as pointed out by Mäler (1991), the shadow value attached to the stock resource should represent the marginal value of the stock resource in all uses. Here only the marginal value of the stock resource in commercial timber production is considered. The marginal valuations associated with the dependence of other forest services such as recreational values for example are difficult to measure, however, technically they should be incorporated in the capitalized value of the stock. Determination of a more appropriate timber stock price is beyond the scope of this study but is an area where further study is needed.

Currently not all the merchantable coniferous stock is allocated to Alberta-Pacific or quota holders. Some of the stock has been reserved for other uses and future allocation. Furthermore, in the last few years, Alberta-Pacific has not always harvested its full deciduous or coniferous AAC. Therefore, valuing the entire change in the merchantable stock may over estimate the actual commercial value that will materialize but it does represent the potential value.

The depreciation of human-made capital must also be considered in an estimate of regional net income. For confidentiality reasons, the actual value of Alberta-Pacific depreciation cannot be reported. Instead an approximate value of Alberta-Pacific's depreciation of human-made capital was estimated using Crestbrook Forest Industries Annual Report (Table A5) and information reported in Anielski (1991). Using Crestbrook's report, Alberta-Pacific's human-made depreciation is estimated at $84,190,000. However, the value reported includes road amortization and therefore may be overstate actual depreciation. A lower estimate is derived from Anielski (1991). For 1990, Anielski found that depreciation in Alberta's Pulp and Paper sector was about $120.69/ADMT of output which, in 1996 dollars, is equivalent to $131.54/ADMT or

$26.41/m^3$ of wood input. Applying this value to the volume harvested in 1996 provides an estimate of $61,379,305. Both these estimates appear to be reasonable when compared to financial information provided by Alberta-Pacific.

Anielski (1991) reported that depreciation in the sawmill industry was approximately $21.13/Mfbm of lumber output in 1990. This equates to $5.37/m^3$ wood input in 1996 dollars. Applying this estimate to the 1996 harvest results in an estimated depreciation of $5,287,275.

Comparison to Government Stumpage Rates

As noted earlier, Alberta-Pacific and other commercial forestry operators are charged stumpage fees on the timber that they harvest. As Anielski (1991) explains, stumpage fees represent one of a number of means by which the government attempts to capture part of the rent associated with pulp, lumber, and other forest product production. Stumpage rates are sometimes used to estimate the value of standing timber and to approximate the rents associated with forestry activities.

The stumpage fees that Alberta-Pacific pays to the Alberta government are set out in Alberta-Pacific's FMA and are the result of negotiations between the Company and the government. These fees are to be paid on all timber that Alberta-Pacific manufactures into pulp where it is cut by or for the Company. Section 34 of the FMA determines the stumpage fees to be $2.09/m^3$ for conifer species and $0.40/ m^3 for deciduous species. These fees are adjusted annually on October 1 to account for changes in the market value of pulp.[32]

The stumpage fees paid on lumber production by quota holders vary monthly according to adjusted Western spruce-pine-fir prices listed in the publication *Random Lengths*. The listed US price per Mfbm is adjusted to account for price changes within the month, the exchange rate, and duty (softwood lumber export tax).[33]

Comparison of government stumpage fees to the rent estimates from this study shows that the government is only capturing a fraction of the total rent associated with pulp and lumber production in the region. In addition, it appears that stumpage rates do not provide an accurate estimate of the rent associated with forestry activities.

Table 4.11
Rent Estimates Compared to Stumpage Rates in 1996 (1996$)

	HBKP	*SBKP*	*Lumber*
Stumpage Rate ($/m^3$)	2.39	0.46	10.20
Rent Estimate ($/m^3$)	36.41-56.71	42.08-59.06	60.89

HBKP and SBKP stand for Hardwood Bleached Kraft Pulp and Softwood Bleached Kraft Pulp.
Lumber stumpage rates are calculated monthly therefore the rate reported is the annual average for 1996.

As noted, stumpage fees only represent one of many mechanisms the government uses to capture rent from forestry activities. Forest products companies are subject to many other forms of charges, fees, indirect taxes and direct taxes.[34] A more

[32] See Table A6 for a historical listing of Alberta-Pacific's stumpage fees and the kraft pulp prices upon which they are based.
[33] See Schedule 3 of the Timber Regulations for more details.
[34] See Anielski (1991) for a comprehensive review of these different types of rent capture.

comprehensive determination of the government's efficiency at rent capture would require considering all these mechanisms. Such an exercise is beyond the scope of this study.

4.4.2 Other Commercial Uses

4.4.2.1 Fishing

In general, there has been a decline commercial fishing in Alberta since the late 1980s. This trend is at least partly due to the moratorium imposed by the Alberta government for environmental reasons.

According to MacLock and Thompson (1996), commercial fishing occurs in several lakes in Northern Alberta. Those that are within the study region or in close proximity of the region's boundaries include Peerless Lake (within the region), Lake Nipisi (partly within the region), and Lac la Biche. Utikima Lake and North Wabasca Lake are just outside the region's boundaries. Catch volume estimates for these lakes are compared to the total provincial catch in Table 4.12.

Table 4.12
Average Commercial Fishing Statistics for 1990/91 to 1994/95

Lake	*Average Catch/Year (kg)*	*Proportion of Provincial Catch*
Lac la Biche	154,900	7.3%
Peerless Lake	39,500	1.9%
North Wabasca Lake	27,300	1.3%
Lake Nipisi	21,100	1.0%
Utikuma Lake	77,400	3.8%
Total	320,200	11.8%

Source: MacLock and Thompson (1996)

Table 4.13
Alberta Commercial Fishing Statistics for 1994-1995

Landings (kg)	*Landed Value*	*Market Value*	*Net Value (Landed - Market)*	*Net Value/kg*
1,432,000	$1,523,000	$2,803,000	$1,280,000	$0.8938

Source: DFO (1996)

According to DFO (1996), 1,432 tonnes (live weight) of fish were marketed by the freshwater fisheries marketing corporation in Alberta in 1994-1995 (May 1 to April 30) representing $2,803,000 in sales. Using the net value per kilogram of these sales as a conservative estimate, the net value of commercial fisheries within and in close proximity to the FMA is $286,194/year ($0.8938/kg * 320,200).

4.4.2.2 Trapping

According to Alberta-Pacific Aboriginal Affairs estimates, there are between 430 and 436 traplines within the FMA (Quin 1998). However, it estimated that each year only about 40% or between 172 and 175 of the lines are active. Quin (1998) also estimates that aboriginals operate about 40% of the traplines in the region. For many of these native people, trapping also serves as a means to pass on traditional knowledge to younger generations.

Although, there are definitely costs associated with trapping activity such as registration fees, transportation, equipment purchase and maintenance, trail maintenance and improvement, and lodging, there are also a number of non-market benefits. Since these costs and benefits are difficult to determine, it is assumed that they approximately balance each other out and therefore, trapping cash revenue can approximate the net benefit resulting from trapping activity.

According to Alberta Environmental Protection, there are about 4,000 trappers in Alberta. The total value of wild fur production was just over 3 million in 1995/96 and just over 4 million in 1996/97 (AEP web site, 1998), making the average revenue per trapper for these seasons, about $750 and $1000. Quin (1998) estimates that the average revenue of a trapper in the region is $1,000/season. This estimate seems to correspond with the provincial average.

Studies which examine trapping activity in Alberta are limited, however, there are two studies that focussed on assessing the value of trapping as part of Environmental Impact Assessments of projects in the vicinity of the FMA region. Boisclair (1985) estimates that average income per trapper in the Lakeland planning area, which lies just outside the northern border of the FMA, was $1,949 in 1982/83 and $1,280 in 1983/84.[35]

A more recent study by Westworth, Brunsnyk & Associates Ltd. (1996) examined annual trapping income derived from four Registered Fur Management Areas (RFMAs) near Fort McKay and Fort McMurray in the Northern part of the FMA. As part of the Westworth, Brunsnyk & Associates Ltd. study, the trapping revenues generated per unit area were estimated. On average, from 1984/85 to 1993/94, the four RFMAs generated $5.95/km^2, with the productivity of the specific RFMA ranging from $3.86 to $7.22/km^2. Table 4.14 applies this range of productivity estimates to the case study region.

Table 4.14
The Value of Trapping within the Case Study Region (68,061.6 km^2)

Productivity($/km^2)		Value (1994$)	Value (1996$)
Low	3.86	262,718	274,669
High	7.22	491,405	513,759
Average		377,062	394,214

Conversion factor: 1994$ to 1996$: CPI for Alberta as listed in Table A10

Given the above information, the total revenue obtained from trapping and associated fur sales in the FMA region in 1996 is estimated to be between $274,669 and $513,759. However, it should be kept in mind that "trapline incomes are highly variable from year to year since they depend upon many external factors such as weather and fluctuations in pelt prices associated with species availability from year to year" (Boisclair 1985 p. 3).

[35] Part of the decrease in average income between the years is attributed to the increase in recreational and agricultural development in the area (Boisclair 1985).

4.4.3 Recreational Activity

4.4.3.1 Hunting

Activity Levels

Recreational hunting in Alberta has been the focus of a number of recent studies. In 1997, the Department of Rural Economy and the Canadian Forest Service conducted two hunting surveys: one that was designed to elicit information on the value of hunting activity in Alberta for 1996; and, the other examines hunters' opinions, attitudes, and values. The results of the activity survey were used to estimate the frequency of big game hunting in 1996 within the study region.

Of the 5,000 surveys that were mailed to licensed hunters, 1731 were returned. Eight of the returned surveys were completely unanswered leaving information on the activities of 1723 licensed hunters. 61 respondents (3.54% of 1721) indicated that they did not hunt in 1996. Of those that hunted (1662) in 1996, only 1429 were able to identify the wildlife management unit/s corresponding to the area where they hunted.

The number of hunting days that occurred in wildlife management units (WMUs) that occur within or overlap with the FMA boundaries are reported in Table 4.15. Of the 1429 respondents, 173 (12.11%) hunted in at least one of the 13 WMUs.

Table 4.15
Big Game Hunting Survey Results

WMU	*Respondents who Hunted in WMU*	*Overnight Trips*	*Number of Nights*	*Day Trips*	*Total Trips*	*Total Days*
509	7	12	13	35	47	48
510	49	83	154	226	309	380
511	11	23	62	51	74	113
512	34	57	151	78	135	229
515	16	20	51	97	117	148
516	14	38	83	9	47	92
517	8	9	33	24	33	57
518	8	18	21	31	49	52
519	18	31	67	110	141	177
529	8	7	25	21	28	46
530	18	30	94	29	59	123
531	6	9	39	16	25	55
542	23	35	216	3	38	219
Total	173[a]	372	1,009	730	1,102	1,739

[a] 173 does not correspond to the total of the column (220) because some respondents indicated that they hunted in more than one of these WMUs.

The activity levels listed in Table 4.15 are based on a sample of 15.66 % of active licensed hunters in 1996 (1429 of 91,232). Assuming that sample was randomly drawn from the population, 1996 activity levels for the WMUs are determined by scaling the sample results upward by a factor of 63.84. The resulting activity levels for the WMUs are listed in Table 4.16. A number of WMUs are not completely within the FMA boundaries, therefore, activity levels were weighted by the proportion of the FMA that lies within the particular WMU. This assumes that the trips (and days) are evenly distributed across the WMU. Although this is unlikely to be the case, information on the exact locations of trips is not available. However, it is anticipated that overall the resulting inaccuracy is not be significant.

Table 4.16
Big Game Hunting Activity Levels in 1996

	WMU Totals		*Proportion of*	*FMA*	
WMU	*Trips*	*Days*	*WMU in FMA*	*Trips*	*Days*
509	3,000	3,064	0.27	810	827
510	19,727	24,259	0.32	6,312	7,763
511	4,724	7,214	0.16	756	1,154
512	8,618	14,619	0.97	8,360	14,181
515	7,469	9,448	0.94	7,021	8,881
516	3,000	5,873	1.00	3,000	5,873
517	2,107	3,639	1.00	2,107	3,639
518	3,128	3,320	1.00	3,128	3,320
519	9,001	11,300	1.00	9,001	11,300
529	1,788	2,937	1.00	1,788	2,937
530	3,767	7,852	0.37	1,394	2,905
531	1,596	3,511	0.47	750	1,650
542	2,426	13,981	0.66	1,601	9,227
Total	70,352	111,018		46,029	73,658

It should be noted that not all recreational hunting activity in the region is focused on big game species. Although, some survey respondents identified trips where bird species were hunted, it is unlikely that the survey results include all small game hunting activity. Consequently, the activity levels in Table 4.16 represent conservative estimates of total recreational hunting activity.

Valuation

In order to determine the value of recreational hunting activity in the FMA in 1996, the activity levels must be combined with a measure of the value of recreational hunting experiences. Unfortunately, this information was not available from the survey used to determine the activity levels. However, there have been a number of studies in recent years that elicit the WTP associated with recreational hunting (see Table 4.17). Adamowicz *et al.* (1997) is one of the most recent studies to estimate the value of big game hunting, specifically moose, in Alberta. The study suggests that WTP/trip ranges from about $6-21 in 1996 dollars. When compared to WTP estimates of other studies from the 1990s listed in Table 4.17 this range appears to be reasonable. Although, studies from the late 1980s suggest higher WTP values, considering recent advances in non-market valuation techniques, it is assumed that recent estimates are more reliable.

Table 4.17
Willingness to Pay for Recreational Hunting

Source	*Data Year*	*Description*	*Value (Data Year $)*	*Value (1996$)*
Bodden and Lee (1986)	1985	Resident Pheasant Hunting (AB, CVM)	17.44/day	24.63/day
Bodden and Lee (1986)	1985	Resident Pheasant Hunting (AB, TCM)	25.37-44.60/day depending on region	35.84-63.00/day depending on region
Swanson *et al.* (1989)	1985	Deer Hunting	105/season/year	148/season/year
Swanson *et al.* (1989)	1985	Moose Hunting	55/season/year	78/season/year
Asafu-Adjaye (1989)	1987	Big Game Hunting (AB)	204.06/year	265.04/year
Filion *et al.* (1994)	1991	Hunting of large mammals (AB)	13.0/day	14.0/day
Filion *et al.* (1994)	1991	Hunting of small mammals (AB)	5.5/day	5.9/day
Filion *et al.* (1994)	1991	Hunting of waterfowl (AB)	16.6/day	17.8/day
Filion *et al.* (1994)	1991	Hunting of other birds(AB)	9.3/day	10.0/day
Filion *et al.* (1994)	1991	All Hunting (AB)	13.4/day	14.4/day
Condon (1993)	1992	Moose hunting (Nfld)	122.54-212.90/season	129.71-225.36/season
McLeod (1995)	1992/3	Moose Hunting (AB), site closure	5.56 (perceived)-10.26 (objective)/trip	5.78 (perceived)-10.67 (objective)/trip
Adamowicz *et al.* (1997)	1992/3	Moose Hunting (AB), site closure using different models	5.81-20.16/trip	6.04-20.96/trip

Values were converted to 1996$ using CPI values for Alberta or Canada as listed in Table A10.

Using the WTP estimate from Adamowicz *et al.* (1997) ($6-21/trip) and the estimated number of trips from Table 4.16 (46,029), the total value of recreational hunting activity within the study region in 1996 is estimated to be between $276,174 and $966,609.

4.4.3.2 Fishing

Activity Levels

Extrapolation of available recreational fishing activity data to the FMA region proved difficult. Activity data based on specific location (i.e. stream or river) was collected as part of the NRBS household survey but was limited to the respondent's three most frequented sites which represented only about 54% of all trips taken. In addition, the NRBS data was in a form that made differentiation of sites within the FMA region difficult.

Most other recreational fishing activity data is collected on a regional basis according to Alberta's eight fish management areas. The Alberta-Pacific FMA lies within the three largest fish management areas, specifically areas 6, 7, and 8. Since the FMA only covers a small portion of the total area covered by these three management areas, the activity levels were weighted based upon the portion of the area represented by FMA land. The validity of this approach is questionable but considering the lack of more spatially exact data it seemed the only alternative. It should be noted, however, that as of

April 1, 1998, new administrative regions are being applied in Alberta (see the 1998 Alberta Guide to Sport Fishing Regulations). There are now three large fish management zones that are divided into 10 watershed units. According to Berry (1998), in the future activity data will be collected according to these watershed units. This should allow the fishing activity within the region to be more accurately determined.

The 1995 National Sport Fishing Survey is the most recent source of information on recreational fishing activity in the fishing management areas that extend into the region. However, another recent study, Graham (1995), includes data related to 1994 resident (Albertans only) angling activity but by the author's own admittance the response rate was so low that the reliability of the results is questionable.

However, Graham (1995) discusses some important points regarding the accuracy of surveys that are limited to fishing license holders which also apply to the results of the National Sport Fishing Survey since its sample was taken from license sale receipts. Graham (1995) notes that the resulting statistics do not account for anglers under 16 and over 65 who are not required to purchase licenses and suggests that "the impact of unaccounted for number of unlicensed anglers on the sport fishery is probably considerable" (p. 7). The activity levels listed in Table 4.18 are, therefore, likely to be conservative.

Table 4.18
National Sport Fishing Survey Results

Fishing Management Area	*Alberta Residents*	*Non-Residents*	*Total Days*	*Proportion of Area in FMA*	*Alberta Residents*	*Non-Residents*	*Total Days within FMA*
6	416,779	8,898	425,677	0.09	37,510	801	38,310
7	113,318	8,168	121,486	0.40	45,327	3,267	48,595
8	967,041	19,559	986,600	0.16	154,727	3,129	157,856
Total	1,497,138	36,625			237,564	7,198	244,761

Fishing Management areas 6, 7, and 8 correspond to the Peace River, Athabasca and lower northeast boreal, respectively.

Value

As with recreational hunting, in order to determine the value of recreational fishing activity in the FMA in 1996, the activity levels must be combined with a measure of the value of recreational fishing experiences. As part of the National Sport Fishing Survey anglers were asked:

> What is the maximum amount of money you would pay PER FISHING DAY before it would have been too expensive to fish at all in Alberta in 1995?

Welfare measures calculated from the responses to this question are listed Table 4.19 along with WTP estimates from other recent studies.

Table 4.19
Willingness to Pay for Recreational Fishing

Source	Data Year	Description	Value (Data Year $)	Value (1996$)
Usher (1987)	1986	Lake of the Woods, ON	3.40/day	4.61/day
Peters (1993)	1990	Closure of 4 different sites in southern AB (RUM)	0.59-1.89/trip	0.68-2.18/trip
Adamowicz (1994)	1990	Resident Sport Fishing, AB (site closure using different models)	1.57-2.15	1.81-2.48/trip
National Sport Fishing Survey	1995	Resident Angling, AB		
		Median MWTP	10/day	10.22/day
		Average MWTP	26.88/day	27.47/day
National Sport Fishing Survey	1995	Non-resident Angling, AB		
		Median MWTP	30/day	30.66/day
		Average MWTP	36.85/day	37.66/day

The validity of the WTP estimates from the National Sport Fishing Survey is questionable due to the wording of the survey question and the lack of reference to budgetary substitutes. Furthermore, in comparison to some of the other WTP estimates listed in Table 4.19, the National Sport Fishing Survey estimates seem high. For this reason, the National Sport Fishing Survey median WTP estimates (i.e. $10.22 for residents and $30.66 for non-residents) will represent the upper bound on actual WTP. For resident anglers, the estimates from Adamowicz *et al.* (1994) appear to provide a reasonable lower bound for WTP. The mid-point of the estimates from Adamowicz *et al.* (1994) is $2.15/trip. Since activity levels for the region are in days and on average trips taken by Alberta residents last just over one day (Graham 1995), the lower bound used for resident fishing is $2/day. Assuming that the ratio of resident to non-resident WTP (1:3) indicated by the National Sport Fishing Survey is correct, $6 ($2 x 3) is used as a lower bound on the WTP of non-resident anglers. Using these ranges of WTP, the total value of recreational fishing in the study region is estimated to range from $518,313 to $2,648,595 (see Table 4.20).

Table 4.20
Value of Recreational Fishing

Estimate		*WTP Scenario*	*Value (1996$)*
Low	Resident	$2/day	475,128
	Non-resident	$6/day	43,185
	Total		*518,313*
High	Resident	$10.22/day	2,427,904
	Non-resident	$30.66/day	220,691
	Total		*2,648,595*

4.4.3.3 Camping

LFS (1994) provides summaries of camping activity within Alberta by entering data provided on self-registration fee envelopes. LFS (1994) suggests that "...the use levels indicated by this report are fairly accurate. However, there is a small degree of non-compliance with user fees and, as a result, camping use levels may be slightly higher in some areas" (p. 2). Day use activity is also monitored but by random visual sampling. For this reason, the day use activity levels attained from this report "only represent the minimum amount of day use" (LFS 1994 p. 2).

Table 4.21 lists the camping activity in 1994 for districts that fall within the study region or are very close to the FMA boundaries. Unfortunately, activity levels for a more recent year were not available.

Table 4.21
Camping Activity (May – October 1994)

Forest	*District*	*Camping Party Nights*
Athabasca	Fort McMurray	1,095
Lac la Biche	Calling Lake	1,105
	Wandering River	402
Slave Lake	Smith	3,152
	Wabasca	1,223
Total		6,977

Source: LFS (1994)

Boxall *et al.* (1996) examine camping trips by Alberta residents to the Rocky-Clearwater Forest during 1994 and based on an aggregate travel cost model find the value per trip to be $52.77. Non-residents of Alberta were not included in their analysis because of the "high probability of multiple destinations for most visitors not residing in Alberta" (p. 617). However, the activity data in Table 4.21 includes all parties regardless of their place of residence.

Using the average number of nights per trip (1.80 as reported in McFarlane *et al.* (1996)) the camping activity levels in Table 4.21 correspond to approximately 3,876 trips (6,977nights /1.8 nights/trip). If the WTP estimate from Boxall *et al.* (1996) is used, the value of these trips is $204,542 in 1994$ (3,876 * $52.77) and $212,211 in 1996$s.

4.4.4 Subsistence Resource Use by Aboriginal Peoples

As noted above, subsistence use by aboriginal people in the region includes wood harvesting, hunting, fishing, trapping, and food gathering and use of other forest materials for making crafts or for use in traditional medicine. Unfortunately, quantitative information on these activities is limited for the Alberta-Pacific region. The Athabasca Native Development Corporation (ANDC) conducted an aboriginal traditional use study that "looked at where, when, and how the aboriginal people of northeast Alberta use the land" (Alberta-Pacific pamphlet). Unfortunately, this database outlines the locations of resources used in subsistence activities but does not include the quantities of the resources in the locations identified or the amounts used each year.

Unfortunately, AEP collects only limited sources of information related to subsistence activities. Since, "...Status or Treaty Indians are allowed to hunt and fish for subsistence purposes without a license" (MacLock and Thompson 1996 p. 50), it is not possible to infer participation rates from purchases of licenses. Metis and Indian trappers are required to be licensed but the number of licenses issued does not reflect whether the fur and meat obtained from these traplines is used for subsistence or commercial purposes.

The NRBS attempted included questions regarding subsistence activities in some of its surveys but "...there were insufficient survey response to provide a detailed description of subsistence activities in the NRBS area" (p. 50). The study estimated that 45% of Status or Treaty Indians participate in subsistence activities. The Traditional Knowledge component of the NRBS asked native people what plants and animals they used and what areas these resources were obtained; however, there was no assessment of the quantity of resources used in a specific segment of time.

Due to the lack of information related to the amount of resource use for subsistence purposes specific to the study region, estimates from other studies were collected. Studies that determine the quantity of resources used for subsistence purposes have been conducted for other areas of Canada. Studies of bush country food use by native communities in other forested regions include: Wein *et al.* (1991)- Fort Smith and Fort Chipewyan; Tobias and Kay (1992)- Saskatchewan, and; Berkes *et al.* (1994)- Hudson and James Bay Lowland, Ontario.

Not all of these studies estimate the monetary value of resources used for subsistence activities but those that do often estimate the value of subsistence activities using replacement values. "Replacement values are obtained by imputing prices using the closest substitutes to harvest products that are available in the nearest market" (Korber 1997 p. 34). Berkes and Fast review several subsistence harvest studies conducted in Canada and include a table of several studies' estimates of the replacement value of subsistence bush meat per household per year (Table 9.4, pp. 240-241). These estimates are included in Table 4.22. Table 4.22 also includes estimates from two more recent studies by Korber (1997) and Beckley and Hirsh (1997).

From Table 4.22 it appears that the value of subsistence activities per household tends to range from about $5,000 to $11,000 depending upon the location and the variety of activities valued in the study.

It is assumed that the reserve population of potential aboriginal beneficiaries from subsistence use of the forest resources within the FMA is between 7,509 and 10,967 (see Table A9). Using the provincial average of Indian Reserve household size from the 1991 Census (4.5 individuals), this represents between 1669 and 2437 households. Table 4.23 uses these population estimates and the range of household subsistence activity values to estimate the value of subsistence activity in the case study region.

Table 4.22
Replacement Value Studies[a]

Study	Data Year	Location	Subsistence Activities Valued	Estimated Value per Household ($)[b]	Estimated Value/Household (1996$)
Tobias and Kay (1992)	1983/84	Pinehouse, SK	Bush Meat	6,290	6,759
Berkes et al. (1994)	1989/90	8 communities in Hudson Bay & James Bay Lowland	Bush Meat	7,453	8,008
Scott (1982)	1975-6	Wemindji, Québec	Bush Meat	8,459	9,089
	1976-7			8,863	9,523
Gamble (1984, 1987)	1982-83	Keewatin Region of the NWT	Bush Meat	15,727	16,898
Wagner (1985)	1983/84	Northern MN region	Bush Meat	1,594	1,712
Korber (1997)	1991	Waterhen, SK	Fuelwood, wild meat (big game, birds), fish, & berries	4,484	4,818
Beckley and Hirsh (1997)	1993/94 (1995$s)	Fort Liard	Meat, fish, berries, fuelwood	7,021	7,131
			Craft sales & trapping	3,775	3,834
			Total	10,796	10,965
Beckley and Hirsh (1997)	1993/94 (1995$s)	Nahanni Butte	Meat, fish, berries, fuelwood	8,694	8,830
			Craft sales & trapping	1,937	1,967
			Total	10,631	10,798

[a] All information taken from Berkes and Fast (1996 p. 240-241), except Korber (1997) and Beckley and Hirsh (1997).
[b] In 1991$s unless otherwise indicated.

Table 4.23
1996 Subsistence Value

Scenario	*Household Value ($)*	*Households*	*Total Value ($)*
Low	5,000	1,669	8,345,000
	5,000	2,437	12,185,000
	11,000	1,669	18,359,000
High	11,000	2,437	26,807,000

Although replacement values are commonly used to value subsistence activities, there are numerous limitations associated with this technique as pointed out by Korber (1997) and Beckley and Hirsh (1997). In particular, Beckley and Hirsh (1997) point out the difficulties associated with attempting to quantify the value Native people derive from living off the land. In the words of Beckley and Hirsh (p. 19-20)

> "There may not be substitutable commodities that could compensate for what would be lost if the opportunity to hunt and trap were not available to indigenous people whose ancestors lived in the same place, and practiced the same activites before them... The Native person's experience of tracking game and "living off the land" like their ancestors may not be quantifiable in the context of mainstream economic theory. The comparison of subsistence goods with store-bought replacements assumes that consumers are "indifferent" to whether they have market goods or subsistence goods. In fact, respondents repeatedly expressed preferences for subsistence goods over store-bought substitutes".

There are a number of steps that could be taken to improve upon the above estimate. As noted above, there is no existing primary data related to the quantity of resources used for subsistence in the area. A survey of the region's First Nations' people which quantifies subsistence could be conducted. The results of the ANDC's Aboriginal traditional land use study and possibly the NRBS Traditional Knowledge survey may be useful in identifying significant subsistence resources that exist in the region that should be included in such a survey. Hirsh and Beckley (1997 p. 20-21) also suggest that the estimation of "...the marginal utility associated with consuming one additional unit of comparable subsistence and market goods..." may provide a better estimate of the marginal value associated with subsistence use than replacement values.

4.4.5 Passive Use Value: Biodiversity Maintenance

In comparison to more intensive land use activities, extensive forest management allows a significant portion of the boreal mixedwood's biodiversity to be maintained. In addition, in Alberta, there are often conditions included in FMAs that are aimed at ensuring that biodiversity is protected. For example, Alberta-Pacific restricts harvesting at certain times of the year in certain areas in order to minimize disturbance of caribou and moose breeding. In addition, forest products companies may institute their own initiatives for protecting or enhancing biodiversity. For example, Alberta-Pacific has voluntarily proposed to set aside an area, approximately 340,000 ha in size, in the northwest portion of its FMA(within FMUs S13, and S14) as an ecological benchmark area. In addition, Alberta-Pacific believes that implementing an ecosystem management approach to harvesting will ensure that biodiversity is maintained.

Biodiversity is extremely difficult to measure and monitor and even more difficult to value. However, attempts to value biodiversity have been made including in the context of forest resource accounting. Adger *et al.* (1995) and Hulkrantz (1992) include the value of biodiversity in their forest resource accounts. Adger *et al.* (1995) uses values implied by "transactions related to natural area conservation in Mexico" including contributions to conservation organizations and programs, a tourism survey and debt for nature swaps (p. 293).

In order to estimate the value of biodiversity maintenance provided by Swedish forests, Hulkrantz (1992) estimates the opportunity costs associated with increasing compares the amount of protected area several different approaches. The opportunity costs are determined by calculating the amount of timber income that have to be forgone to reach the target level of protection of 10% of the total land area. Hulkrantz compares this estimate to the country's population the aggregate WTP using a WTP estimate from a CVM survey which focussed on protection of 300 endangered species of flora and fauna in Sweden's forest.

The only species in the FMA known to be in threatened status is the woodland caribou, which inhabit regions of old growth in the boreal forest. A couple of recent studies have estimated the existence value of this species. Tanguay (1993) estimates Saskatchewan household' WTP for the preservation of woodland caribou in northwestern Saskatchewan. The woodland caribou of northwestern Saskatchewan are of the same subspecies as those in the Alberta-Pacific FMA and may actually migrate between these areas.

In one survey version, respondents were asked an open-ended WTP question regarding how much their household would be WTP each year for ten years to establish a Caribou Maintenance Program that would preserve the current range and numbers (3,600) of the caribou population. Another survey version elicited WTP using a discrete choice question which asked the respondent to choose between no maintenance program and committing to an annual household payment of a specified amount for ten years. Tanguay (1993) found that based an open ended WTP question that Saskatchewan households are WTP (1992$s) an average of $14.66/household for the caribou conservation program (p. 60). Analysis of the discrete choice responses revealed that Saskatchewan households are WTP a median of $80.84 and a mean of $97.99 for the program (p. 61).

Another recent survey found that in 1994, Edmonton households' median WTP/year for old growth forest protection was between $89 and $122 (Haener and Adamowicz 1998). However, since the good described does not match the situation as well as that used in the Tanguay study, only WTP estimates from the Tanguay study will be used

Statistics Canada's most recent census data reveals that the population of Alberta 1996 was 2,696,826 and there were a total of 984,275 households. As shown in Table 4.24, applying the low and high WTP estimates above at the provincial scale implies an annual existence value of between about $15 and $102 million.

Table 4.24
Willingness to Pay for Caribou Protection (1996$)

WTP ($)/household		Value ($)
Low	15.52	15,275,948
High	103.73	102,098,846

To arrive at an estimate of the net value associated with caribou protection, the costs of ensuring protection should be subtracting from the WTP estimate. As noted above, the protective measures taken by the Company include restricting harvesting activities and use of the ecosystem management approach. Separation of the costs associated with these measures would require determining the difference in costs incurred with and without these measures. This would be very difficult. Furthermore, since the cost estimates used in the determination of timber rent are based on current practices, the cost of these measures has already incorporated in the timber value account. Perhaps

The opportunity cost approach can also be applied. The area proposed to be set aside lies within FMUs 13 and 14 which have a combined area of 825,506 ha. Therefore the proposed ecological benchmark area represents approximately 41.2% of these FMUs. The net growth (growth in productive stock) on these FMUs was calculated to be 475,917 m^3 for the deciduous net volume and 177,500 m^3 for the coniferous net volume. Assuming that this growth is evenly distributed throughout the FMUs, the annual growth that might be expected to occur on the area set aside is about 41.2% of these volumes. Assuming that the sustainable AAC for this area is equivalent to the annual growth, the annual amount of deciduous and coniferous timber that Alberta-Pacific is forgoing by setting this area aside for protection is about 196,078 m^3 and 73,130 m^3, respectively.

Table 4.25
Opportunity Cost of Liege River Annual Allowable Cut (1996$)

Rent Estimate	*$/m^3*	*Pulp Type*	*Growth/yr (m^3)*	*Value ($)*
Low	36.41	Hardwood	196,078	7,139,200
	42.08	Softwood	73,130	3,077,310
Total				*10,216,510*
High	56.71	Hardwood	196,078	11,119,583
	59.06	Softwood	73,130	4,319,058
Total				*15,438,641*

There is also another component of the opportunity cost of biodiversity production. Alberta-Pacific's Draft Detailed Forest Management Plan (Alberta-Pacific 1997 p. 73) outlines how the Company estimates its AAC. As part of ecosystem management, operators are required to leave some trees standing on each cutblock in order to ensure that there is some stand structure available for wildlife. To account for the operational requirements of implementing ecosystem management, 5% (about 106,100 m^3) is netted out of the gross deciduous AAC and 1% (16,200 m^3) is netted out of the gross coniferous AAC (Alberta-Pacific DFMP 1997). A range of potential values associated with this loss in AAC is given in Table 4.26.

Table 4.26
Opportunity Cost of Wildlife Trees (1996$)

Rent Estimate	*$/m³*	*Pulp Type*	*AAC (m³)*	*Value ($)*
Low	36.41	Hardwood	106,100	3,863,101
	42.08	Softwood	16,200	681,696
			Total	*4,544,797*
High	56.71	Hardwood	106,100	6,016,931
	59.06	Softwood	16,200	956,772
			Total	*6,973,703*

The sum of opportunity costs ranges from $14,761,307 to $22,412,344. The WTP and opportunity cost estimates are compared in Table 4.27. The WTP estimates are significantly higher than the opportunity cost estimates. Overall, the low and high estimates of biodiversity protection vary significantly, ranging from about $0.55 to $102 million.

Table 4.27
Value of Biodiversity Maintenance ($)

	Method	
Scenario	*Surveyed WTP*	*Opportunity Cost*
Low	17,776,007	14,761,307
High	102,098,846	22,412,344

4.4.6 Environmental Control Service: Carbon Sequestration

Forest play a role in the global carbon cycle since trees and other forest biomass act as temporary carbon sinks. This carbon sink function provides a welfare generating service since sequestration of carbon decreases the amount of atmospheric carbon which contributes to the greenhouse effect and the possibility of global climate change.

In the model presented in section 4.3.4, carbon sequestration services provided by the forest are incorporated as a service flow which depends on the annual change in the timber stock. It should be noted that this is not the only option for incorporating this types of service into forest resource accounts. Alternatively, carbon can be modeled as a stock resource that provides current and future benefits. The annual change in the stock should then be used to depreciate or appreciate the value of the stock. Fankhauser (1994) might advocate this method. He describes GHG emissions as stock pollutants since the level of damage is related to the amount accumulated within the atmosphere and "...a tonne of emissions has its impact not only in the period of emissions but over several time periods" (p. 163).

However, the alternative viewpoint, which is taken here, is that carbon sequestration only provides a service in that it allows future damages to be avoided. Therefore, it is changes in the carbon stock which are valuable since they assist in the stabilization of GHG. Furthermore, the sequestration of carbon in the form of biomass does not represent a permanent removal of carbon from the atmosphere; it aids in the temporary stabilization of GHG levels. Forestry activities alter atmospheric carbon levels in other ways as well some of which may be construed as stock effects but these are not considered here but are discussed briefly below.

In this study, it is assumed that the net change in carbon is mainly attributable to changes in tree biomass. Therefore, the change in tree biomass over the year and the proportion of this biomass represented by carbon must be determined. In order to determine the amount of carbon within tree biomass (where biomass includes all parts of the tree), Hoen and Solberg (1994)'s estimate of 50% will be used. This is a conservative estimate since the measure of growth is taken from gross forest inventory data which tracks only the volume of roundwood which is likely contains a higher carbon content than other tree parts.

The change in tree biomass is calculated using an estimate of the annual growth of roundwood volume for the entire region (merchantable and non-merchantable) and subtracting removals in the forms of land conversion and fire. From the biomass value an estimate of the net change in the volume and mass of standing trees within the FMA can be calculated (Table 4.28). Low and high estimates of the amount of carbon are provided. The low estimate assumes that the carbon within harvested trees does contribute to the net amount of carbon sequestered. For the high estimate, the harvested volume of timber is not netted out because it is assumed that carbon remains sequestered in the resulting forest products. In reality, some amount between zero and the total amount of carbon within the harvested volume is actually sequestered since forest products are subject to decay and therefore release carbon back into the atmosphere.

Table 4.28
Net Change in Tree Biomass

	Low Estimate		*High Estimate*	
	Deciduous	Coniferous	Deciduous	Coniferous
+Gross Growth	3,312,431	3,363,214	3,312,431	3,363,214
-AP Harvest	-1,973,000	-350,747	NA	NA
-Quota Holder Harvest	0	-984,595	NA	NA
Land Use Change	-134,705	-85,368	-134,705	-85,368
-Fire	-16,698	-9,367	-16,698	-9,367
Net Change in Volume (m^3)	1,188,028	1,933,137	3,161,028	3,268,479
Net Change in Mass (oven-dry tonnes)	429,615	668,730	1,143,091	1,130,665
Amount of Carbon Sequestered (tonnes)	214,808	334,365	571,546	565,333
Total Carbon Sequestered (tonnes)	549,173		1,136,878	

Conversion factors: green to oven-dry shrinkage: aspen 11.8%, white spruce 11.3%; oven-dry density: aspen 0.41 t/m^3, white spruce 0.39 t/m^3 (Mullins and McKnight 1981, pp. 75-76)

These estimates are only approximate measures of the net amount of carbon sequestered in the region. For a more accurate estimate of the annual net change many other factors must be considered. For examples of more complete analyses of the contribution of the forest industry to carbon emissions at the national scale, see Kurz *et* *al.* (1992) for Canada, or Pingoud *et al.* (1996) for Finland. These analyses consider factors such as fuel and energy use by mills and vehicles, decay of forest products in use, decay of forest biomass, recycling, etc.

Value

Due to uncertainty regarding the impacts of increased concentrations greenhouse gases in the atmosphere, determining the marginal value associated with the sequestration of carbon is difficult. However, the value associated with the sequestration of carbon has been considered in a number of studies, including resource accounting applications.

Hulkrantz (1992) estimates the value of the carbon fixing services provided by the Swedish forests using two different methods. First, he values the net increase in the carbon inventory of the forest using the effluent fee for carbon dioxide emissions in Sweden. Hulkrantz assumes that the effluent fee represents a "politically determined shadow price of emissions, and thus on absorption too" (p. 296). The second method used by Hulkrantz assumes that "the opportunity cost of storing fixed carbon by not cutting trees is the timber income foregone" (p. 296). Hulkrantz notes that his assessments account for the absorption of carbon into forests only and do not account for the fact that the carbon in harvested trees will also remain sequestered for some period.

Adger *et al.* (1995) attempt to include the value of carbon storage in their estimate of the "total economic value" of forests in Mexico. Adger *et al.* assume that the value of carbon absorption to society is equal to the expected damage avoided. They use the damage estimate from Frankhauser (1995) of $US 20/ton C and "apply them to once and for all carbon-flux changes to give a capital value to the world of the global-warming damage avoided in maintaining [Mexican forests]" (p. 290). Since the authors use the capital value of carbon adsorption, they essentially assume that changes in the stock of carbon are permanent.

Frankhauser (1994) is among many economists who estimate the cost of greenhouse gas (GHG) abatement and focus on permanent reductions in emissions levels. There are also several studies that estimate the present value of future damages associated with rising levels of emissions. Estimates from some of these studies are listed in Table 4.29.

If we assume that the value to society of carbon sequestration services provided by the forest can be approximated by the abatement costs avoided (i.e. costs of abating GHG by other methods) then the estimates in Table 4.29 can be used to derive this value. It should be noted that "...the shadow value of a ton of emissions today depends on the level of emissions in future periods" (Fankhauser 1994 p. 165). Part of the variation in study estimates results from differing assumptions regarding future emissions levels.

However, the study estimates are for permanent changes in GHG levels and we are looking for an estimate of the marginal value of annual fluxes. As shown in Table 2.29, annualizing using a 5% discount rate, converting to metric tonnes and 1996 Canadian dollars provides an estimate of the annual flows corresponding to the present value estimates of these studies.

Table 4.29
Carbon Abatement Cost Estimates

Study	*Value Estimated*	*Target*	*Study Estimate ($US/tC)*	*Annuity Value ($1996Cdn/tC)*
Manne and Richels (1990)	Lost Production from GHG controls	15% above 1990 levels	250	16.6
Nordhaus (1991)	Optimal C tax	Optimal control (11% decline from baseline emissions)	7.33	9.02
Nordhaus (1993)	Optimal C tax using DICE (Dynamic Integrated Climate Economy) Model	Optimal control	5.3 in 1995 6.8 in 2005 10 in 2025	0.34 0.44 0.63
Peck and Teisberg (1992) in Fankhauser (1994)	Optimal C tax		10-12 (1991-2000) 12-14 (2001-2010)	0.63-0.76 0.76-0.89
Fankhauser (1994)	Marginal Costs of doubling of 1990 GHG emissions		20/tC (1991-2000) 28/tC (2021-2030)	1.41 1.98

Conversion to $1996Cdn uses the exchange rate and Implicit Producer Price Index (GDP) for the study year, as listed in Table A10.

Using the range of estimates from Table 4.28 and Table 4.29 ($0.34 to $16.6), the value of carbon sequestration services provided by the case study region is calculated in Table 4.30.

Table 4.30
Value of Carbon Sequestration

Scenario	*WTP ($1996/tC)*	*Carbon Sequestered (tonnes)*	*Value ($1996)*
Low	0.34	549,173	186,719
	0.34	1,136,878	386,539
High	16.6	549,173	9,116,272
	16.6	1,136,878	18,872,175

4.5 Results and Discussion

The values estimated in section 4.4 are compiled in Table 4.31 to form the Forest Resource Account for the Study Region. Table 4.31 also includes other information that will aid in the discussion of the results including the percentage of the average total welfare estimate that each component represents is listed and, where, applicable, the range of uncertainty associated with component estimates.

Table 4.31
Summary of the 1996 Forest Resource Account for the Case Study Region (1996$s)

		Low	High	Average	Range of Uncertainty	% of Average Total Net Income	
Commercial Forestry							
Pulp Production		86,596,364	132,603,948	109,600,156	46,007,584	47.15%	
Lumber Production		59,951,990	59,951,990	59,951,990	NA	25.79%	
Subtotal				169,552,146			72.94%
Change in Timber Capital		44,433,870	60,235,669	52,334,770	15,801,799	22.51%	
Change in Human-made Capital	Pulp	-61,379,305	-84,190,000	-72,784,653	NA	-31.31%	
	Lumber	-5,287,275	-5,287,275	-5,287,275	NA	-2.27%	
Subtotal				-25,737,158			-11.07%
Total				143,814,988			61.87%
Other Commercial Uses							
Fishing		286,194	286,194	286,194	NA	0.12%	
Trapping		274,669	513,759	394,214	239,090	0.17%	
Subtotal				680,408			0.29%
Recreational Use							
Hunting		276,174	966,609	621,392	690,435	0.27%	
Fishing		518,313	2,648,595	1,583,454	2,130,282	0.68%	
Camping		212,211	212,211	212,211	NA	0.09%	
Subtotal				2,417,057			1.04%
Subsistence Uses							
Aboriginal Land Use		8,345,000	26,807,000	17,576,000	18,462,000	7.56%	7.56%
Passive Use							
Biodiversity Maintenance		14,761,307	102,098,846	58,430,077	87,337,539	25.14%	25.14%
Environmental Control Service							
Carbon Sequestration		186,719	18,872,175	9,529,447	18,685,456	4.10%	4.10%
Total Net Income		149,176,231	315,719,721	232,447,976	166,543,490	100.00%	100.00%

The account finds the total net income of the forest resource in the region to be $232 million on average. There is a significant degree of uncertainty associated with this estimate. The lower and higher bounds are estimated to be $149 million and $316 million, respectively. The largest absolute range of uncertainty is associated with biodiversity maintenance. There is also a large degree of uncertainty associated with the value of pulp production, carbon fixing and subsistence activities.

Since the total stock of capital depreciates over the year, total gross income ($258 million) is significantly higher than net income. Although, timber capital appreciates over the year, human-made capital depreciation is significantly larger causing overall capital depreciation to be about $26 million.

Using average component values, the largest component of total net income in the forest resource account is pulp production and the smallest is camping. Human-made capital depreciation is also very large in absolute value, as are biodiversity maintenance and the value of the change in the timber stock.

From the subtotals in the account, it can be seen that production of commercial forest products (including depreciation) accounts for over half (62%) of the total net income. Other commercial uses, specifically fishing and trapping, account for less than 1% of total net income. This demonstrates the importance of forestry activities to the market economy of the region.

Non-commercial uses account for a large portion, nearly 40%, of net income, despite the fact that not all non-market forest services could be included. This stresses the importance of considering these values in regional decision-making and in the assessment of regional sustainability. The large passive use value associated with the maintenance of biodiversity illustrates that the region generates income flows that extend across the province and that changes to the ecosystem will effect the welfare of individuals living in other regions.

Subsistence resource use also represents a significant portion of the region's net income. The forest obviously plays an important role in the lives of the aboriginal people in the region. The consequences of overlooking this role when making forest management decisions could be significant.

Using the results to make conclusions regarding the sustainability of regional activity is difficult since the account is developed for only one year. Furthermore, as discussed, the account does not provide all the information need to evaluate sustainability in a broad sense. However, some comments can be offered. Since timber capital appreciated in 1996, it appears that current harvest levels are sustainable and commercial forestry activity in the region appears to meet the criteria of strong sustainability–no net depletion of natural capital. However, it does not appear that the Hartwick rule for sustainability—reinvestment of Hotelling rents (price minus marginal cost) from non-renewable resource extraction into new natural or man-made capital—has occurred. This suggests that the value of the regional wealth may be falling. This is not surprising since, although, a very large capital investment was associated with the construction of the pulp mill, net investment is now largely composed of the depreciation of this capital.

As noted earlier, no resource accounting system is comprehensive due the difficulty and expense associated with estimating with some non-market values. The resource accounting application carried out in this chapter focussed on some of the important forest services provided by the case study region. However, the account could be expanded to include other forest services. This would improve the account's usefulness as a tool in assessing sustainability and providing information for policy and planning purposes.

Some prospective avenues for expanding the account can be identified. In the case study, consideration of environmental control services (or environmental stock services) was limited: only the carbon sequestration and biodiversity maintenance services provided by the forest was included. There are many control services provided by the forest which have been considered in other resource accounting applications and could potentially be incorporated into the account for this region.

Costanza *et al.* (1997) suggest that the value of these 'ecosystem services' can be considerable. They estimate the total value of ecosystem services provided by the boreal forest at US(1994)$302 per hectare. However, the methods used to derive these estimates are not clearly outlined and therefore, their reliability is questionable.

Additional stocks changes could also be included in the account. Although, only the changes in human-made and timber capital are valued in this study, changes in other forms of 'environmental capital' also affect future well being. For example, changes in stocks of big game species in this period may not influence current income flows but they may influence future income flows by decreasing recreational hunting values. In his valuation of 'changes in environmental stocks', Hulkrantz (1992) includes depletion of exchangeable soil cations and reindeer forage. Hulkrantz's estimates for these services suggest that they are small compared to commercial forestry but they are still significant.

Although not included in this study, some resource accounting applications adjust net income for environmental damage resulting from pollution and industrial activity. As discussed in section 4.3.4, environmental damage can be incorporated through evaluations of changes in environmental capital. Another option is to incorporate the damage through decreases in the value of environmental control services. Since the negative effects of environmental damage on production are reflected in changes in production costs, only the household valuation of such damage needs to be determined. However, this is not likely to be an easy task. Determining the amount of damage is also not straightforward in most cases. For example, for pollution, valuing environmental damage requires more than quantifying the amount of pollution emitted. Only pollution not assimilated by the environment will influence welfare.

There are also a number of nature related and recreational activities which were not included in the forest resource account. These include activities such as wildlife viewing, canoeing, boating, hiking, climbing, and other outdoor experiences. Unfortunately, information related to the frequency of such activities within the region is currently not available and there are few estimates of the value associated with participation in these types of activities.

The Survey of the National Importance of Wildlife to Canadians includes questions regarding participation in various forms of outdoor recreation. Since the survey also asks where the activities occur, technically it would be possible to determine an estimate of activity in the study region by desegregating the data based on activity location. However, this is likely to be a tedious process that may not provide very accurate results. Incorporation of the value associated with these activities in the forest account would probably require a primary study, but may add valuable information to the account.

4.6 Summary

In 1996, KPMG prepared a project report (Simpson 1996) outlining the contribution of Alberta-Pacific to the local, regional and national economy. The report took a very traditional approach and focused on only the market benefits arising from the Company's operations and the sawmills within the FMA.

This study goes beyond a simple analysis of the monetary benefits of pulp and sawmill production in the region. An attempt is made to determine the net benefits of commercial forestry and non-commercial use of the forest. The values of the carbon sequestration and biodiversity maintenance services of the forest are also estimated. The purpose of this exercise has been to provide a clearer picture of the direct and indirect benefits provided by the forest. This case study provides the basis for future estimates that when tracked over time can provide information regarding the sustainability of income flows from the region.

Chapter 5 Simulation of Future Conditions: Incorporation of Risk

5.1 Introduction

This chapter will investigate the implications of fire and price risk on the time path of the net income measure developed in chapter 4. The simple model presented in chapter 4 is developed assuming a deterministic setting. However, as will be demonstrated, this assumption is not valid for the case study region. Recent literature has discussed the welfare measurement implications of relaxing the assumption of perfect foresight in a theoretical context, however, empirical illustrations are limited. The generalization of welfare measurement to the stochastic context has also been discussed. In this chapter, simulations of future fire and price risk are used to illustrate the effect of risk on the time path of the net income measure. The results suggest that the value of risk and its associated stochasticity must be considered when using the net income measure as an indicator of sustainability.

The chapter will be organized as follows. First, the advantages and disadvantages associated with altering the assumptions of the simple growth model which is generally used as the basis for deriving national product related welfare measures will be discussed from a practical point of view. Second, definitions of risk and uncertainty will be reviewed and the relevance of these phenomena to forest resource accounting will be discussed. In the next section, the methods used to simulate the effects of fire and price risks on the future values on the case study region's net income are outlined and the empirical results are presented. Finally, the implications of these simulations are discussed.

5.2 Relaxing the Assumptions: Advantages and Disadvantages

In its simplest form, the Ramsey growth model includes numerous assumptions. As noted earlier, Weitzman (1976), Hartwick (1990) and Mäler (1991) develop an indicator of sustainability (Green NNP or NWM depending on the author) that can be calculated using currently available information; there is no need to speculate about future quantities or prices. However, as Brekke (1997) points, their results rely on the assumption that "central parameters are constant over time" (p. 517). According to Brekke (1997 p. 517), "Weitzman and Hartwick avoid making assumptions about the future by assuming constancy or rather time invariance... [However] in many applications, assuming constancy in the future may be unreasonable".

Relaxing the time invariance assumption requires explicitly defining the paths of the parameters. For example, the paths of parameters such as technological progress, resource discovery, and population growth can be explicitly defined (see Aronsson *et al.* 1997, chapter 4) by including differential equations in the optimal control problem that describe the paths of these variables. In cases where the time path of the variable is not known with certainty but can be characterized using a probability distribution, stochastic differential equations are used to characterize the uncertain paths of variables.[36] This causes the welfare maximization problem to become a stochastic optimal control problem.

There are both advantages and disadvantages associated with relaxing the assumptions of the simple Ramsey Growth Model. In many cases reality may be

[36] For examples see Hung (1993) or Aronsson *et al.* (1997), chapter 7 and 8.

illustrated more effectively by imposing specific conditions on the paths of parameters or assuming that the paths of some variables are uncertain. Numerous articles have demonstrated how, in theory, imposing inappropriate assumptions regarding the future can lead to biased estimates of welfare. Furthermore, conclusions regarding the sustainability of the economy based on the resulting welfare estimate could also be incorrect.

However, as discussed in section 3.5.3, relaxing the assumptions of the simple Ramsey Growth Model results in national product related welfare measures that are considerably more complicated to utilize for actual welfare calculations. A more complex model requires the collection of additional data and usually results in less straightforward welfare calculations. As a result, there have been very few attempts to empirically account for the resulting complications in resource accounting applications. In practice, most resource accounting frameworks are based on simple models such as the one derived for this case study in chapter 4.

Therefore, altering the assumptions of the simple form of the growth model may not be warranted in all cases, since the information required to calculate the revised welfare measure may not be available and/or the additional information provided may not be worth the added complexity. In some cases, the degree and probability of bias resulting from assuming away a more complex characterization of the future may not be significant whereas in other cases it may be highly significant.[37] In empirical resource accounting applications, the challenge is to determine when the costs of modifying the simple growth model are outweighed by the benefits.

5.3 Risk and Uncertainty

5.3.1 Clarification of Terms

The terms 'uncertainty' and 'risk' are used in many different ways in conversational and academic language. Montgomery (1996) and Lutz and Munasinghe (1994) discuss how these terms are used in an academic sense. According to Montgomery (1996), the term "risk", in its common usage refers to "the possibility of suffering harm or loss... [and] can be described in terms of the nature, the incidence, the timing and the likelihood of an outcome" (p. 66). Uncertainty, on the other hand, refers to "the condition of being in doubt" (p. 66). Alternative definitions of risk and uncertainty are given by Lutz and Munasinghe (1994 p. 40):

> [R]isks are involved when probabilities can be assigned to the likelihood of an event, such as an industrial accident, to occur... Uncertainty describes a situation where there is little known about future impacts and where, therefore, no probabilities can be assigned to certain outcomes, or where even the outcomes are so novel that they cannot be anticipated (p. 40).

This distinction between risk and uncertainty is recognized in this chapter, in that where a subjective probability distribution can be assigned to a parameter, the term risk is used.

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[37] See for example Weitzman and Löfgren (1997) which presents a method for accounting for labour-augmenting technological change in their estimate of Green NNP for the US economy.

5.3.2 Importance of Risk and Uncertainty to Forest Income Flows

There are a number of sources of uncertainty associated with estimating an index of current and future wellbeing derived from forest resources. Uncertainty arises due to imperfections in measurement of activity levels and WTP. These measurement errors lead to uncertainty regarding the accuracy of component values. In recognition of this type of uncertainty, in chapter 4 a range of possible values was given for most components of the accounting framework. There is also uncertainty regarding the validity of the assumptions and models used to formulate the index.

Uncertainty and risk are associated with future income flows from forest resources. The timber harvesting stems from uncertainty regarding both future environmental and market conditions. Changes in environmental conditions can alter the growth and characteristics of the timber stock and thereby influence commercial forestry, recreational activity, biodiversity and other forest services. For example, as already seen in chapter 4, the weather can influence harvest costs and the amount harvested in a given year. Market conditions can also influence future income flows from the forest. Timber flow and stock values can change in response to output price fluctuations stimulated by factors such as consumer preferences, development of substitutes, and technological advancements. In cases where there is enough information about future environmental or market conditions to attach a subjective probability distribution to particular outcomes, future conditions can be described as risks as opposed to uncertainties.

Many aspects of future conditions cannot be anticipated, however, there are some parameters for which an equation or probability distribution could be used to characterize movements over time. Fire risk, an environmental risk, and price risk, a market-related risk, are examples. A number of different fire risk models can be used to attach a subjective probability to the likelihood of a fire occurring in an area. It is expected that incorporating the distribution of fires over time in the forest resource accounts will influence the size of the timber stock in future periods, thereby affecting the value of NNP in future periods. The historical variability in market prices, pulp and lumber prices in this case, can also be used to obtain a reasonable estimate of the distribution that future prices are likely to follow. Incorporating such information is anticipated to have a similar effect to fire risk in that the value of future harvests and timber stock changes will change over time.

5.3.3 Implications for Welfare Measurement

As mentioned in section 3.5.3, the implications of relaxing the assumption of perfect foresight on welfare measurement are discussed in Mäler (1991), Dasgupta (1995), Aronsson and Löfgren (1995) and Aronsson, Johansson, and Löfgren (1997). Mäler and Dasgupta (1990), Dasgupta (1990), Hung (1993), Aronsson and Löfgren (1995) and Aronsson *et al.* (1997) have mathematically illustrated how different types of uncertainty can be incorporated into national product related welfare measures. Dasgupta and Mäler (1990) and Dasgupta (1995) derive an expression for NNP that accounts for future uncertainty regarding discrete events that are expected to affect the future stocks of capital. Hung (1993) examines the specific case of uncertain pollution stock effects that result from the existence of an unknown critical level of pollution beyond which drastic losses occur.

The functional form of the national product related welfare measure that results when uncertainty is incorporated depends, among other things on the functional form of the probability density function used to characterize the stochastic variable's distribution. However, some general conclusions about the effect of uncertainty on the national product related welfare measure can be noted.

According to Aronsson and Löfgren (1995), in the case of uncertainty, the welfare measure includes a term that accounts for the value of risk. Furthermore, when the future values of variables are allowed to follow a stochastic process, then the *generalized* Hamiltonian includes the present value of *expected* future utility. Any terms that are added to the NNP measure to account for time dependence would also be expected values. For example, in the case where there is non-attributable technological change, the welfare measure should include a term representing the *expected value* of future technological change (Aronsson and Löfgren 1995).

Similarly, Aronsson *et al.* (1997) show that the generalized Hamiltonian is "the sum of the instantaneous utility, the expected infinitesimal increment of capital valued at its marginal expected current value, plus the valuation of risk associated with a given investment" (p. 155). If there is risk aversion, the value of risk is negative and aggregate welfare is lower. Other than the additional risk adjustment term[38], the essential form of the NNP is similar to its deterministic counterpart, however as stressed in Hung (1993), shadow prices are now "contingent (rationally anticipated) values" (p. 388).

Brekke (1997) considers how uncertainty alters the way in which a national product related welfare index is used to make interpretations regarding sustainability. Brekke (1997 p. 521) suggests that "...since future rents are uncertain, we cannot determine a consumption level that can be sustained under all sets of circumstances. A possible extension of the concept of sustainable consumption would be the requirement that expected future consumption should be at least as large as current consumption". Using a deterministic income measure, such as the one estimated in chapter 4, in a stochastic setting may lead to inaccurate conclusions regarding the sustainability. The reason being that there will be an inherent amount of variability in income that results from risk. Brekke (1997) suggests that a more reasonable sustainability rule in these circumstances is one that requires that the expected value of income flows be non-declining over time.

Fire and price risks have been identified as potentially important forms of risk in the case study region. If these forms of risk are significant, the literature discussed in this section suggests that the net income measure for the region should contain a term or terms that capture the influence of these forms of risk on future utility. In addition, the shadow prices used to value the other components of net income should represent contingent or rationally anticipated values. Without these adjustments, the deterministic income measure will be inaccurate and use of the index to assess sustainability would be inappropriate.

Adjusting the net income measure for the region would require re-formulating the model to account for stochasticity. A stochastic differential equation, which characterizes

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[38] As noted above, the functional form of the risk adjustment term depends on the model and the probability distribution used to characterize the time path of the stochastic variable.

the influence of risk on future income flows, would have to be added to the problem. However, a number of other complicating factors would also have to be considered. Mäler (1991) and Hartwick (1990) explain that only unanticipated (or partially anticipated) shocks to the economy are relevant to current measure of wellbeing. Correctly anticipated changes have "already been capitalized in other prices and therefore already been included in the net national income concept" (Mäler 1991 p. 13). Estimating contingent shadow prices could be complicated since it may be difficult to determine the degree to which current prices already reflect risk.

The practical question that must be addressed is whether it is enough to simply qualify our interpretations of net income or whether the net income measure for the region should be formally adjusted to account for risk. Simulation exercises such as the one carried out in this chapter provide a practical alternative to re-formulation of deterministic welfare indices. The simulation allows the significance of risk and its expected influence on future wellbeing to be assessed. This information can be used to qualify interpretations of temporal changes in the deterministic welfare index. Therefore, the sustainability rule suggested by Brekke (1997) can be informally applied.

5.4 Case Study Simulations

It is anticipated that in the forested region under consideration, useful information may be obtained by characterizing the future distributions fire risk and price risk. The data necessary for incorporating these distributions are readily available and the procedure required is straightforward.

The simulations illustrate the effect of fire and price risks on the realization of the study region's net income over a 20-year period. Only the effect of these risks on commercial forestry is considered; however, in reality, the other components of the net income measure would also be influenced, especially in the case of fire risk.

Fire and price risk are incorporated into the measurement of futures values of net income for the region through simulations of the future flows associated with the change in the merchantable timber stock. All simulations assume that these forms of risk do not influence other components of the net income measure. First, fire risk is simulated then price risk and finally both types of risk are simulated together.

As noted, the simulations predict the annual regional net income for the next 20 years. This simulation period is used since this corresponds to the duration of the FMA and corresponds to the planning horizon used in a typical general development plan (GDP) (LFS 1998). For each of the 20 years, 500 draws are made from the probability distribution characterizing fire and/or price risk. A large number of draws are required because, as will be seen, the distributions are highly stochastic. It is anticipated that 500 draws will be sufficient to characterize the shape of the distribution of the annual net income values. A great number of draws would give a more precise picture but would also be more computationally demanding.

In all cases, annual net income is reported in 1996$. Annual values are not discounted and therefore represent the net income predicted to occur in that year.

5.4.1 Fire Risk

Armstrong (1998) analyzes the distribution of fire risk over time for a region in northeastern Alberta that closely corresponds to the case study region From his analysis, he finds that the distribution of fire risk, when accounting for suppression efforts, can be characterized as a lognormal with a mean annual burn rate of 0.006296% of forest area and standard deviation 2.853. (Without the logarithmic transformation, the mean annual burn rate is 0.001152 or 0.1152%). Five hundred 20-year random draws from this distribution were simulated.

The simulations require a number of assumptions. It is assumed that deciduous and coniferous harvest levels (*H*) depend solely on the level of the respective timber stock (*S*). Harvest levels are assumed to be a constant percentage of the timber stock based on the amount of stock harvested in 1996, but limited to a maximum of 5% above the harvest level in 1996. In 1996, Alberta-Pacific harvested about 0.7439% of the deciduous stock and 0.2358% of the coniferous stock in the region. Quota holders harvested about 0.6618% of the coniferous stock. Therefore,

$$H_t^d = (0.007439)S_t^d \tag{18}$$

$$H_t^c = (0.002358 + 0.006618)S_t^c \text{ where } H_t^c = H_t^{cA} + H_t^{cQ} \tag{19}$$

The superscripts d and c are used to differentiate between deciduous and coniferous timber and the superscripts A and Q are used to differentiate between Alberta-Pacific and quota holder coniferous harvest. It is assumed that all deciduous harvest over the 20-year period can be attributed to Alberta-Pacific. The relative proportion of coniferous stock harvested by Alberta-Pacific and quota holders is assumed to remain constant at the 1996 level.

Since it is assumed that harvest levels are proportional to stock levels, changes in stock levels over time must be characterized. It is assumed that the deciduous stock changes over time according to the following equation:

$$S_t^d = S_{t-1}^d + G_{t-1}^d - C_{t-1}^d - H_{t-1}^d(S_{t-1}^d) - B_{t-1}^d \tag{20}$$

Similarly, changes in the coniferous stock are represented by

$$S_t^c = S_{t-1}^c + G_{t-1}^c - C_{t-1}^c - H_{t-1}^{cA}(S_{t-1}^c) - H_{t-1}^{cQ}(S_{t-1}^c) - B_{t-1}^d \tag{21}$$

where G is growth, C is volume lost to land use conversion, and B is volume burned. Annual growth and land use conversions are also assumed to remain constant proportions of the stock based on 1996 levels. Annual growth of the deciduous stock is set at 1.0784% and annual growth of the coniferous stock is set at 1.2299%. Annual land use conversion is set at 0.006680% of the deciduous stock and 0.006604% of the coniferous stock.

Using the above equations and the random draw of burn rates, volumes of timber harvested and annual stock changes are predicted for the next 20 years. The averages of the high and low rent estimates from chapter 4 values are used to value the harvests and stocks changes. It is assumed that other components of net income remain constant at 1996 levels.

5.4.1.1 Results

Descriptive statistics are given for the simulation parameters in Table 5.1. The simulation process results in a sample of 500 20-year paths of net income. Therefore, for each of the 20 years, there are 500 predictions of net income each corresponding to a different path. Descriptive statistics for each of the 20 years are provided in Table 5.2. Some of the highlights of the results are briefly reviewed in this section. The significance of the results of all three sets of simulations is discussed in section 5.5.

Figure 5.1 shows the mean of yearly net income values and the 95% confidence interval around these values (from Table 5.2). The confidence interval shows the area on the graph which, if all 500 simulated time paths were drawn, would encompass 475 paths. Visual representations of the simulated net income values are also provided for selected years.

Table 5.1 reports the mean of the 10,000 draws from the lognormal distribution used to characterize annual burn rate in the region is 0.0051457 or 0.51457% of total area. The standard deviation of the sample of annual burn rates is 0.041551 or 4.1551%.

Selected years were chosen to illustrate the distribution of the 500 draws for a given year. The distributions of net income for years 1, 10, and 20 are illustrated using cumulative frequency diagrams (Figures 5.2, 5.4, and 5.6). Since the range of the distributions are very large but most values are grouped tightly around the upper end of the distribution, histograms and cumulative frequency curves which focus more on the upper end of the distributions are also provided (Figures 5.3, 5.5, and 5.7).

Fire obviously plays a large role in determining the net income in the region. Summary statistics (Table 5.2) show that large variability in the net income measure can be expected over the next 20 years. The means of the 500 draws for each year range from $89 (year 8) to 165 million (year 11). Figure 5.1 shows that although the upper confidence interval around these means is fairly stable, the lower confidence interval fluctuates from year to year and significantly further from the mean than the upper confidence interval.

For each year, the range of the 500 draw values is extremely large (as high as $20 billion) and, for some years, the standard deviation is over $1 billion. However, the distribution is highly skewed with most values predicted to be relatively close to the mean, but several values very far below the mean. This appears to be true for all years as indicated by the similarity between the cumulative frequency diagrams and histograms for years 1, 10, and 20.

Table 5.1
Summary Statistics for Fire Risk Simulation Parameters

	Ln Rate	*Rate*
Mean	-9.02915	0.0051457
Standard Deviation	2.84245	0.041551
Minimum	-19.82560	2.4539E-09
Maximum	2.16502	1.0000
Range	21.99062	1.0000
95% Confidence	0.055711	3.4017E-02
Interval	(-9.0848,-8.9734)	(4.5701E-7, 0.034018)

Table 5.2
Fire Risk
Summary Statistics: Net Income for Years 1-20 (1996$)

Year	Mean	Standard Deviation	Minimum	Maximum	Range	95% Confidence Interval Low	95% Confidence Interval High
1	116,610,420	1,055,197,335	-20,093,106,282	235,169,782	20,328,276,064	-576,488,474	235,161,260
2	129,951,621	980,969,502	-20,128,747,064	235,802,565	20,364,549,630	-336,741,674	235,781,410
3	172,198,468	262,450,783	-2,326,218,830	236,433,237	2,562,652,068	-614,603,125	236,372,335
4	118,449,569	683,855,647	-7,907,320,174	237,052,385	8,144,372,559	-665,175,881	236,972,881
5	132,681,508	780,010,365	-15,374,749,619	237,710,421	15,612,460,040	-397,334,195	237,572,313
6	131,835,075	973,621,222	-20,333,134,228	238,336,738	20,571,470,966	-451,841,196	238,121,089
7	109,557,706	718,332,280	-8,664,743,002	238,975,116	8,903,718,118	-1,066,302,314	238,627,041
8	88,660,532	1,177,700,378	-20,285,724,374	239,502,649	20,525,227,023	-339,880,901	239,214,219
9	95,805,268	884,006,340	-16,523,438,645	240,176,840	16,763,615,485	-939,559,544	239,900,727
10	119,471,845	990,521,253	-19,988,652,305	240,775,745	20,229,428,051	-437,943,270	240,320,275
11	164,800,082	370,106,867	-5,443,856,588	241,561,991	5,685,418,579	-180,798,186	240,812,338
12	120,473,591	971,325,285	-20,592,058,424	241,773,024	20,833,831,448	-707,633,639	241,114,534
13	137,204,830	413,880,749	-4,167,073,376	242,778,395	4,409,851,771	-858,800,700	241,981,530
14	138,177,661	564,405,469	-10,536,979,658	243,129,949	10,780,109,607	-514,204,763	242,376,039
15	138,322,402	420,474,358	-6,578,633,519	243,964,427	6,822,597,946	-768,202,949	243,135,866
16	105,937,086	1,086,497,727	-20,749,718,844	244,556,327	20,994,275,172	-229,623,712	243,514,770
17	154,642,362	512,657,709	-10,692,503,162	245,208,684	10,937,711,846	-397,106,795	244,228,011
18	92,587,209	1,314,520,910	-20,844,819,549	245,148,338	21,089,967,887	-384,537,272	244,628,435
19	141,570,089	963,327,119	-20,011,856,358	246,289,263	20,258,145,622	-65,430,098	245,000,957
20	138,961,315	623,584,087	-11,651,124,716	246,780,843	11,897,905,559	-303,074,876	244,910,210

Figure 5.1
Fire Risk: Mean and Confidence Interval for 20-year Time Path of Net Income

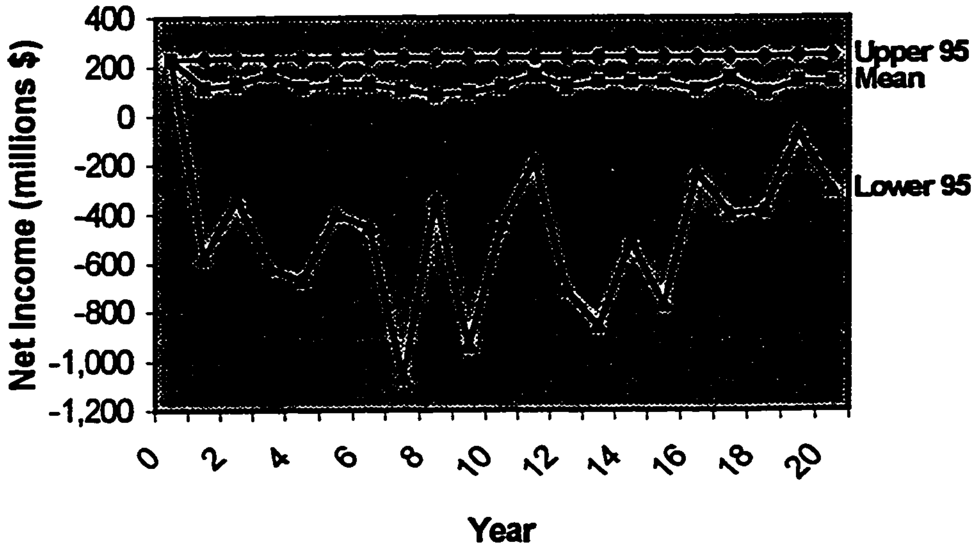


Figure 5.2
Fire Risk: Distribution of Net Income Values for Year 1

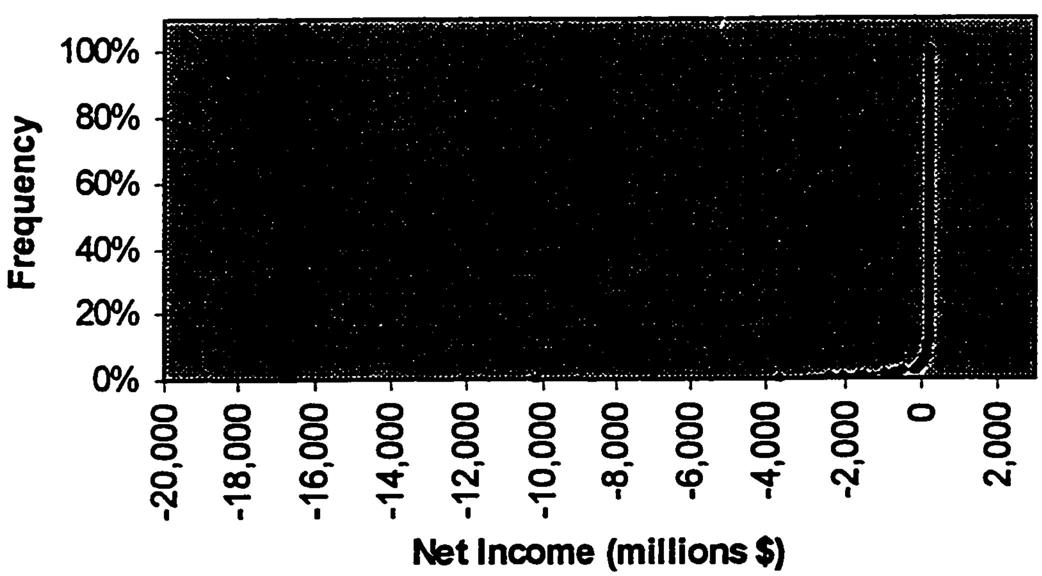


Figure 5.3
Fire Risk: Histogram of Net Income Values for Year 1

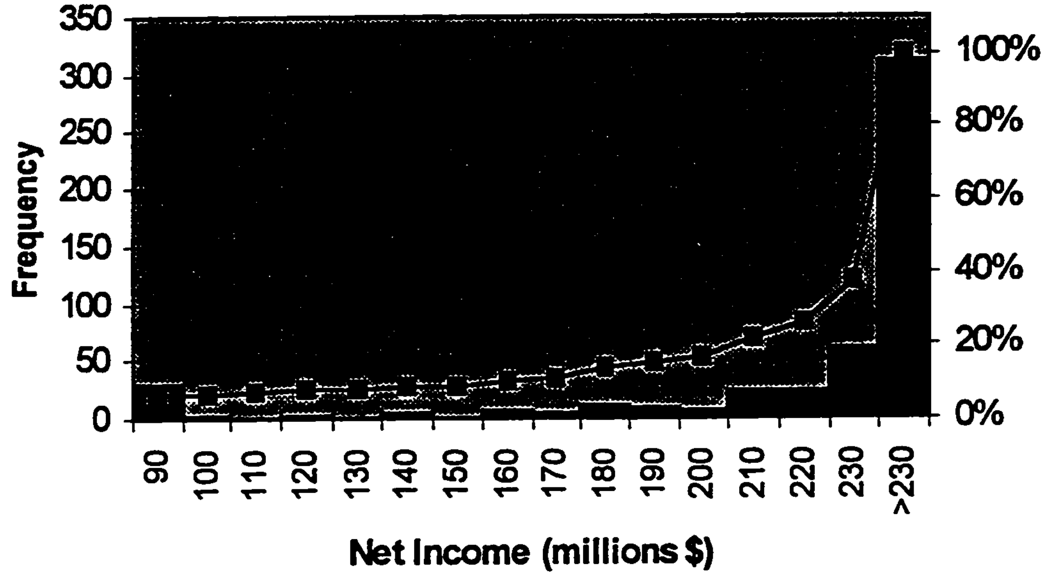


Figure 5.4
Fire Risk: Distribution of Net Income Values for Year 10

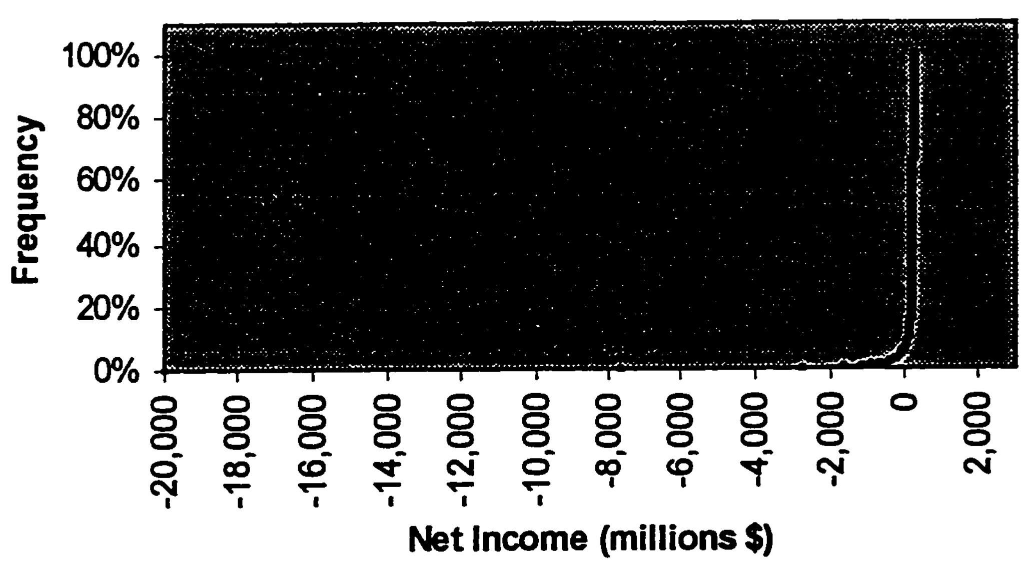


Figure 5.5
Fire Risk: Histogram of Net Income Values for Year 10

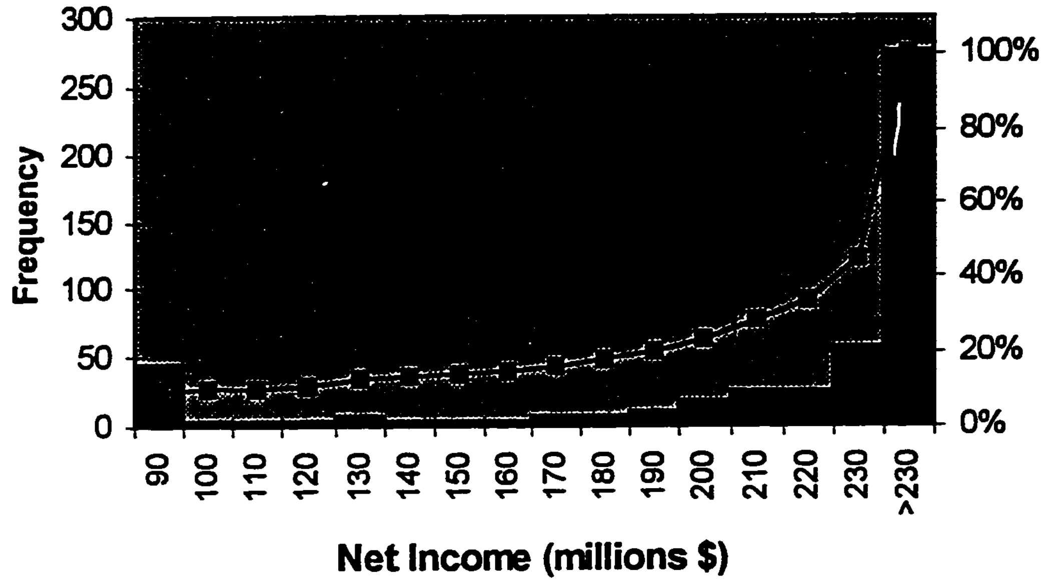


Figure 5.6
Fire Risk: Distribution of Net Income Values for Year 20

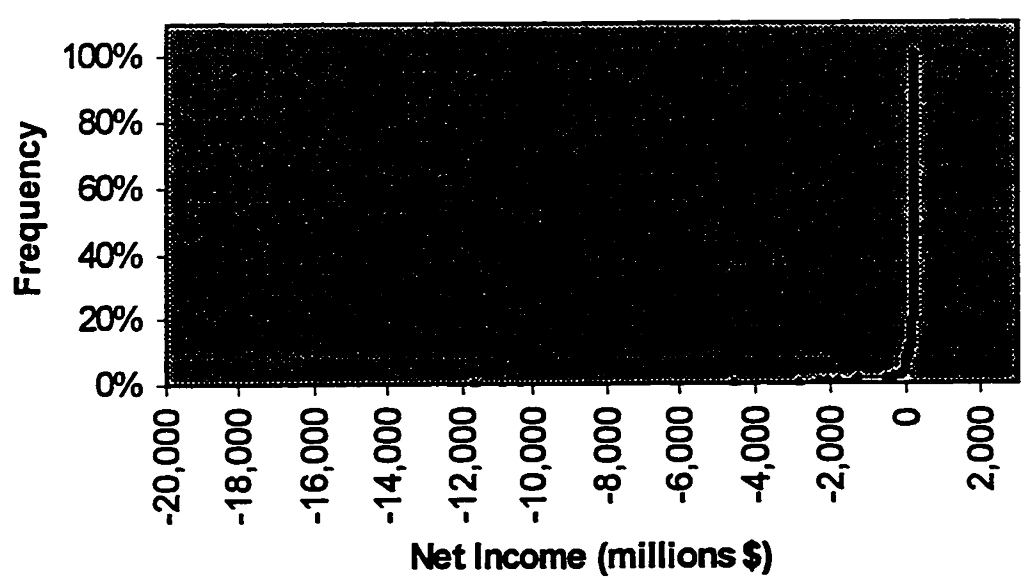
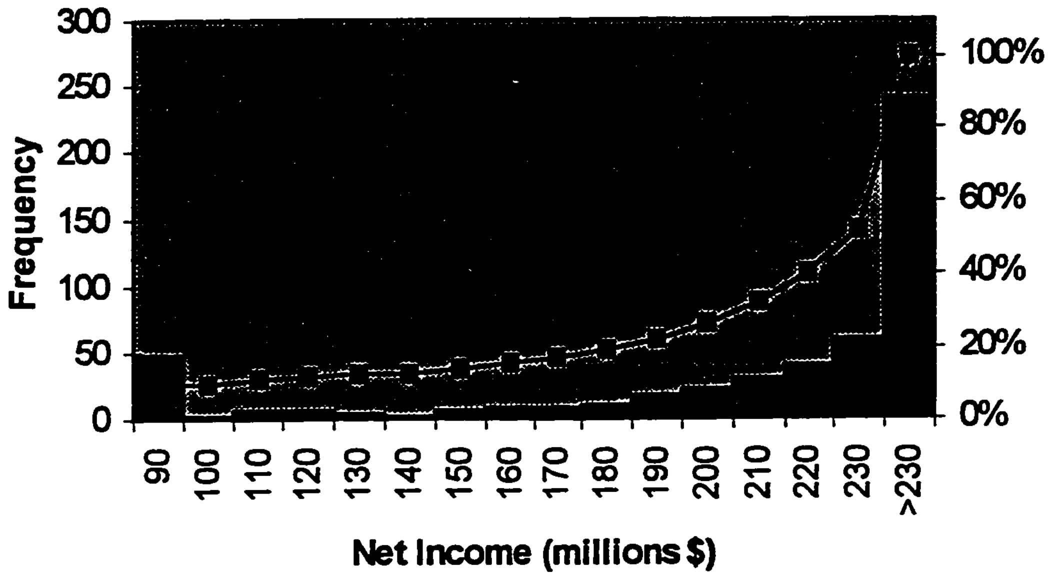


Figure 5.7
Fire Risk: Histogram of Net Income Values for Year 20



5.4.2 Price Risk

As with the fire risk simulations, the simulation of price risk requires the distribution of future prices to be explicitly defined. In this case, the distributions of pulp and lumber prices were estimated using historical time series data. Lumber prices for western spruce-pine-fir (f.o.b. mill net or factory gate) were obtained from Natural Resources Canada (1996) and USDA (1997) which report annual average prices from *Random Lengths*. Northern bleached hardwood and softwood pulp prices were obtained from the Pulp and Paper North American Fact Book (1996).[39]

Price movements over time can be modeled in many different ways. Here the characterization of future price movements is kept relatively simple. The following regression equations were estimated for each price series:

Autoregressive 1 (AR1):

$$P_t = \alpha_1 P_{t-1} + \gamma + e_t \qquad (22)$$

Autoregressive 2 (AR2):

$$P_t = \alpha_1 P_{t-1} + \alpha_2 P_{t-2} + \gamma + e_t \qquad (23)$$

Logged Autoregressive 1 (lnAR1):

$$\ln P_t = \alpha_1 \ln P_{t-1} + \gamma + e_t \qquad (24)$$

Logged Autoregressive 2 (lnAR2):

$$\ln P_t = \alpha_1 \ln P_{t-1} + \alpha_2 \ln P_{t-2} + \gamma + e_t \qquad (25)$$

The above equations were estimated using historical annual average prices that were converted to 1996 Canadian dollars. A combination of factors including overall model significance (p-value), coefficient significance, examination of residuals was used to select the equations that would be used in the simulations. For hardwood and softwood pulp the AR2 relationship appeared to explain price movements best, whereas for lumber, lnAR1 was found to provide the best fit. The parameters of the regressions used to predict future prices are listed in Table 5.3.

Table 5.3
Equations for Future Price Movement

Price Series	*Number of Years (n)*	*Equation Type*	*Coefficient* (α_1)	(α_2)	*Intercept* (γ)	*Standard Error* (σ_e)
HBKP	20	AR2	0.75598	-0.54057	652.56185	151.8762645
SBKP	20	AR2	0.86759	-0.62316	699.86508	141.2023369
Lumber	22	lnAR1	NA	0.70015	1.75496	0.2015913

Note the relatively high standard error values for all three regressions. Even the selected models leave much of the variation in prices unexplained. As noted above, the method for predicting future prices is kept relatively simple in this analysis, however, a variety of more elaborate methods might be applied. For example, the pulp and lumber market are sensitive to a number of factors including the interest rate, exchange rates and

[39] Since, as noted in chapter 4, f.o.b. mill net prices for pulp were not available, prices for pulp delivered to the US are used. Again, this is accounted for in the estimate of AVC.

trade policy (i.e. softwood lumber tax). Predictions of the future path of these variables might also be used to forecast future pulp and lumber prices. Similarly, the futures markets for pulp and lumber could be used to assist in predicting future prices.

In order to isolate the influence of future price, the annual deciduous and coniferous harvests are kept at a constant at the percentage of the stock equal to that which applied in 1996. This means that opening and closing stocks and the equations that determine stock volumes over time in the fire simulations are not required. The harvest level and change in the stock remain at the same volumes as in 1996. The average of low and high variable cost estimates from section 4.4.1.1.5 are used to calculate pulp and lumber rent. As with the fire simulations, 500 draws of 20 years each are made from the error term distributions.

5.4.2.1 Results

Tables 5.4-5.6 provide descriptive statistics the parameters of the HBKP, SBKP, and lumber price simulations. As in the fire risk section, tables of descriptive statistics are also provided for the resulting net income values for the 20 years of the simulation (Table 5.7). Figures corresponding to those in the fire section are also provided (see Figures 5.8 through 5.10). Since there was little difference between the distribution of values for years 1, 10 and 20, in this case, a cumulative frequency diagram and histogram are only shown for year 10.

For the 10,000 draws, Tables 5.4-5.6 report the mean rent values to be $71.32 for HBKP, $75.68 for SBKP, and $36.90 for lumber. The pulp rent values are significantly higher than the average rent values estimated for 1996 ($46.56 for HBKP and $50.57 for SBKP), whereas the lumber rent is much lower ($60.89 in 1996).

Figure 5.8 shows that the time path of net income has fairly stable confidence intervals over time. The upper and lower confidence intervals appear to be equidistant from the mean. Table 5.7 reports that for the 20 years, mean net income ranges from about $133 million (year 1) to $374 million (year 4). Looking at each year separately, the range (maximum minus minimum) of the 500 draws for a given year spans from about $481 million (year 1) to $766 million (year 17). The standard deviations associated with the yearly means are generally about $100 million. Figures 5.9 and 5.10 show that the distribution of net income for year 10 closely resembles the normal.

Table 5.4
Summary Statistics for Hardwood Bleached Kraft Pulp (HBKP) Price Simulation

	Error Term	*Price ($)*	*Rent ($/m³)*
Mean	-2.34	816.73	71.32
Standard Deviation	149.77	212.61	43.39
Minimum	-608.92	11.24	-93.06
Maximum	524.85	1,625.06	236.29
Range	1,133.77	1,613.82	329.35

Table 5.5
Summary Statistics for Softwood Bleached Kraft Pulp (SBKP) Price Simulation

	Error Term	*Price ($)*	*Rent ($/m³)*
Mean	-0.56	910.71	75.68
Standard Deviation	141.11	221.97	37.88
Minimum	-528.32	76.96	-66.60
Maximum	473.75	1,696.65	209.79
Range	1,002.07	1,619.68	276.40

Table 5.6
Summary Statistics for Lumber Price Simulation

	Error Term	*lnP*	*Price ($)*	*Rent ($/m³)*
Mean	-0.00116	5.8875	375.39	36.90
Standard Deviation	0.2031	0.2856	108.23	25.22
Minimum	-0.8364	4.7525	115.88	-23.56
Maximum	0.7346	7.0043	1,101.32	206.05
Range	1.5710	2.2517	985.44	229.61

Figure 5.8
Price Risk: Mean and Confidence Interval for 20-year Time Path of Net Income

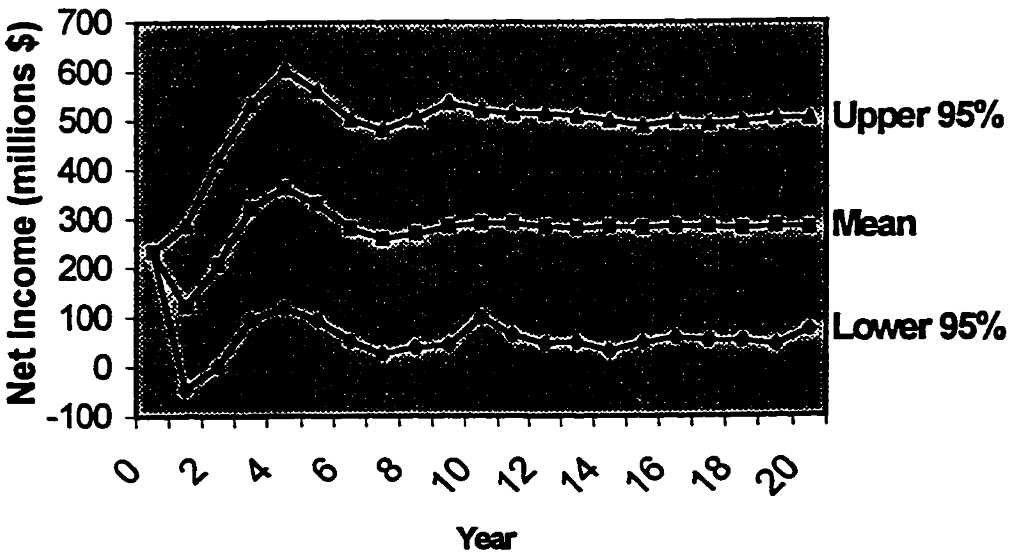


Table 5.7
Price Risk
Summary Statistics: Net Income for Years 1-20 (1996$)

Year	Mean	Standard Deviation	Minimum	Maximum	Range	95% Confidence Interval Low	95% Confidence Interval High
1	132,652,963	85,331,798	-107,717,104	373,386,290	481,103,393	297,607,298	-34,121,181
2	217,327,107	108,864,616	-198,818,416	519,666,078	718,484,494	431,749,697	14,003,479
3	333,558,596	111,718,879	23,701,480	670,787,381	647,085,901	544,806,778	106,766,980
4	374,045,681	114,329,801	56,137,490	681,430,517	625,293,027	614,569,846	130,393,535
5	341,695,134	118,581,537	-71,164,594	661,926,889	733,091,483	571,224,574	104,675,475
6	292,079,288	119,789,461	-26,387,973	618,820,754	645,208,727	513,805,795	62,900,614
7	270,380,654	115,411,542	-12,775,418	586,486,802	599,262,220	492,720,228	37,844,184
8	279,858,602	124,704,589	-126,502,310	602,966,124	729,468,433	515,757,126	52,159,173
9	295,253,982	126,499,876	-33,937,820	698,238,855	732,176,676	547,705,475	57,401,590
10	301,800,017	110,656,455	-81,129,479	616,546,904	697,676,383	532,495,242	109,963,133
11	300,906,762	117,409,660	-65,464,129	642,610,827	708,074,956	526,046,531	75,202,022
12	293,857,916	114,026,773	-27,325,863	628,773,758	656,099,621	525,111,869	59,236,726
13	290,562,958	120,528,565	-50,450,637	702,038,739	752,489,376	519,753,835	61,900,121
14	294,065,459	118,178,581	-64,820,969	690,101,276	754,922,245	510,622,229	45,204,085
15	292,330,342	113,990,182	-50,511,900	640,145,507	690,657,407	501,771,911	60,912,587
16	296,121,149	110,497,149	-74,427,260	631,355,080	705,782,339	509,433,080	70,264,627
17	294,649,669	110,993,325	-73,253,465	693,235,967	766,489,432	504,513,004	65,928,935
18	290,401,097	114,166,257	-44,252,301	683,026,917	727,279,218	507,753,541	64,516,762
19	294,098,760	118,520,425	-81,856,761	650,218,503	732,075,264	514,677,218	57,112,557
20	293,084,266	107,669,083	-81,703,817	654,300,076	736,003,893	514,319,253	84,561,418

Figure 5.9
Price Risk: Distribution Net Income Values for Year 10

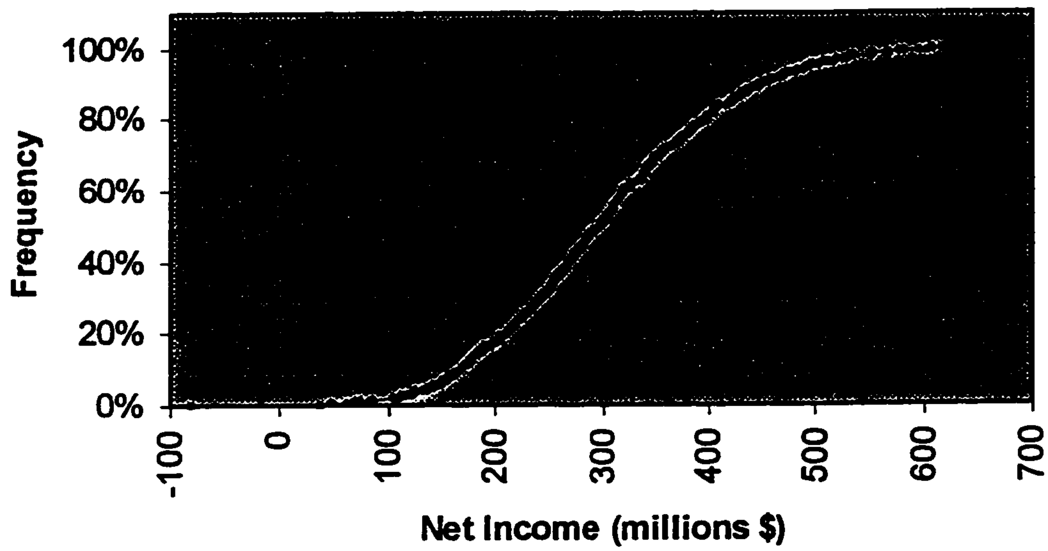
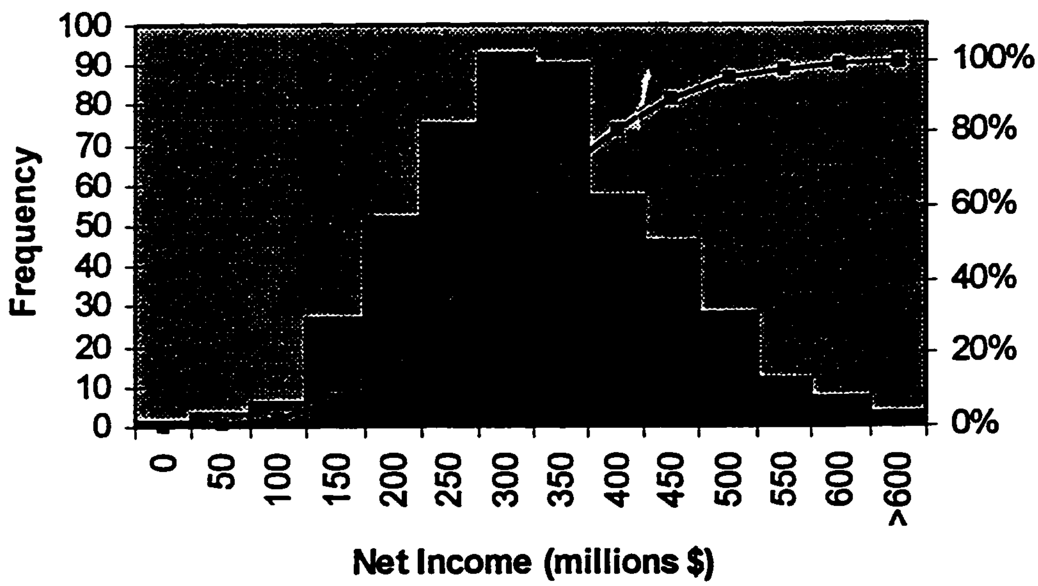


Figure 5.10
Price Risk: Histogram of Net Income Values for Year 10



5.4.3 Fire and Price Risk

In reality, timber capital is subject to both fire and price risk. Therefore, simulating both types of risk together may provide a more realistic and applicable results. The final set of simulations uses the fire risk and price risk parameters from the previous simulations to illustrate the combined effect of these two types of risk of the value of NNP.

5.3.3.1 Results

As with the previous simulations, the results of this combined simulation are summarized in a table of descriptive statistics (Table 5.8) and a series of figures (Figures 5.11 through 5.13). As with the price risk simulation, a cumulative frequency diagram and histogram are only shown for year 10.

Figure 5.11 shows that the mean yearly net income values form a somewhat unstable path. The upper confidence interval of this path is relatively stable in comparison to the lower confidence interval, which is highly sporadic across years. Table 5.8 confirms the variability in the yearly means, which range from about $60 million (year 9) to $241 million (year 3). The standard deviations associated with the means of yearly net income range from about $408 million (year 3) to almost $2 million (year 18).

Figures 5.12 and 5.13 show that the distribution of year 10 values takes on a highly skewed shape. Although most values occur near the mean, a large number of the 500 draws are well below the mean.

Figure 5.11
Fire and Price Risk: Mean and Confidence Interval for 20-year Time Path of Net Income

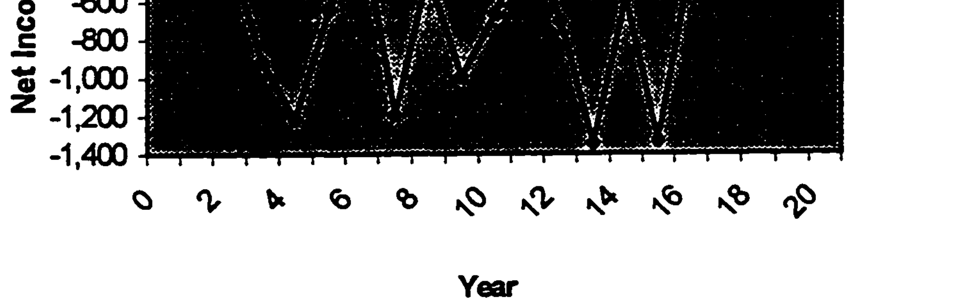


Table 5.8
Fire and Price Risk
Summary Statistics: Net Income for Years 1-20 (1996$)

		Standard				*95% Confidence Interval*	
Year	*Mean*	*Deviation*	*Minimum*	*Maximum*	*Range*	*Low*	*High*
1	80,734,363	615,658,543	-11,760,070,593	885,422,743	12,645,493,336	315,087,376	-96,976,259
2	69,730,462	1,596,643,809	-32,664,288,725	510,171,573	33,174,460,298	429,817,316	-331,677,251
3	241,060,264	407,695,106	-3,684,066,547	614,039,922	4,298,106,470	525,381,396	-918,165,546
4	133,482,017	1,579,037,079	-21,081,790,527	689,570,736	21,771,361,264	591,251,783	-1,211,489,474
5	177,157,617	1,416,105,320	-28,822,695,762	674,764,892	29,497,460,653	561,979,335	-636,645,555
6	138,971,969	1,807,660,708	-38,703,424,949	598,281,140	39,301,706,089	498,034,050	-218,509,091
7	124,114,046	828,721,014	-10,277,801,415	583,631,664	10,861,433,079	481,813,615	-1,207,673,581
8	84,172,217	1,697,430,983	-31,861,691,289	603,519,662	32,465,210,951	502,355,665	-453,297,968
9	60,405,755	1,803,052,831	-35,546,881,071	698,941,938	36,245,823,009	509,318,631	-1,001,084,200
10	137,911,333	1,278,024,044	-19,730,393,867	625,600,799	20,355,994,666	534,407,954	-674,525,522
11	185,967,921	707,766,848	-10,534,065,638	650,554,487	11,184,620,126	517,998,471	-253,134,866
12	142,119,812	1,187,311,917	-24,681,762,745	647,297,149	25,329,059,894	500,115,644	-704,785,677
13	142,712,045	723,780,515	-9,615,622,956	723,982,850	10,339,605,806	502,249,285	-1,357,505,422
14	174,623,786	676,058,716	-12,689,934,300	708,600,515	13,398,534,815	497,872,001	-587,202,808
15	150,550,540	709,837,811	-11,886,681,970	611,093,314	12,497,775,284	484,241,102	-1,343,342,935
16	123,725,615	1,424,357,936	-24,300,764,322	632,239,069	24,933,003,391	501,960,094	-388,014,557
17	197,224,102	627,032,282	-12,935,159,351	578,181,933	13,513,341,284	509,407,984	-451,437,655
18	88,098,684	1,940,246,088	-33,942,473,741	665,026,098	34,607,499,840	492,991,374	-529,393,821
19	155,258,608	1,826,066,393	-40,283,826,853	614,329,680	40,898,156,533	512,088,105	-82,846,996
20	138,589,643	1,247,730,057	-25,360,159,564	601,258,691	25,961,418,255	485,560,553	-398,101,861

Figure 5.12
Fire and Price Risk: Distribution Net Income Values for Year 10

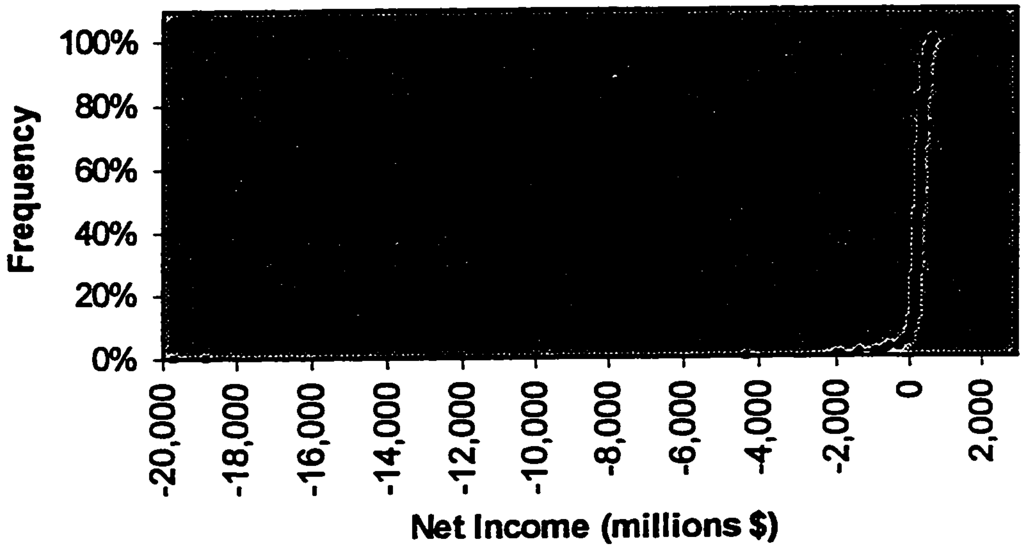
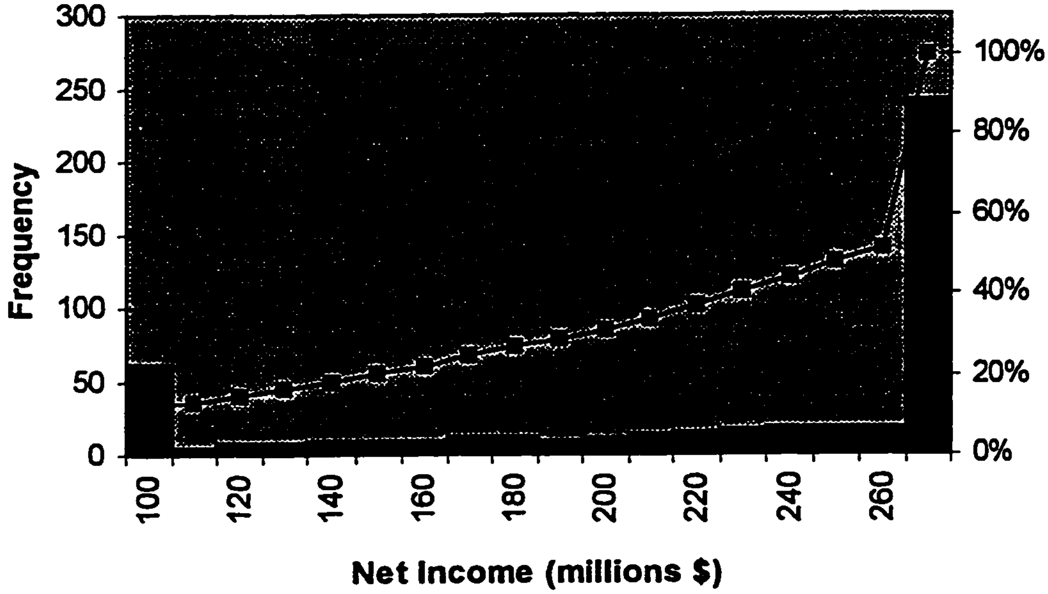


Figure 5.13
Fire and Price Risk: Histogram Net Income Values for Year 10



5.5 Discussion

The simulations suggest that fires and price changes play an important role in determining the annual net income of the region. Due to the influence of these risks on commercial forestry, the net income of the region can be expected to fluctuate significantly from year to year. Fire risk, in particular, creates the possibility of large declines in annual net income. As modeled in the simulations, large fires cause the amount of timber harvested for commercial purposes to decline and significant depreciation of the timber stock.

The first set of simulations isolates the influence of fire risk. The summary statistics show that large variability in annual net income can be expected over the next 20 years. The distribution of the net income predicted for a given year is highly skewed with most values predicted to be relatively close to the mean, but several values far below the mean. The reason for these results is related to the lognormal distribution of forest fires. Although the mean burn rate is very small, the lognormal form combined with the high variance of the burn rate distribution means that in some years the burn rate is 1 or very near to 1 (i.e. the entire forest or almost the entire forest burns). In these years, the flow of income falls to near zero since there is no stock to harvest.[40] Due to the large decrease in the volume of timber, the value of the change in the timber stock is negative and very large in absolute value. Overall, the result is that net income is subject to large and stochastic declines due the influence of fire risk. Figure 5.1 shows that although the expected value of net income remains fairly constant across years, the degree of confidence associated with the expected value does not remain constant.

The means of net income for the 20 years are lower than the net income value estimated for 1996 (approximately $232 million). This is not surprising considering that a relatively small area burned in 1996 since the median of the lognormal distribution was used. The skewed form of the lognormal distribution causes the mean burn rate to be much higher than the median.

In the price risk simulations, the amount of harvest is assumed to remain constant at the 1996 level. Therefore, any changes in annual net income are directly attributable to pulp and lumber price fluctuations. The price risk simulation predicts much less variability in yearly net income values. The distribution of net income for year 10 closely resembles the normal. This is expected to an extent since the simulated error terms for SBKP and HBKP were normally distributed. However, the influence of the error term for lumber prices, which was drawn from a lognormal distribution is less apparent.

The results of combined simulation show that when fire and price risk considered together the variability of expected net income for a given year increases (see standard deviations in Table 5.8). In addition, the possible 20-year path of net income is more difficult to determine as illustrated by Figure 5.11. In comparison to the corresponding figure for the fire risk simulation, the 95% confidence interval is wider. The distribution of draws for a given year shows that fire risk plays the main role in determining the value of net income. Figures 5.12 and 5.13 show that the distribution of year 10 values takes on a highly skewed shape similar to that depicted for year ten in Figures 5.4 and 5.5. The influence of the distributions simulated for the price error terms is apparent but very small.

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[40] It is assumed that the salvage value is minimal. Burnt wood fibre would contaminate pulp production; however, in some cases, timber from burned areas can be recovered for other uses.

The overall effect is that the two forms of stochasticity compound each other, however, the effects of fire risk dominate. This is not surprising considering that standard deviation associated with the simulated burn rate is so high.

From the simulations it can be concluded that risk, particularly fire risk, plays an important role in determining net income in the case study region. This suggests that using changes in net income as measured in chapter 4 to assess the sustainability of income flows from the region must consider the role of risk in causing net income to fluctuate over time. According to Mäler (1991), Dasgupta (1995) Aronsson *et al.* (1997) and others, sustainable development requires that NNP (or net income in this case), be non-decreasing over time. However, such an interpretation relies on the assumption that the welfare measure is the stationary equivalent of current and future wellbeing.

As already discussed in chapters 3 and 4, for this to be the case the model used to derive the welfare must accurately depict the evolution of the economy over time and include all factors that influence welfare. It has already been noted that the net income measure in developed in chapter 4 fails to incorporate all components of welfare, however, even so, there is still the potential to use the measure to assess whether the income flows from the components included in the measure are sustainable. The simulations suggest that using the net income measure to assess sustainability must be further qualified. The stochasticity of risk, particularly fire risk, means that fluctuations in net income are to be expected and, for the most part, these fluctuations cannot be avoided. Thus, the reason for including a risk adjustment factor in the net income measure in stochastic setting is apparent.

The results of the simulations can be used to provide an estimate of the magnitude of the risk adjustment factor to be applied to the estimate of regional net income from chapter 4. The mean of the 10,000 draws from the lognormal distribution used to characterize annual burn rate in the region is 0.0051457 or 0.51457% of total area. Since 0.51457% of the remaining timber stock can be expected to burn in the following year, this expected loss should be deducted from the value of the change in the timber stock. For the 10,000 draws from the distributions used to predict price changes, the resulting mean rent values are $71.32 for HBKP, $75.68 for SBKP, and $36.90 for lumber. The mean yearly rent values were also calculated and discounted to the present using a discount rate of 5%. The means of discounted rent values are $43.52 for HBKP, $47.16 for SBKP and $22.94 for lumber. These mean values might be considered rationally anticipated values and used as the current value expected shadow prices. Table 5.9 outlines how these values are used to estimate the expected value of the change in the timber stock. It is assumed that the other components of net income are not influenced by risk and, therefore, their values do not change.

Table 5.9
Expected Value of the Change in Timber Stock in 1996 (1996$)

	Product	1996 Change in Stock	Expected Loss due to Fire	Stock Change Valued	Estimate of Expected Rent ($/m^3)	Stock Change Expected Value
Deciduous	HBKP	693,323	3,568	689,755	43.52	30,018,138
Coniferous		386,800	1,990	384,810		
Alberta-Pacific (26.3%)	SBKP	101,728	523	101,205	47.16	4,772,828
Quota holder (73.7%)	Lumber	285,072	1,467	283,605	22.94	6,505,899
Total						41,296,865

HBKP and SBKP stand for Hardwood Bleached Kraft Pulp and Softwood Bleached Kraft Pulp.

The value of the change in the timber stock used to estimate regional net income in chapter 4 was $52,334,770. When accounting for fire risk and expected price changes, the value of the change in stock is predicted to be $41,296,865. This suggests that the deterministic estimate from chapter 4 ($232,447,976) over estimates regional net income. The simulations suggest that to account for fire and price risk, net income should be adjusted downward by about $11 million. As noted earlier, the simulations in this chapter do not account for all factors necessary to provide an exact estimate of the adjustments required; however, the magnitude of the suggested adjustment appears to be reasonable.

Formal incorporations of fire and price risk into the net incc me measure would provide a more accurate estimate of the adjustment required. Besides the incorporation of the probability distributions, which characterize these risks, other adjustments to the deterministic model may be needed. The extent to which fire and price risks are already reflected into current prices must be considered when estimating shadow prices. For example, using price forecasts, Alberta-Pacific can attain a reasonable idea of future prices, at least in the near term. Alberta-Pacific may be able to hedge against fire and price risk to a limited extent by keeping an inventory of wood fibre which can be drawn down when required or built up is prices are low.

The influence of fire risk and price risk on other components of forest income would also have to be considered. The simulations only consider the influence of risk on the income generated by commercial forestry. In reality, these risks may alter the value of other forest services. The influence of fire risk on non-timber values is the most significant omission from the simulations. Fire influences plant and wildlife populations, which in turn affects trapping, subsistence resource use, and passive use values associated with biodiversity. However, the impact of fire is not easy to predict since although a fire may destroy certain plants and wildlife habitat in an area, other species thrive in the early successional stages that dominate in recently burned areas. Fire will also influence recreational values if the aesthetic quantity of recreation sites declines and big game are more difficult to hunt. Fires play a role in the carbon cycle by releasing carbon dioxide into the atmosphere. Therefore, the carbon sequestration services provided by the forest will be tied to the frequency and size of fires. If the influence of fire on these components of net income was considered the predicted regional net income would probably be even more sporadic and the adjustment to current net income needed to account for this risk would be larger.

There are also other forms of price risk that could have been considered in the simulations. Price variability also occurs in the commericial trapping and fishing sectors. If the stock of furbearers and fish had been incorporated in the model of the regional economy then this risk would have to be considered when estimating the shadow price associated with changes in these stocks.

The practical question that must be addressed in resource accounting applications is whether it is enough to simply qualify our interpretations of net income or whether the net income measure should be formally adjusted to account for risk. The answer to this question is likely to depend on the particular situation. As has been discussed, adjusting the net income measure would require re-formulating the model to account for stochasticity. The nature of risk may not lend itself to quantification. The probability distribution associated with the stochastic variable may be complex and it may be difficult to determine the degree to which current prices already reflect risk. In other cases, incorporation of risk may be rather straightforward.

Simulation exercises such as the one carried out in this chapter provide a practical alternative to re-formulation of deterministic welfare indices. The simulation allows the significance of risk and its expected influence on future wellbeing to be assessed. This information can be used to qualify interpretations of changes in the deterministic welfare index. Of course, simulations cannot depict reality perfectly but they can provide useful information related to the role of risk and the relative magnitude of the risk adjustment factor that theory prescribes should be incorporated into the welfare index in a stochastic setting.

The simulations also provide some insights related to forest policy. The simulations illustrate the substantial benefits could be realized by decreasing the risk of fire and in particular the occurrence of very large fires. In statistical terms, decreasing the standard deviation of the burn rate would decrease the expected income losses. This is also apparent when examining the equation for the mean of a lognormal distribution

$$\bar{a} = \exp\left(\frac{\mu + \sigma^2}{2}\right) \tag{28}$$

where a refers to annual burn rate and μ is the median of the population (see Armstrong 1998 for more details).

The LFS and the forest industry already partake in fire suppression activities; however, it appears that additional measures may be warranted. In particular, measures aimed at decreasing the variance associated with the burn rate. To the extent that the benefit of these fire suppression activities exceeds the additional costs, they will improve wellbeing. It should also be kept in mind that fire plays an important ecological role in the Boreal Forest is part of the forest's natural disturbance regime (Hunter 1992; Armstrong 1998). The long run ecological implications of disrupting this regime by increasing fire suppression efforts beyond current levels limiting large fires are not certain. However, Alberta Pacific's transition to 'ecosystem management' is motivated by the belief that harvest practices which emulate the forest's natural disturbance regime preserve biodiversity and ecological integrity more effectively than traditional harvesting practices (Alberta Pacific 1997). The trade-off between the benefits of additional fire suppression to commercial forestry may be outweighed by the ecological consequences.

The simulations also show the importance of giving industry the means by which to hedge against financial risks. Currently, forestry companies engage in a number of risk hedging activities. As noted, Alberta-Pacific can hedge against the risk of fires to an extent by maintaining an inventory of wood fibre. The Company can also purchase some fibre from private woodlots and sawmills or sell salvaged timber to mills that are able to use it.[41] It would be interesting to investigate whether or not current levels of risk hedging are optimal or whether there would be net benefits associated with additional measures. To the extent that net benefits could be realized, perhaps government regulation and policy would have a role.

5.6 Summary

The derivation and measurement of a welfare index that incorporates the implications of current activities on future utility, requires making assumptions regarding the future state of economy. In most cases, these assumptions include the absence of risk and uncertainty. Therefore, most resource accounting systems paint a deterministic picture of the world implying that the future is known with certainty, or at least that, future uncertainties cannot be meaningfully characterized. The NNP approach is the exception. Recent literature related to the use of national product related welfare measures has shown that in a stochastic setting, theoretically consistent the welfare measures include contingent shadow prices and a term representing the expected value of risk.

Considering that a multitude of different conditions, constraints or assumptions can be imposed on the future in a growth theoretic framework, the challenge is determine when the added complexity that accompanies such alterations is outweighed by the additional information provided. The simulations in this chapter demonstrate a method for determining the relative importance of risk to income flows. As an alternative to formally incorporating risk into the welfare index, the information from these simulations can be used to qualify interpretation of the deterministic welfare index.

For the case study region, the simulations demonstrate the relative importance of two forms of risk, fire risk and price risk, which influence net income flows in the region. The effect of fire risk appears to play a considerably more important role than price risk. The distribution of net income for the selected years shows that, fire can burn the entire timber stock and cause huge income losses. Whether formally or informally, the threat of this occurrence should be considered in today's measure of welfare. Risks should be considered when using the net income measure to make conclusions about the sustainability of income flows in the region.

[41] This introduces the issue of substitution between public and private capital.

Chapter 6 Conclusions, Recommendations and Future Research

6.1 Summary and Conclusions

This study has provided a review of the development of resource accounting and recent applications to forest resources. This review suggested that, although national resource accounts have been developed by several nations, regional level resource accounting is a new initiative.

Theoretical justification for the use of national product related welfare measure or Green NNP as an indicator of sustainability was discussed. The complications associated with the use of Green NNP as a welfare measure and as an indicator of sustainability were reviewed and the means by which these complications are recognized in the resource accounting case study were noted.

Chapter 4 outlined the development of a forest resource account for a region of public land in northern Alberta. The case study demonstrated the numerous assumptions required to derive a measure of net income for the region. During the study, various complications related to determining the relevant boundary of activity, collection of activity levels and shadow values of forest services were encountered. Wherever possible, these difficulties were discussed with the hope that identification of these difficulties would aid other researchers in the development of forest resource accounts for other regions.

The case study forest resource account was developed for a region of public land. Forest product companies are allocated the rights to timber on public land subject to numerous conditions, many of which are aimed at ensuring that the forest is managed in a sustainable manner. Forest resource accounts can be used in combination with other ecological and sociological information to monitor progress toward the goal of sustainable forest management. Therefore, forest resource accounts provide information of interest to industry, government, and the public.

The case study revealed that, of the forest services included in the account, commercial forestry was largest. However, the value other forest services, particularly, biodiversity maintenance and provision of resources for subsistence activities, were also significant. The account also showed the range of uncertainty associated with many of the component value estimates and in doing so illustrated the need for improved information related to these forest services. Although, regional net income was only estimated for one year, it appears that the criteria for strong sustainability was met since timber capital appreciated over the period. However, it does not appear that the Hartwick rule, which prescribes that the proceeds from resource extraction be re-invested so that the total capital stock remains constant, was complied with.

Although, the case study resource account was developed for a region of public land, a similar framework could be applied to private land. Industrial activity on private land is not subject to the same constraints and conditions as activity of public land; however, industry may still find that resource accounts assist in substantiating their claims of environmental sustainability. Environmental and social responsibility are increasingly becoming goals of private corporations who recognize the benefits of differentiating their product from others on environmental or social grounds (for more on this topic see Rubenstein (1994)).

Risk and uncertainty have not been incorporated in most resource accounting frameworks; however, recent literature has investigated the implications of relaxing the assumption of perfect foresight. Chapter 5 discussed the importance of risk and uncertainty to the welfare measurement and more specifically the measurement of net income from forest services in the study region. It was found that risk, particularly fire risk, plays an important role in determining future realizations of net income. To be an appropriate indicator of sustainability, the measure of net income should consider the value of risk. Several authors have demonstrated how risk can be formally incorporated into welfare measures like Green NNP, however, the resulting measure can be considerably more complex than its deterministic counterpart. A practical alternative to the formally incorporating risk is to use simulations of the type outlined in this chapter, to provide information about the expected value of risk. This information can be used to apply a stochastic version of a sustainability rule that requires that the expected value of net income be non-declining.

Overall, several aspects of this study make it a valuable contribution to existing literature. First, as noted, there are few resource accounting applications at the regional level. This study has revealed numerous practical considerations that are unique to the regional and forestry context. Second, the consideration of risk and uncertainty in resource accounting has been considered from a theoretical perspective, but empirical investigations are absent from the literature. The study empirically demonstrates the importance of risk to future net income for the case study and provides a practical alternative for ensuring that the influence of risk is considered when using resource accounts to assess sustainability.

6.2 Limitations

A number of limitations should be kept in mind when interpreting the results of this study. The first relates to the reliability of data. The study utilized mainly secondary data and therefore illustrates relatively inexpensive techniques for estimating activity and value levels. The accuracy of activity and value estimates might be improved through primary data collection. However, the costs involved must not become prohibitive. There is a trade-off between accuracy and comprehensiveness and cost. This point is emphasized by IIED *et al.* (1996). In addition, some pieces of information including the portion of the region which burned in 1996 and the exact volumes harvested by Alberta-Pacific were not available, therefore, based on other information reasonable estimates were determined.

Limitations are also associated with the various assumptions made throughout the study. For many of the components of the forest account, the estimation of shadow or accounting prices used methods that rely on assumptions that not necessarily realistic. Wherever possible, these assumptions were identified. For example, the estimation of timber rent using the residual valuation approach relied on numerous assumptions including that average variable costs are a proxy for marginal costs. It should also be noted that applying the same rent estimate to stock changes as used to value harvests, implies that stock changes were subject to average transportation costs. This may not be the case, since in some years stock changes may be concentrated in areas relatively far from the mill.

Even though the simulations discussed in chapter 5 were used for mainly illustrative purposes, it should be noted that fire and price risks were simulated based on fairly straightforward models. Other more complicated models of forest fire occurrence and risk include a variety of parameters including weather, environmental, human, and spatial factors (i.e. Vega Garcia *et al.* 1995; Fried and Torn 1990). Similarly, models of price movements are often considerably more complex than those used in this study. More complex models could have been used but it is unlikely that the general results would be different.

This study has assumed that sustainability is a meaningful concept at the regional level. However, Pezzey (1992) addresses numerous issues related to whether sustainability is a meaningful concept below the global level. Many of these issues have been only briefly addressed in this study. For example, transboundary pollution and the use of resources from outside the region were not incorporated in the regional resource accounts for the study region. In addition, the derivation of regional net income (NNP) relies on a number of assumptions as noted in section 4.3.4. The assumption that of economy is perfectly competitive may be less likely to hold at the regional level and in the forestry context in Alberta. Forest products companies are designated an area to manage by the government and, therefore, in a sense have a spatial monopoly. In the case study, the forest products valued are traded on international markets and, therefore, the prices are likely to represent competitive prices. However, the Company's actual production costs may be inflated compared to the cost levels that might materialize in a perfectly competitive market. Since the pulp and lumber production costs used in the in this study were taken from a variety of sources, it is difficult to say if they were distorted.

As noted by Brekke (1997 p. 522) "to define sustainability as the requirement that consumption be non-declining in expectations ignores risk aversion". The implications of risk aversion on sustainability were not considered in this study. Therefore, the discussion of risk and its implications on resource accounting implicitly assume risk neutrality and may not generalize to the case of risk aversion.

Perhaps the most important limitation of this study is related to an issue addressed by Sorg Swanson *et al.* (1992). According to Sorg Swanson *et al.* (1992 p. 352),

> "Component valuation is useful as an indicator of value; however, component values cannot generally be added to arrive at a valid measure of total value… [and] …if different techniques are used to measure component values and then aggregated, this may result in a conceptually invalid total value. Whether holistic total value is greater than or less than piecewise total value depends on the number of components, budget shares, and complementary and substitution relationships".

Ideally, the shadow prices attached to the components of resource accounts should consider such interactions. In this study, it is implicitly assumed that the components of net income are separable goods. If this assumption is incorrect then the net income measure may be biased. Determining the degree of this bias would involve comparing the sum of the component values to the value attained from some form of holistic valuation procedure. However, in practice applying the type of holistic valuation is difficult, however it could be incorporated into a primary study of certain component values as is briefly suggested in the next section.

Finally, there is also some uncertainty regarding the feasibility of regional level resource accounting due to the sensitivity of some of the information required. In this study, the actual costs associated with pulp and lumber production in the region were either not available or could not be reported for confidentiality reasons. Statistics Canada does not publish regional level indices, producer prices, and other types of information in cases where there are very few companies. Such measures are taken so as to keep the financial positions of individual companies confidential. Therefore, the willingness of industry and government to maintain regional level resource accounts and to publicize their status is questionable. Industry may be reluctant to reveal details of resource accounts but perhaps they may be willing to report the main results annually (i.e. tables such as Table 4.31). There may also be some doubt as to whether resource accounting should be undertaken initiated by industry since there may be incentives for them to misreport or misrepresent the results. There may be a need for some form of government regulation or perhaps cooperation if regional resource accounting is to produce accurate and reliable results.

6.3 Recommendations

As noted in section 6.1, in developing the forest resource account for the case study region, numerous difficulties unique to the forestry and regional context were encountered. One of the major difficulties encountered when determining component values was that physical, and in some cases value data was collected according to biological management zones (i.e. wildlife management units, fisheries management units, watersheds, etc.) which do not correspond with the zone of industrial activity (in this case the FMA). Enhanced cooperation and joint planning between industry and the government could allow data to be collected in a way that would allow it to be readily used by both industry and the government. If the government and industry shared expenses for data collection, resource accounting may become a more feasible endeavor for industry. Geographic information systems (GIS) may a valuable tool in allowing provincial level information to be used at regional levels.

On this note, it is also recommended that, whenever feasible, non-market component values be estimated using primary data specific to the region for which the resource account is developed. The feasibility of primary data collection would be improved if government and industry coordinated their efforts and shared expenses. Surveys could be developed so that data is more easily segregated into both administrative zones and zones of industrial activity. Primary data collection will improve the accuracy of results and will enable the data collection to be tailored to the specific need. In addition, the problem of double counting discussed in the previous section could be addressed in the survey design. For example, survey questions could be designed to value components that are not likely to be separable activities (i.e. recreational hunting and fishing) in a more holistic fashion.

Primary surveys of the forest services for which activity levels and values are highly uncertain would be particularly beneficial. Based on the results of this study, efforts might focus on determining improved estimates of the passive-use value associated with the level of biodiversity maintained in forested regions and the value of subsistence resource use by First Nation peoples.

In this study, the forest resource account was developed at an aggregate level. However, aggregate account could be divided into sub-account for different sub-regions. For example, forest resource accounts developed at the FMA level could be further spatially refined based on FMU. This would provide more detailed information on the distributional consequences of regional activities over time and how changes in welfare are linked to landscape changes. Information related to forestry activities should be relatively easily quantified by FMU. The task may be more difficult for other forest services. However, if maps were incorporated into primary surveys and respondents were asked to identify the location of activities, some activity levels and marginal values could be delineated based on FMU. Again, GIS could probably used to summarize and track the information over time.

WTP surveys of the type discussed above do not necessarily need to be administered every year. If marginal values are determined based on levels of measurable ecological and social variables, then it may be possible to administer WTP surveys less frequently and use changes in ecological and social variables to estimate changes in certain values. Developing WTP models of this type would also allow the implications of changes in forest management on regional net income to be predicted.

6.4.1 Future Research

This study has uncovered many potential avenues for future research. Several research possibilities have already been alluded to in the previous sections of this chapter and in previous chapters.

The search for WTP values in the resource accounting exercise uncovered the need for improved measures of the value of certain forest services. In particular, the value of the forest in maintaining biodiversity maintenance and providing resources for subsistence uses is not well known. Improved estimates of the shadow prices of these services would allow estimates of the net income provided by forested regions to be more accurate.

The resource accounting system developed in this study did not consider how the benefits of the forest services are distributed. Identifying the beneficiaries of forest services would allow the resource account to provide valuable information on the distributional consequences of changes to forest resources across time. The distribution of timber rent is a particularly important issue since it is a public resource. A study examining the distribution of timber rents such as the one by Anielski (1991)

There are also other possibilities for future research related to the estimation of timber rent and the value of timber capital. In a resource accounting context, it may be useful to apply different rent values to cut wood. These rent values would reflect different levels of value added. For example, different rent values would be applied to timber left roadside versus in the woodyard. This would avoid irregularities in the accounts that occur when harvesting occurs but the wood is not transported to the woodyard due to adverse weather. The value of inventories as a hedge against risk may also be more easily incorporated into the account.

The development of more comprehensive regional resource accounts is another project that may prove useful. Additional forest services could be included in the forest resource account. The account could also be expanded to subsurface resources. This might provide valuable insights into the influence of oil and gas activity on forest services.

Forest resource accounts could be used more extensively for prediction and modeling. The appropriate methods for developing account for these purposes could also be investigated. Presumably, such accounts would include more information related to the interaction between the components of the accounts. For example, bio-monitoring may be linked to resource accounts so that the relationship between environmental quality and consumptive and non-consumptive values can be determined. As noted in section 6.4, this may also allow component values to be estimated using demographic, social and ecological information as opposed to a primary survey. Comparing the results of this type of estimation and the results of a primary survey would also be interesting.

In Meisner (1997)'s TCM of recreational fishing site choice in northern Alberta, the forest fire variable (the number of years since a fire, human or natural) was found to be highly significant. The results showed that "a burned out portion of the forest would create a negative impact on the visual aesthetics and decrease the probability of choosing the site" (p. 48). The fire risk simulations in this study only consider the influence of fire on commercial forestry. Incorporating the influence of fire risk on non-market values would be an interesting extension.

The simulations in chapter 5 illustrate the influence of fire and price risk on future realizations of net income. However, fire or price risk could be formally incorporated into the regional net income measure by including stochastic differential equations that characterize the movement of these variables over time in the growth model used to derive the welfare measure. In the case of fire risk, the functional form of the lognormal distribution would determine the form of the risk adjustment term that would be included in the new measure of net income.

Another interesting avenue for future research would be to investigate whether or not current levels of risk hedging amongst forest products companies are optimal or whether there would be net benefits associated with measures. This research could potentially provide useful policy recommendations.

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Appendices

Appendix I
Additional Information Related to National Level Resource Accounting

The Need for Adjustments to the National Accounts

As noted in chapter 2, contribution of natural resources to production and economic performance are not well represented in the SNA. This has led to three main criticisms of the current national accounting framework:
defensive expenditures (expenditures for measures taken to mitigate the impacts of environmental damages) are included in final demand and should be subtracted because they do not increase welfare;
the value of environmental degradation to households and firms are not (or only partially) deducted in computed net national income; and
the change in the value of the stock of environmental resources is not included in the accounts (Milon, 1995).

Based on these deficiencies it has been suggested that the SNA adjusted or supplemented to appropriately account for natural resource depletion and environmental degradation. A number of different frameworks have been proposed for this purpose, some of which will be described in the next section.

National Level Resource Accounting Frameworks

There is no consensus amongst the academic community and practitioners as to the appropriate degree to which environmental and natural resource accounts should be integrated in the SNA. However, the satellite system originally formulated by Bartelmus *et al.* (1991), and expanded in the form of the system of integrated satellite accounting suggested by the UN (Prudhan and Lonergan, 1992), outlines methods which many countries have used to develop their resource accounting systems.

The Statistical Division of the United Nations (UNSTAT) developed a framework for a System of Integrated Environmental-Economic Accounting (SEEA) which was published in 1993 as an SNA handbook titled *Integrated Environmental and Economic Accounting* (Bartelmus, 1995). The system presented is intended to "supplement the existing SNA with information on the interface between the natural environment and the economy" (Prudhan and Lonergan, 1992, p. 11). The system contains provisions for physical and monetary accounting (described below), with direct linkage to the SNA.

Bartelmus *et al.* (1991) specify the major objectives of the SEEA as follows: compilation of a set of physical accounts with linkage to monetary accounts and balance sheets; separation of traditionally aggregated stocks and flows to identify certain environmental relationships, primarily expenditures on abatement as well as defensive or mitigative measures; completion of monetary accounts for both depletion and degradation due to anthropogenic causes; extension of the concept of capital to include natural assets; and, adjustment of accounting identities (also outlined in Bartelmus, 1995).

The physical accounts of the SNA can be categorized as three main types. The first type consists of the physical flow accounts for products and non-produced natural assets which involve the expansion of the supply and use tables in the SNA to include both economically and naturally produced resources. The second type are the physical flow accounts for residuals which also utilize the supply and use tables to describe the origins and destinations of the waste products of economic production. This includes both inter-industry flows such as recycling and direct deposition of waste material in natural regimes. The final type of physical accounts is the non-financial asset accounts which consist of expanded SNA asset accounts for natural assets which include biological assets, land and soil assets, fossil and mineral reserves, water and air (Prudhan and Lonergan, 1992).

Designed as supplements to the conventional accounts of the SNA, the monetary accounting structures of the SEEA includes estimates of the economic value of resource depletion and environmental degradation. The use/value added tables describing domestic production, value added, final and intermediate consumption of goods and services are expanded and the asset or balance sheets are extended to show the opening and closing stocks of naturally and economically produced assets (Prudhan and Lonergan, 1992).

Based on the system outlined above, possible revisions of national accounting aggregates have been recommended. One of these revised aggregate measures is Eco-Domestic Product (EDP) which is net domestic product (NDP) minus the value of environmental depletion and degradation and the value of natural assets as a component of industrial output. Environmentally adjusted gross domestic product (GDP) is calculated by subtracting expenditures on environmental protection. Further subtraction of the value of depletion or degradation of the environment due to economic activities gives sustainable GDP (Bartelmus et al., 1991).

Several countries have developed (but not necessarily implemented) resource accounting systems that supplement their SNA. Depending on which adjustments to the SNA a country identifies as most important for their needs, several countries have proposed resource accounting frameworks with different combinations of the modifications outlined in the SEEA. Some systems are limited to physical accounts (Denmark and Norway for example) since some countries do not feel that the costs and uncertainties involved in determining the economic value of physical changes in the accounts is worthwhile considering the added information that it provides.

Therefore, these countries argue against the need for monetary resource accounts that can be used to calculate EDP and other environmentally adjusted macro-accounting aggregates. However, other countries such as Sweden consider the calculation of environmentally adjusted measures of national expenditure to be a worthwhile endeavor and therefore their systems include monetary accounts. Kristrom (1995) and Prudhan and Lonergan (1992) describe a number of different resource accounting systems that have been proposed by several countries.

A number of case studies have also been undertaken by the United Nations and the World Bank to identify the benefits of adjusting the national accounts of developing countries. These studies generally focus on the divergence between conventional and environmentally adjusted GDP or GNP and the implications on resource development decisions. Case studies of this type have been completed for Indonesia (Repetto *et al.*, 1991), Costa Rica (Soloranzo, 1991), Thailand (Sadoff, 1995), and several other countries. These studies have made valuable contributions to resource accounting methodology through identifying practical difficulties and they have clearly illustrated the inadequacy of the conventional SNA and reliance on it as a tool in make environmental and resource policy decisions.

Scandinavian Studies

Kristrom (1995) reviews the contribution of Scandinavian countries to the development of national accounting systems and the lessons learned from their experiences.

Norway introduced a resource accounting system in 1978 that was limited to physical terms. In the system resources are categorized as material (e.g. mineral, biotic, and inflowing resources like hydropower) or environmental (e.g. emissions to air for different pollutants). A material account specifies the "in- and outgoing resource base including adjustments other than gross extraction (discoveries, reappraisals, new technology); an extraction and trade part, where extraction import, and export are recorded by sector; and a domestic use part" (p. 158).

Like Norway, Denmark also limits its resource accounting to physical terms. The Danish Commission on Resource Accounting did not support monetary accounting because they did not want to disrupt what they felt was the fundamental purpose of the national accounts: " to portray the functions of a market economy" (p. 160). They also felt that the accounting system would be transformed in a "normative direction, since NNP would be partially transformed into a welfare indicator while the rest of the system continued to be a measure of production and income. The commission also pointed to problems of valuing non-market goods, including problems of properly pricing nonrenewable resources in the national accounts. Finally, the commission underlined the difficulties of valuing environmental damages that could not be tied to the activities of any specific nation" (p. 160).

Sweden also created a commission to assess the feasibility of resource accounting. The resulting study suggested, among other things, that the country pursue resource accounting that includes both physical and monetary accounts. "The commission argues that monetary accounts open the possibility for analyzing a richer set of issues than a system based solely on physical units" (p. 160).

Resource Accounting in Canada

At the national level there are two main natural resource accounting programs in Canada. The program coordinated by the Institute for Research on Environment and Economy (IREE) at the University of Ottawa is investigating the possibility of linking the natural resource accounts to the SNA but the primary purpose of the program is to provide a "...formal framework for the organization of statistical data on the stocks, flows and status of natural resources" (Prudham and Lonergan, 1992, p. 2).

The Environment and Natural Resources division at Statistics Canada has begun to develop its own framework for natural resource accounting. Within this framework, the natural resource accounts will be a supplement to the current SNA (similar to satellite accounts suggested by the UN) (Prudhan and Lonergan, 1992, p. 2-3).

Appendix II
Calculation of the User Cost Associated with Resource Depletion

El Serafy (1989) outlines methods for separating user cost from value added for both renewable and non-renewable resource exploitation. For non-renewable resources, the procedure requires that the finite series of revenue from resource sales be converted into an infinite series of real income. The capitalized values of the two series are set equal so that the user cost or depletion factor can be derived from the permanent stream of income. The relevant equation is:

$$\frac{X}{R} = 1 - \frac{1}{(1+r)^{n+1}} \quad \text{(A1)}$$

where X = value added or true income
R = total receipts net of extraction costs
r = discount rate
n = number of periods of exploitation
X/R = ratio of real value added to total receipts
1 - X/R = user cost or depletion factor (p. 32)

It should be noted that the above calculation is very sensitive to changes in the discount rate and extraction rates.

Applying the user cost approach to renewable resources requires calculating the cost to sustain the productivity of natural capital (maintenance cost) and subtracting from the total revenues of the activity that depletes or degrades the resource. Difficulties determining the appropriate maintenance activity to value may arise when there are serveral technically feasible methods that have varying costs and benefits since there is no apparent means of choosing among them. Data availability may be the determining factor in many cases (El Serafy, 1989).

Appendix III
Tables referred to in Chapter 4

Table A1
Alberta-Pacific's Net/Productive Land Base in 1996

	Species Mix	*Area (hectares)*	*% of FMA*
FMA	Coniferous	551,301	9.0
	Coniferous/Deciduous	273,049	4.4
	Deciduous/Coniferous	322,547	5.2
	Deciduous	920,880	15.0
	Deciduous	136,071	2.2
	"A" Density Deciduous	18,377	0.3
	Total	**2,222,225**	**36.1**
Outside FMA	Coniferous	32,739	
	Coniferous/Deciduous	15,766	
	Deciduous/Coniferous	14,913	
	Deciduous (C understory)	5,698	
	Total	**69,116**	
Total		**2,291,341**	

Source: Alberta-Pacific's Detailed Forest Management Plan (Draft, p. 49)

Table A2
1996 Timber Volume and Growth for Entire Area of Forest Management Units

	Gross Area (7,211,917 ha)		Net Area (5,500,937 ha)[a]	
	Volume (m^3)	Growth (m^3)	Volume (m^3)	Growth (m^3)
Deciduous	323,360,388	3,450,047	275,436,229	2,936,464
Coniferous	234,606,051	3,450,640	154,262,184	1,902,591
Total	557,966,438	7,705,650	429,698,413	4,839,055

[a] Net Area refers to 15+/10 cm utilization

Table A3
Bleached Kraft Pulp Mill Cost Component Estimates (1990$)

Cost Category	*Cost ($/ADMT)*
Delivered Wood	211
Energy	30
Chemicals	62
Labour	64
Other Materials	61
Average Variable Costs	428
Transportation Costs	97
Overhead	56
Average Total Costs	581

Source: Anielski (1991 p. 172)

Table A4
Pulp Production Costs (1990$)

	Average Variable Costs ($/ADMT)	Average Total Costs ($/ADMT)	Opportunity Cost of Capital ($/ADMT)	Average Total Costs including capital costs ($/ADMT)
HBKP	428	570.00	253.03	823.03
SBKP	428	581.00	253.03	833.03

Source: Anielski (1992 p. 84 & 172)

Table A5
Alberta-Pacific Financial Information as Inferred from Crestbrook's 1996 Annual Report

	Crestbrook Share (40%)	*Alberta-Pacific Total (100%)*	*Alberta-Pacific/ADMT*[a]
Current Assets	32,436,000	81,090,000	179
Property, plant and equipment	441,381,000	1,103,452,500	2,439
Other assets	23,953,000	59,882,500	132
Total assets	497,770,000	1,244,425,000	2,751
Current liabilities	13,728,000	34,320,000	76
Long-term liabilities	389,194,000	972,985,000	2,151
Equity	94,848,000	237,120,000	524
Total liabilities	497,770,000	1,244,425,000	2,751
Net Sales	78,228,000	195,570,000	432
Cost of sales	67,252,000	168,130,000	372
Selling, general and administrative	3,312,000	8,280,000	18
Depreciation and amortization	33,676,000	84,190,000	186
Earnings (loss) from operations	-26,012,000	-65,030,000	-144
Financial	34,448,000	86,120,000	190
Net earnings (loss) before income taxes	-60,460,000	-151,150,000	-334
Cash provided by (used for) Operations	-26,297,000	-65,742,500	-145
Financing	30,402,000	76,005,000	168
Investments	-7,550,000	-18,875,000	-42
Total decrease in cash	-3,445,000	-8,612,500	-19

[a]Using 1996 production of 452,360 ADMT

Table A6
Pulp Prices and Dues

	HBKP			*SBKP*		
Year	US Price[a] ($/ADMT)	CDN Price ($/ADMT)	Dues ($/m³)	US Price[a] ($/ADMT)	CDN Price ($/ADMT)	Dues ($/m³)
1992	540	652.71	0.49	600	725.23	2.28
1993	385	496.68	0.40	455	586.99	2.09
1994	535	730.63	0.56	560	764.78	2.57
1995	867.5	1,190.60	0.90	910	1,248.93	4.18
1996	**510**	695.40	**0.46**	**560**	763.57	**2.39**
1997	547.5	758.07	0.47	610	844.61	2.60

[a] The US price is used in the calculation of stumpage fees.
HBKP and SBKP stand for Hardwood Bleached Kraft Pulp and Softwood Bleached Kraft Pulp.
Source: Dunnigan, AEP 1998

Table A7
Softwood Lumber Cost Component Estimates (1990$)

Cost Category	*Cost ($/Mfbm)*	*Cost ($/m³)*
Delivered Wood	130	30.290
Labour (direct, indirect, and maintenance)	51	11.883
Energy	11	2.563
Miscellaneous	61	14.213
Gross Variable Costs	225	52.425
Residue Income	30	6.990
Net Variable Costs	195	45.435
General and administrative	5	1.165
Total Average Variable Costs	200	46.600

Conversion Factor: 0.233 Mfbm/m³ wood input
Source: Anielski (1991 p. 171)

Table A8
Sawmill Industry Rent Estimate (1990$)

Year	Lumber Price	Residue Income[a]	AVC	Rents before Capital Costs	Opp. Cost of Capital	Rent ($/Mfbm output)	Rent ($/m³ wood input)[b]
1990	185.85	30	230	-14.15	33.82	-47.97	-11.18

[a] Residue Income is the income resulting from the sale of chips and shavings.
[b] Conversion factor for lumber output to wood input is 0.233 mfbm/m³ as listed in Anielski (1991, p. 178)
Source: Anielski (1991 p. 80)

Table A9
Aboriginal Population of Case Study Region

Indian Reserves in FMA	*Reserve #/s*	*1997 Population*	*1991 Population*
Athabaska Chipewyan First Nation	196, 196A, 196B	634	555
Bigstone Cree Nation	166, 166A-D, 183	5,170	4,243
Chipewyan Prairie First Nation	194	530	464
Fort McKay First Nation	174, 174A, 174B	462	430
Fort McMurray #468 First Nation	175, 176, 176A-B	491	407
Heart Lake First Nation	167	222	623
Subtotal		7,509	6,722
Indian Reserves in close proximity			
Beaver Lake	131	725	602
Whitefish Lake	155, 155A, 155B	1,542[a]	1,372
Metis Settlements in close proximity			
Gift Lake		783[a]	697
Peavine		408[a]	363
Subtotal		3,458	3,034
Grand Total		10,967	9,756

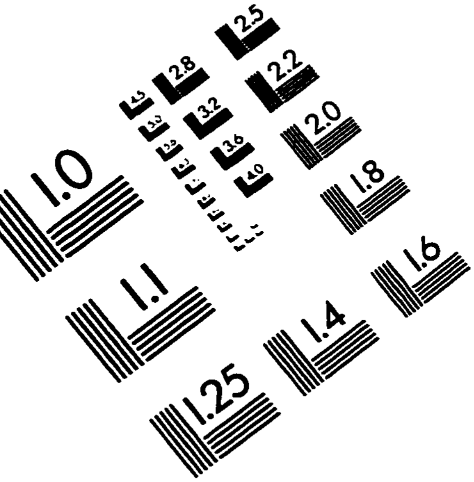
[a] A recent population estimate was not available therefore the 1991 population figure was scaled upward by a factor of 1.124 which is equal to the average ratio of 1997 to 1991 population for the other communities.
Sources: 1991 Census Data & First Nations in Alberta (1997)

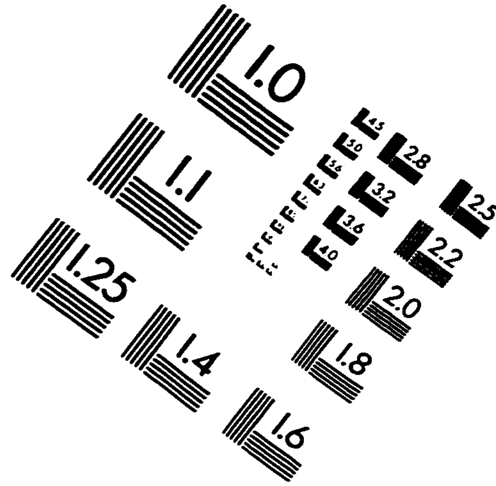
Table A10
Annual Average Indices and Exchange Rates

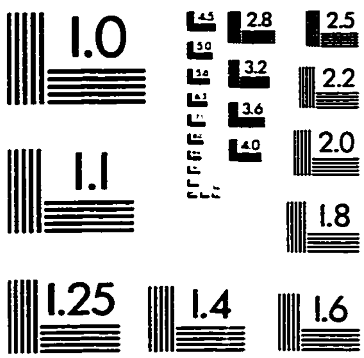
	Consumer Price Index (CPI)		*Implicit Producer Price Index, GDP*[a]	*Exchange Rate ($Cdn to $US)*
Year	*Alberta*	*Canada*	*Canada*	
1975			48.975	1.01716
1976			53.225	0.98603
1977			56.575	1.06344
1978		55.9	59.950	1.14066
1979	62.8	61.0	65.950	1.17142
1980	69.2	67.2	72.975	1.16923
1981	78.1	75.5	80.875	1.19890
1982	87.0	83.7	87.925	1.23373
1983	91.5	88.5	92.300	1.23241
1984	93.9	92.4	95.200	1.29507
1985	96.7	96.0	97.650	1.36551
1986	100.0	100.0	100.000	1.38947
1987	104.0	104.4	104.700	1.32598
1988	106.8	108.6	109.550	1.23070
1989	111.3	114.0	114.875	1.18397
1990	117.7	119.5	118.450	1.16677
1991	124.6	126.2	121.875	1.14573
1992	126.4	128.1	123.400	1.20872
1993	127.9	130.4	124.675	1.29009
1994	129.7	130.7	125.600	1.36567
1995	132.7	133.5	127.525	1.37245
1996	135.6	135.6	129.100	1.36352

[a] Seasonally adjusted.
Sources: CANSIM data series P685196, P490000, D20556, and B3400

IMAGE EVALUATION TEST TARGET (QA-3)







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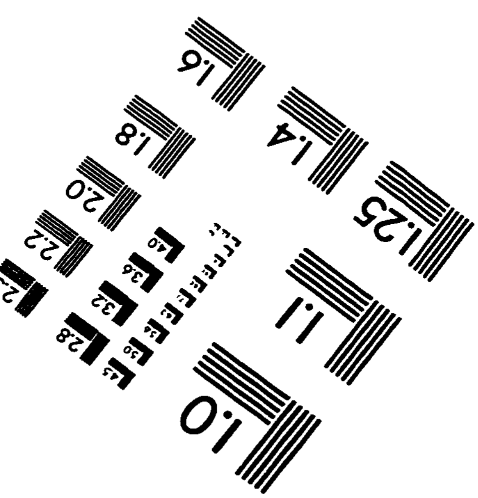

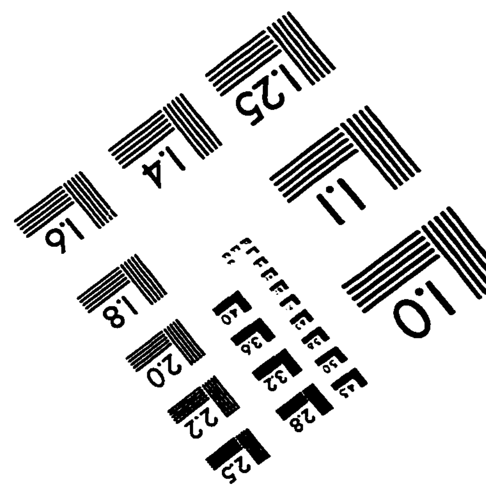

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