UBC Social, Ecological Economic Development Studies (SEEDS) Student Reports

CQuest Carbon Sequestration Initiatives for Alex Fraser Research Forest:

Business and Management Plans

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Business Plan



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A Business Plan for Establishment of CQuest Carbon Initiatives Consultation Firm

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Executive Summary

Carbon Sequestration is an emerging market that has become a multi-billion dollar industry in less than 20 years. As more companies, organizations, states, provinces, and countries start to enter the carbon market, today would be the optimum time to capitalize on the growing market.

Our business plan outlines how we will use the growing carbon market as an opportunity to become a consulting company that is the provincial leader in carbon sequestration projects. Sequestering carbon above the baseline level of current practices allows one to gain carbon credits. These credits can be sold, bought, and traded with other organizations and nations as part of the Kyoto Protocol agreement between various countries. Since many of the policies surrounding the new market has yet to be sanctioned by the government, companies who wish to join the market often become confused by the ambiguity involved in carbon projects. Our clients will be provided with consulting and training services to help them understand the dynamics of the emerging carbon market, including current regulatory standards and opportunities presented by voluntary markets.

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1.0 Business Description

CQuest is a new organization based out of the University of British Columbia's Faculty of Forestry and developed by four of its graduating students. They operate as a consulting and analytical firm aimed at developing carbon sequestration initiatives for privately managed forests in British Columbia. The firm inspects current management practices and assesses whether augmentation can create additional carbon pools to be sold as offsets in a national or international market place. Many businesses are taking a proactive approach towards expected legislation that will require carbon neutral operations; thus creating an atmosphere where forest managers have an opportunity to potentially sell carbon they sequester to help alleviate eco-debt.

1.1 Management Team

Consultation on carbon markets is conducted by Tim Hsu of CQuest with the assistance of Dr. Gary Bull of UBCs faculty of Forestry. Forest modeling is conducted by Felix Capitulo of CQuest and assisted by Dr. John Nelson of UBC Forestry and his graduate student, Garret McLaughlin. Information collection, design, feasibility, management and marketing is conducted by CQuest members Felix Capitulo and Graham Cameron, as well as two Forest Operations graduates, Martin Lewynsky and Timothy Hsu, whose interests and expertise range from harvest operations to fire and finance. Based out of the Cariboo-Chilcotin, the firm operates under the Cariboo-Chilcotin Land Use Plan (CCLUP) and adheres to the Forest and Range Practices act as outlined by the government of British Columbia's Ministry of Forests and Range.

1.2 Key Initiatives and Goals

The primary goal is to work with managers of privately owned forests to understand and develop carbon sequestration opportunities that generate revenue to supplement forest income. Management practices at a baseline year create a 'business as usual' scenario upon which we can measure sequestration levels for comparison to levels created by our modeling techniques. The implementation of new management activities creates a carbon pool larger than what would have normally been found in the forest and we aim to capturing the value of those activities in the form of carbon credits. Based on changing management priorities, forest policy, and rebound of the forest sector, future sequestration initiatives should be reassessed every 10 years to examine economic feasibility and opportunity cost

1.3 Marketability

Environmental conscientiousness has become a leading concern for individuals, organizations, and governments. Many forest products now require a level of environmental certification to be distributed by larger dealers as a result of consumer desire and government legislation. There are various trading bodies that have developed to meet growing demand for carbon offsets and as more governments implement taxation and incentivized offsets, companies and individuals are looking for opportunities to alleviate their carbon footprint. One of the best ways to remove carbon from the atmosphere and sequester it in long term materials is through the growth of forests. By creating and boosting the carbon stock in a forest system, we are able to take ownership of the additionalities and sell equivalent tons of CO_2 through a national or international carbon trading body.

1.4 Comparative Advantage

There are no other carbon sequestration firms currently operating in the Cariboo-Chilcotin. This provides us with an opportunity to showcase the prospects and expertise of our company, create awareness of the industry, and spearhead growth within the local market. Social awareness has increased significantly in recent years as the effects of global warming are being felt and scientific data corroborates the environmental changes that so many are noticing. A greater understanding of the effect our daily actions has on the environment has reached main stream media and the public is demanding solutions. Many of the management practices that have been adopted sequester significant amounts of carbon dioxide from the atmosphere. Therefore, forest systems provide an excellent opportunity to demonstrate the viability and economic feasibility of projects such as this. Proactive management policies and decisions that have been implemented across BC have already given a boost to the development of carbon pools and limited the additional costs associated with further increasing stock.

1.5 Marketing Strategy

The primary source of exposure for our company will be through word of mouth. A demonstration project is being conducted in the Alex Fraser Research Forest (AFRF) which produces an annual progress report submitted to the Provincial Government and Faculty of Forestry at UBC. The AFRF also draws specialists conducting research in various fields and there is a large amount of information sharing between these individuals. There are two local newspapers that update Cariboo residents of new projects and initiatives being undertaken in their community: the Cariboo Advisor and the Cariboo Sentinel. By creating a successful demonstration project and generating revenue for the forest, we can inspire other potential clients to seek our expertise. Since this project is being conducted as a demonstration initiative, no monetary gains will be made by our company at this time. Future projects however will not be pro-bono and our clients will be required to pay a competitive hourly rate for our consulting and analytical expertise. Furthermore, since the company is still in its developmental stages we expect that once established, CQuest will be able to operate with half as many personnel for the foreseeable future.

2.0 Business Overview

2.1 Mission Statement

CQuest is committed to providing the highest caliber of consultation and analytical services based on up-to-date industry knowledge and the understanding of strategic objectives of our client, while maintaining ecological soundness during the maximization of carbon storage.

2.2 Vision Statement

Through the providence of realistic and effective consultation, we will assess carbon stocks and sell carbon credits on international markets. With positive application of knowledge, we will help forest managers to realize an underutilized and misunderstood resource for the betterment of our clients, ourselves, and our planet.

2.3 The Team

CQuest is composed of four University of British Columbia Forestry students in their final year of study. Their expertises are extensive, ranging from forest resource management to operations, modeling and finance.

2.4 Demonstration Project Site

The Alex Fraser Research Forest is located on two blocks totaling 9802 ha outside of Williams Lake, BC (Day, 2007). The forest, in its present form, has been in operation since 1987 and is a venue for advanced forest research conducted by the University of British Columbia. The forest covers the Sub Boreal Spruce (SBS), Sub Boreal Pine Spruce (SBPS), Interior Douglas-Fir (IDF), and Interior Cedar Hemlock(ICH) Biogeoclimatic (BEC) zones and was previously been managed for high-grading operations and clearcut harvesting techniques before being taken over by the university. Since its conception, stand rotation ages have been increased, marginal lands replanted, wildlife and old growth reserves established, and advanced silvicultural initiatives undertaken (Day, 2007).

2.5 Industry Analysis and Trends

The EU carbon market has been rapidly growing over the past decade. Currently in phase II of carbon market development, they are able to buy and sell carbon credits internationally to help offset the carbon emissions of business and government with other Kyoto compliant countries (Chevallier, 2010). Emission trading has been steadily increasing every year (Figure 1) and is projected to reach $US 3.5 trillion by 2020 (Capoor and Ambrosi 2007).

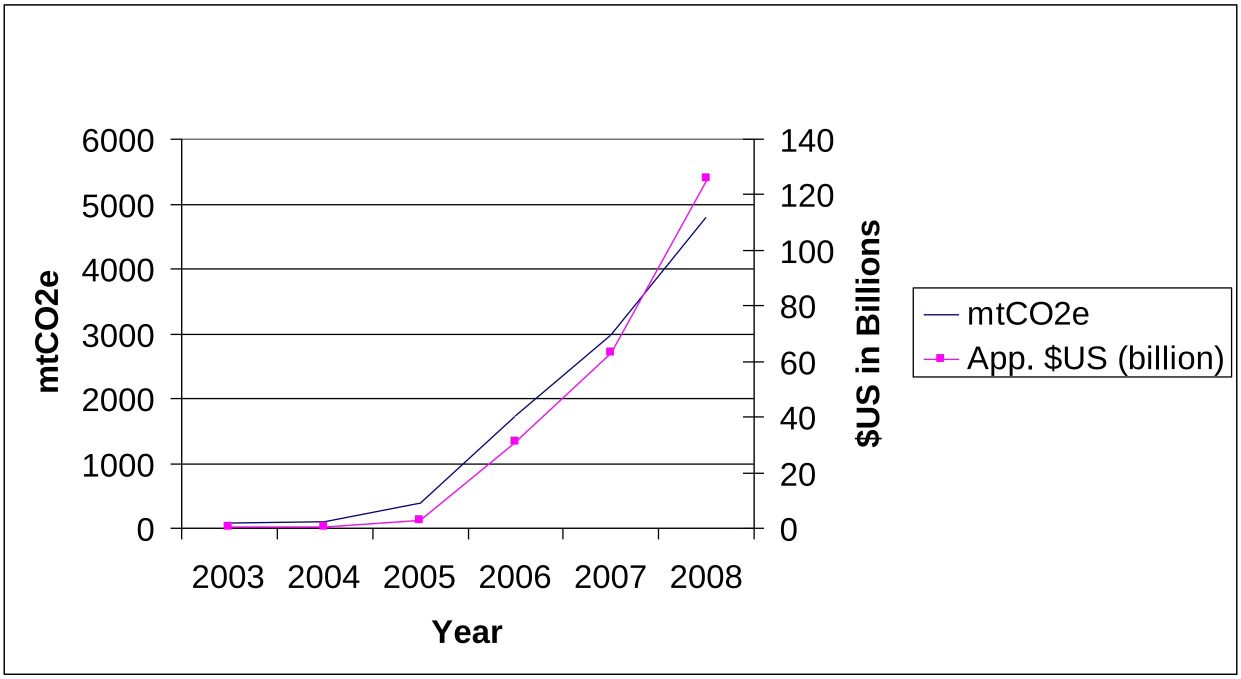

Figure 1: Stats from World Bank: State and Trends of the Carbon Market Chart (2003-2008)

3.0 Carbon Markets

3.1 Chicago Climate Exchange

Launched in 2003, the Chicago Climate Exchange is a cap and trade system that companies enter into voluntarily. Companies are required to either reduce emissions from their operations by physically limiting output or purchase unused credits from other businesses if they cannot meet their cap limitation. Third party verification is required to ensure credibility and validity of offset claims (Chicago Climate Exchange [CCX2], 2010). Sequestration is based off of 1990 forest conditions and the enrichment or reforestation projects that have been implemented. Prices range from $1-5/ton CO_2e which is much lower than other markets due to voluntary status of the market. Emission reductions are legally binding once a party enters into the market. Urban forestation and forest enrichment programs are eligible based off the annual increase in carbon stocks of above-ground biomass. CCX holds 20% of carbon stock back in a reserve pool which is released to project owners at the end of the program (Chicago Climate Exchange [CCX1], 2010).

3.2 European Climate Exchange

The world leader in CO2e offset trading, the European Climate Exchange trades in futures contract lots composed of 1000 EU allowances. Each allowance is representative of 1 ton of CO_2e at the current market price (European Climate Exchange [ECX3], 2010). Following the guidelines set out in the Kyoto Accord and the standard developed under the United Nations Framework Convention on Climate Change (UNFCCC), the ECX deals mostly with Afforestation and Reforestation. Between 2006 and 2008, prices fluctuated (Figure 2) between approximately €13.00 and €30.00 per ton of CO_2e, averaging at €21.50 (European Climate Exchange [ECX2], 2010).

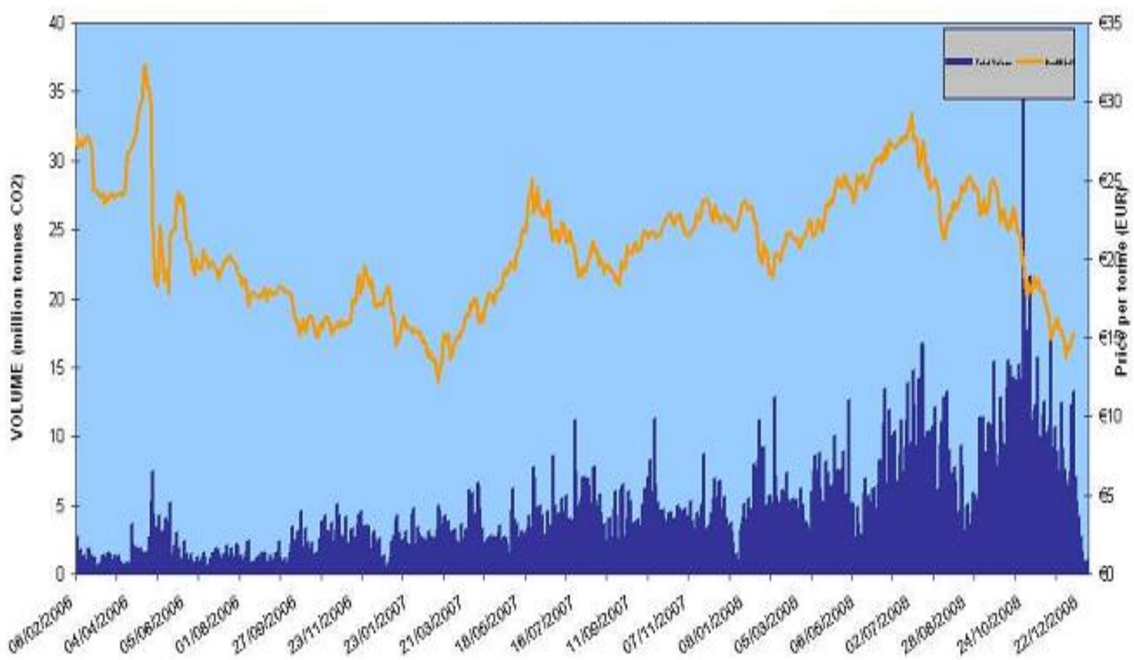

Figure 2: ECX Price and Volume fluctuations between Feb 2006 and Dec 2008.

3.3 Pacific Carbon Trust

Developed in 2008 by the Government of British Columbia, the Pacific Carbon Trust was designed to deliver made-in-BC greenhouse gas offsets for the residents of BC. PCT focuses on emissions reductions and utilizing higher efficiency technologies (ie: hybrid heating). Currently, PCT is working to develop land-based forestry offset solicitation but legislation is as yet to be ratified. Projects must be validated and verified by objective third parties and our purchases must support offset projects that would otherwise not go forward without offset sales (Pacific Carbon Trust [PCT4], 2010). Project price is dependent on bidding by the project proponents and the evaluation criteria used in awarding contracts. Proponents are able to choose an internationally recognized quantification protocol for their industry and adapt it for BC (Pacific Carbon Trust [PCT2] 2010). The protocol chosen must be high quality and compliant with both the ISO-14064 standard and BC Emission Offsets Regulation (EOR) requirements. Credits are based off post reductions, meaning they will be recognized after they have actually occurred. PCT does not currently accept ex-ante offsets. Carbon prices are set by the government at \$20/ton CO_2e in 2010, \$25/ton CO_2e for 2011, and \$30/ton CO_2e from 2012 onward (Pacific Carbon Trust [PCT4], 2010).

4.0 Marketing Plan

4.1 Product

CQuest provides clients with consulting services regarding carbon sequestration opportunities. We provide comprehensive assessments and analysis of financial returns for forest investments associated with sequestered carbon from managed forest offset projects. Strategies for evaluating, verifying, and trading forestry offset carbon credits will be developed and implemented dependant on the chosen carbon exchange. CQuest will utilize modeling techniques to customized carbon sequestration initiatives based on client inventory data and growth and yield models. Inventory databases for clients will be maintained for the reporting and verification of net changes in carbon stocks.

4.2 Promotional Strategy

CQuest provides consulting service to land owners, industry, and forest managers regarding carbon sequestration and carbon markets. Carbon sequestration projects are incorporated as part of forest management to find new revenue streams and include both above and below ground biomass assessments. As part of its marketing efforts, CQuest will advertise in both forestry and conservation magazines as well as send representatives to participate in trade shows. We will promote through a website to describe our services in depth and demonstrate successes from past carbon sequestration projects. Local news papers will also report on our establishment and valuable exposure will be gained through the networking connections made during our demonstration project at the AFRF. Our services will be advertised through past client successes, facilitating connections to other forest owners regarding the possibility future carbon sequestration projects in their forest.

4.3 Pricing Strategy

On ground consulting services will be priced at $150.00/hour. This price covers variable costs and our consultation time. For projects that generate revenue for the client, we charge 5% of the net carbon revenue or the total hourly cost, whichever is greater. In the event that no profit is gained from carbon sequestration, mandatory payment of our hourly base consultation fee is required.

4.4 Place

Located in the central Cariboo region, CQuest has its main office in Williams Lake, BC. Being centrally located in the Cariboo will help establish our organization within the region and will reduce our initial cost by limiting transportation time to clients who reside in the region. After our service is well recognized locally, we can examine expansion into other regions drawing on brand awareness, public perception, and customer loyalties.

4.5 Target Market

The target market is that of private forest land owners looking for opportunities to generate revenue from their forest while maintaining ecological soundness and forest stewardship values. Industry and businesses with requirements to be carbon neutral will also be targeted as government legislation begins to include a wider range of operations. Many opportunities exist for utilization of forest systems in carbon sequestration since so much of British Columbia is forested. There is an increasing trend towards environmental stewardship on the public's behalf, leading to increasing areas of reserve and protection. Our service is sustainable and environmental, which can increase the number of potential customers wanting to take part in a carbon sequestration project. There are forest tenure holders, forestry companies, woodlots, and community forests that are identified as potential customers. We want to distinguish our company by providing excellent services which are both sound and profitable. Low timber market prices and global economic hardships have created a need for alternative generation of revenue for many players in the forest sector.

5.0 Operations

The operation of CQuest is broken down into 6 components: consultation, research, site assessment, modeling, analysis, and reporting. Being centrally located in the Cariboo region, we are able to quickly reach potential work sites and gather information from the BC Ministry of Forests and Range district office in Williams Lake, BC.

5.1 Consultation

CQuest provides consultation opportunities for land owners who wish to examine the potential of entering into the carbon marketplace. We will assess the profit potential based off of current stand and management conditions to highlight where opportunity to gain additionalities may exist.

5.2 Research

Research must be conducted to obtain historical records of previous management on the lands in question. This helps demonstrate areas of potential gain for utilization in the carbon initiative project and develops a working picture of the forest in question.

5.3 Site Assessment

In the event of lacking documentation with respect to basic stand and stocking level information, we will conduct surveys to identify current conditions and gather other relevant information needed to model the carbon potential.

5.4 Modeling

Modeling software to project stand growth, alternative management, silvicultural practices, and carbon sequestration levels will use the programs Table Interpolation Program for Stand Yields (TIPSY 4.1), Forest Planning Studio (FPS-Atlas), and Carbon Budget Model (CBM-CFS2).

5.5 Analysis

Analysis of the growth curves, alternative management practices, and carbon budget will reveal the most beneficial opportunities with respect to financial gain while tracking changes to forest structure over a period up to three centuries long.

5.6 Reporting

A concise report detailing the research conducted, areas assessed, models developed, analytical conclusions, and financial gains will be composed for delivery to our clients both timely and efficiently.

6.0 Management and Organization

The management team consists of four individuals with relevant business and forestry background to conduct all operations listed above. Our management team has experience and training enabling these operations to be conducted without need of any additional labor. New employees will be hired on a project basis to complete more specialized tasks if necessary.

Graham Cameron: Project Manager

Graham Cameron has excellent project management and leadership abilities which are essential in a strong team. Extensive field experience and knowledge of interior forest systems are an asset to CQuest due to our primary area of development and operation. During the summer, Graham works as a Crew Supervisor for the Cariboo Fire Centre. He has spent time developing an ongoing project at the William's Lake Airport to demonstrate how fuel reduction can be accomplished with minimal cost to a community while maintaining biodiversity, and ecological soundness while creating training sites for the Fire Crews based in close proximity.

Felix Capitulo: Modeling Specialist

Felix Capitulo is skilled in modeling and scenario development for carbon sequestration projects. He has technical aptitude and abilities for complex problem solving and extensive interest in the development of new methodology for forest stand management. His experience working with modeling software includes but is not limited to CBM-CFS3, TIPSY, and FPS-ATLAS. Felix effectively produces the complex forest databases utilized in carbon sequestration projects.

Martin Lewynsky: Operational Engineer

From his experience in the field and undergraduate studies, Martin provides the necessary skills for alternative problem solving and knowledge application to client-specific situations. He is tasked with feasibility assessments of any projects with respect to forest operation, engineering, and economic analysis. He is a Forest Operations student, specializing in Forest Engineering. Originally from 100 Mile House, Martin comes from a Forestry and Natural Resource based background and was quick to gain experience in the industry, working in a local sawmill during his boyhood years. The past three summers he has worked with a Forest Consultation company with operations in many areas of the province. He has been based out of Prince George, Campbell River and Kamloops, gaining a broad range of experience relating to operations based field work. He continues to work towards his degree and in the future looks to gaining both RPF and PENG designations.

Timothy Hsu: Accountant

Timothy is skilled with numbers and their use in decision making. He has accounting experience and will be responsible for creating financial reports and assessing profitability of projects. He enjoys the business aspects of the project requirements and has the ability to ensure that projects are financially feasible.

7.0 Development, Milestones, and the Management Plan

7.1 Goals

- Maintain a stable level of profit
- Ensure the highest level of consultation services
- Enhance the quality of our services by enlarging our customer base and provide a diverse combination of services while maintaining a high standard of operation

7.2 Milestones

One Year:

- Increase public awareness of our business and gain a foothold in the market as we introduce ourselves to the Cariboo region

Five Year:

- Reduce number of management personnel as business becomes more streamlined to reduce cost
- Narrow the scope of activities by eliminating services that are not increasing profit margin
- Assess expansion into other areas of the province

7.3 Achievements to Date

- Developed a pilot and demonstration project with Alex Fraser Research Forest for the ECX carbon market
- Created open dialogue between UBC and AFRF with respect to carbon sequestration opportunities

- Increased local knowledge of global carbon market and potential opportunities there in

7.4 Exit Strategy

If the event that our business is unprofitable, we will to sell our office and vehicle to recover lost value. Any bank loans will be settled and remaining assets will be liquidated. All assets will be sold at market value and will be used to pay off any remaining debt.

8.0 Financial Analysis

Using the demonstration project developed for AFRF we will show that revenue generated for CQuest through consultation and sequestration projects can be a successful business venture.

8.1 CQuest Operating Costs

Operation of CQuest as a consulting firm requires limited fixed and variable costs (Appendix IV). A loan of $50,000 is required to cover our costs for the first year. It will be paid back in full over three years at an interest rate of 8% compounded annually. The startup expenses for our business are outlined below (Table 1).

Startup Expenses	
Legal and Accounting	$ 300.00
Office Supplies	$ 200.00
Office Equipment	$ 800.00
Design	$ 50.00
Website	$ 300.00
Total	$ 1,650.00

Table 1: Initial Startup Cost

8.1.2 Break-Even Analysis

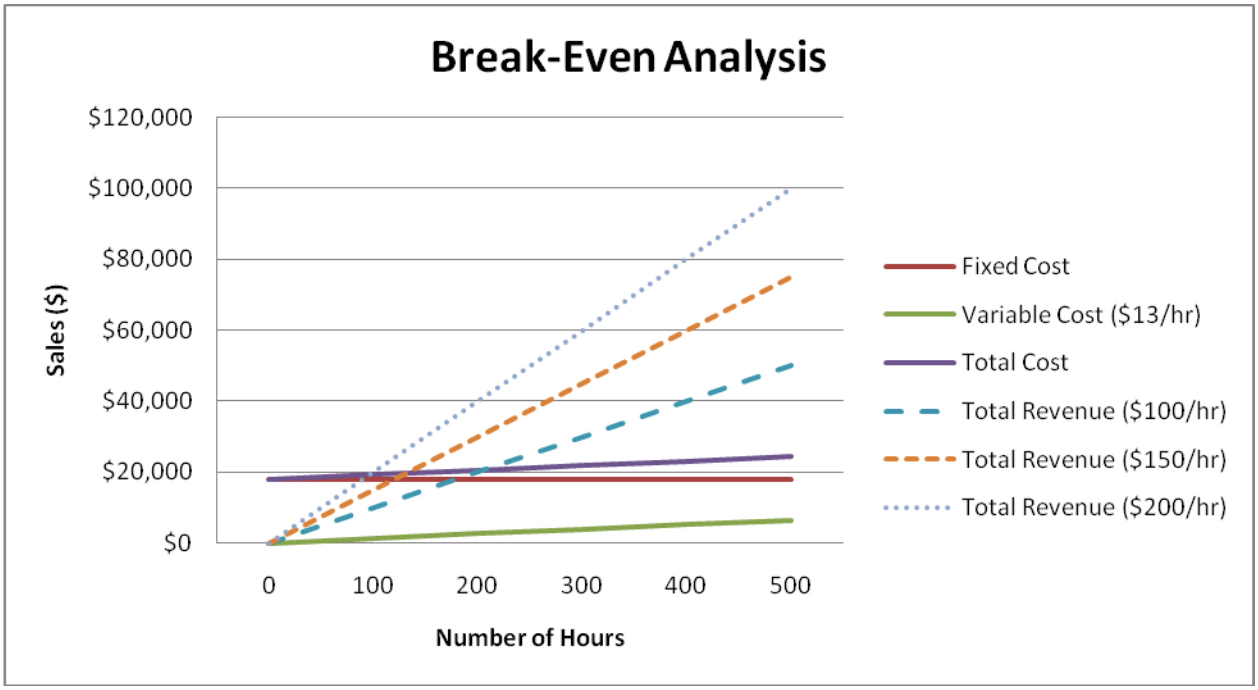

Figure 3: Break-Even Analysis for CQuest operations

From Figure 3, the most appropriate price is $150/hr. At that hourly rate, the number of hours worked is approximately 150 hours or about 19 days spent consulting at a conservative 4 hours per day. At $100/hr, we will be incurring too much monthly debt to develop our business The price at $200/hr is unrealistic since contracting rates are usually set at approximately 100-$150/hour and we wish to remain competitive.

Consulting Base Fee		
Hourly Rate ($/hr)	$	150.00
Daily Rate ($/day)	$	600.00
Monthly Rate ($/month)	**$**	**12,600.00**

Table 2: Base consultation fee

Above the breakeven point provided in Figure 3, our company also receives additional revenue from completed projects that generate revenue for clientele (5% of carbon offset revenue). For example, in the carbon project we have developed here, CQuest generated revenue in the amount of $24,912.81 (Table 3). If a project produce no additional revenue from carbon offset, our company will still charge for project development and charge our hourly rate for time spent. However, if there is additional revenue from carbon offset, we will be operating with a surplus.

5% of Net Revenue	
Net Revenue (annual)	$ 498,256.19
Net Revenue (monthly)	$ 24,912.81

Table 3: Revenue Generated for CQuest from AFRF project

8.2 Timber Harvesting

To compare the different carbon sequestration alternatives with timber harvesting, the costs and revenues associated with timber harvesting must be calculated. Current log values are obtained from Ministry of Forests and harvesting costs from the Coast Appraisal Manual (Table 4 and Table 5 respectively). TIPSY modeling software is used to derive harvesting costs and to model the revenue that can be expected from timber harvesting.

Species Group				
Product	SPF	Df-Larch	Hem-Bal	Cedar
Sawlogs	37.34	47.03		96.7
Peelers	55.3	58.14		
Poles/House	75.65			201.4
Minor Products				
Pulpwood	27.53			
Wtd. Average	**37.03**	**54.38**		**110.23**

Table 4: Interior Log Prices ($/m3) for the three months from Nov 1, 2009 to Jan 31, 2010

Appraisal Cost Estimates	
Activity	$/m3
Basic Silviculture	$5.00
Administration	$2.00
Layout	$6.00
Stump to Dump	$42.00
Total	$55.00

Table 5:Average cost estimates from Coast Appraisal Manual

Harvesting Revenue Analysis	
Average Annual Net Harvest Area (ha)	167
Harvest Revenue ($)	$2,842,841.00
Tree-to-truck Cost ($)	- $948,226.00
Haul Cost ($)	- $421,842.00
Harvest Profit ($)	$1,472,773.00

Table 6:Harvesting costs and revenue

From the timber analysis, harvesting profit that can be realized is averaged at $ 1,472,773.00 annually, as outlined above in Table 6.

8.3 Carbon Sequestration

Carbon as a source of revenue is assessed with respect to the scenarios proposed in the carbon sequestration project. Since the AFRF has reduced its rate of timber harvesting due to poor economic conditions, a new revenue stream is needed to fund operations. Scenarios will be assessed to determine if one scenario or a combination of scenarios would be economically feasible.

An opportunity cost exists with respect to carbon sequestration projects. Areas reserved for carbon management activities must be removed from the harvestable land base for the duration of a carbon project. However, market trends show great potential for growth and the price of carbon offsets can be expected to increase in the near future. For the purpose of this report, the current carbon price will be considered to be $US 20.30/ton of CO_2e based off a current market price on the ECX of €15.26.

The carbon market is relatively new and standards are yet to be ratified in BC. In some cases, protocols and methodologies to govern activities do not exist and due diligence must be demonstrated to ensure credible accountability. The risk of fire and insect damage is very real in forest systems and can negatively affect stand growth. CQuest's projects incorporate the generation of a 20% buffer to act as a reserve pool in the event of natural losses. The Carbon Budget Model (CBM-CFS2) was used to measure carbon sequestered in each alternative scenario with respect to the Base Case (2007 Base Case). Carbon additionality was measured based on an 80 year projection. To calculate revenue, additionality in terms of tons of CO_2e (tons of Carbon dioxide equivalency) is multiplied by current market value.

8.3.1 Afforestation Option

Afforestation occurs only on a small percentage of the land base; therefore, only minor gains can be achieved with this scenario. Afforestation is restricted to roads and landings in the Knife Creek block that have been permanently deactivated for over 10 years. Approximately 30 ha of land are currently available for the afforestation initiative. Gross revenue from carbon additionality is outlined below in Table 7, but additional operation costs of rehabilitation before planting were not included since exact determination of road and landing condition was not possible at this time.

Revenue from carbon credits for Afforestation	
Carbon Revenue	
$/ton CO2e	Total
$13.47	$149,635.54
$20.30	$225,508.64
$30.31	$336,707.73

Table 7: Afforestation Scenario

8.2.2 Fertilization and Improved Seed Stock

The second option that was examined was the implementation of fertilization and improved seed stock. There are currently 1717 ha of 25 year old stands where fertilization gains can be made. After future harvesting, the area is to be planted with improved seed stock. The area is located within the Gavin Lake block and is identified as a primary targets for this treatment. A conservative estimate, based off of agricultural fertilization costs was used for cost assessment and was applied across the identified area through TIPSY modeling as represented in Table 8.

Fertilization Cost	$300/ha
Area to fertilize	1717 ha
Total fertilization cost	-$515,100

Table 8:Estimate of Fertilization Costs

Combined Revenue from timber harvest and carbon credits for Fertilization and Seed Stock					
Timber Revenue ($US)	Fertilization Costs ($US)	Carbon Revenue $US/ton CO2e	Total C Revenue $US (decade)	Total C Revenue $US (annual)	Net Revenue (annual)
$1,472,773.00	-$515,000	$13.47	$3,700,478.40	$370,047.84	$1,327,820.84
		$20.30	$5,576,816.00	$557,681.60	$1,515,454.60
		$30.31	$8,326,763.20	$832,676.32	$1,790,449.32

Table 9:Combined revenue at different Carbon credit pricing

There is a profitable opportunity represented through fertilization and genetic gains for the ~1700 ha of 25 year old forest (Table 9). Although our fertilization estimate is on the low side, that cost spread over 10 years will not exceed $557,000 annually. When combined, revenue generated through harvesting and carbon will positively increase the profit margin of the forest. This scenario can be expanded to include all stands as they are harvested, planted with improved seed stock, and fertilized as they reach 25 years of age; however, we could not include this due to time restrictions.

8.2.3 Reduced Harvest

Reduced harvest is the result of cutting a volume less than the annual allowable cut (AAC) from the baseline year. The carbon maintained and sequestered as a result of a reduced harvest is an additionality that can be sold as carbon credits. Since harvesting has already been significantly reduced in the Knife Creek block, these scenarios are aimed towards operations in the Gavin Lake block. In our modeling we looked at four different reduction scenarios. The four scenarios include reducing harvests by 25%, 50% and 75% as well as no harvest. The graph below shows the carbon volumes for all of these scenarios as well as the 2007 base case projected over a 300 year period.

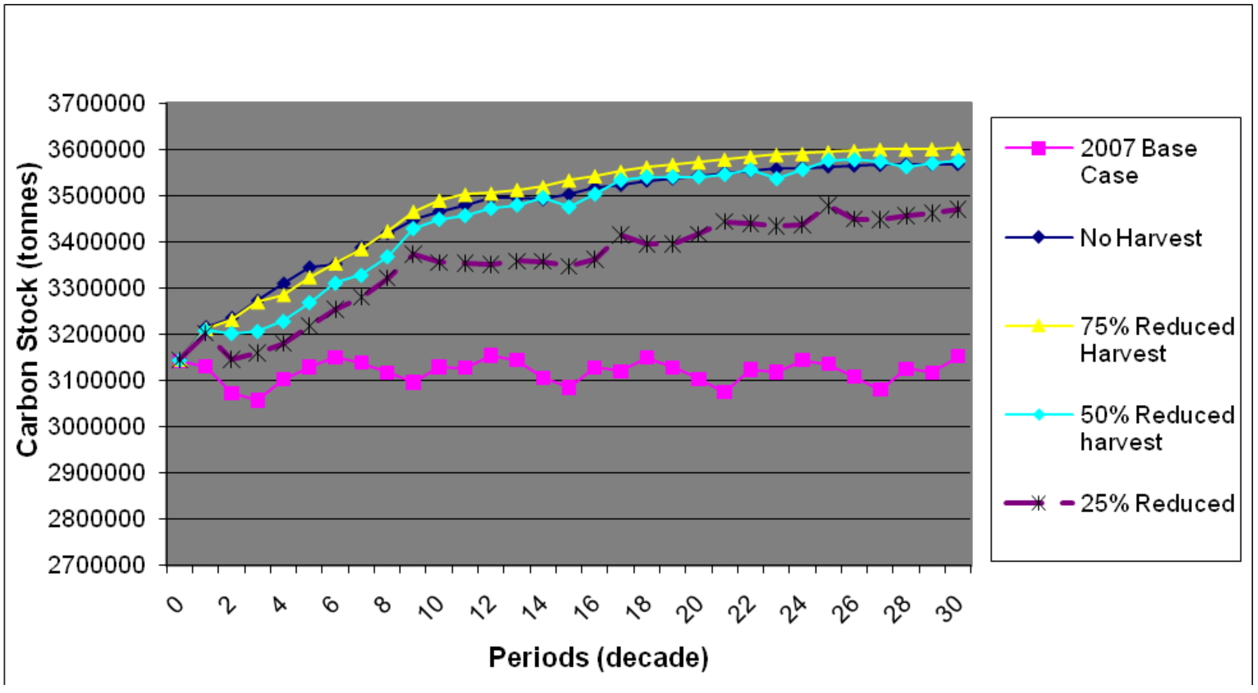

Figure 4: Reduced harvesting scenarios compared to the 2007 Base Case

As evidenced by Figure 4, a 75% reduction in harvest creates the highest sequestration levels. Of note are the gains made in both the 75% reduction and 50% reduction creating additionalities greater than or equal to the 'No Harvest' option respectively. This is attributed to altered stand conditions and improved growth rates from harvesting practices. After harvest, residual trees are released and there is an increase in resource availability which creates additionalities.

2007 AAC	14000 m^3
2007 AAC	167 ha
75% Reduced Harvest	3500 m^3
75% Reduced Harvest AAC	41.7 ha
Average Volume/ha	84 m^3/ha

Table 10:75% Harvest Reduction Specifics

Harvesting Revenue Analysis	
Average Annual Net Harvest Area (ha)	41.7
Harvest Revenue ($)	$709,859.10
Tree-to-truck Cost ($)	$236,772.60
Haul Cost ($)	$105,334.20
Harvest Profit ($)	$367,752.30

Table 11: 75% Reduced Harvest Timber Analysis

Combined Revenue from timber harvest and carbon credits for Reduced Harvest				
Timber Revenue ($)	Carbon Revenue $US/ton CO_2e	Total C Revenue $US(decade)	Total C Revenue $US (annual)	Net Revenue $US (annual)
$367,752.30	$13.47	$3,306,163.01	$330,616.30	$698,368.60
	$20.30	$4,982,561.92	$498,256.19	$866,008.49
	$30.31	$7,439,480.38	$743,948.04	$1,111,700.34

Table 12:75% Reduced AAC harvest and carbon. Combined revenue at different carbon pricing.

This alternative represents a very promising scenario whereby we can continue to harvest 25% of the AAC while creating additionalities while generating revenue from both timber (Table 11) and carbon (Table 12) under conditions that would have previously suspended all operations. Although revenues are not substantial, they still represent a situation facilitating continued operations and local job stability for forestry workers.

8.2.4 Scenario Comparison

Upon examination of the three scenarios (Table 13) we note that the most productive opportunity with respect to carbon sequestration is the Fertilization and Improved Seed Stock scenario. Although it will have high implementation costs associated with the fertilization process, we expect monetary gains made will offset cost and generate profits. It can further be expanded for application across the forest as mentioned in Sec. 8.2.2.

The Afforestation scenario, while not very productive in a carbon sequestration sense, shows great potential for generating revenues to cover mechanical restoration of degraded areas typified by old landings and roads within the forest. This can be thought of as a self-funded restoration effort through carbon sequestration.

The Reduced harvest scenario shows great prospect for ensuring the continuation of harvesting operations in the forest. During times of economic downturn the forest suspends harvesting operations. If the AAC is reduced by 75% to ~3500 m^3 and a harvest is still conducted, we can gain additionalities from the harvest reduction and increased carbon storage while still generating some minimal profit from harvesting efforts. This creates a situation that will benefit the Research Forest through revenue generation, as well as provide much needed work for the local forest sector.

Comparison of Sequestration levels from Base Case 2007					
Scenario (@ 80 Year Projection)	Additionality (ton CO_2e)	Additionality (20% Reduction)	Total C Revenue $US (decade)	Total C Revenue $US (annual)	Net Revenue $US (annual)
2007 Base Case	0	0	$-	-	-
Afforestation	13,886	11108.8	$225,508.64	$22,550.86	$22,550.86
Fert. & Seed Stock	343,400	274720	$5,576,816.00	$557,681.60	$1,515,454.60
Reduced Harvest	306,808	245446.4	$4,982,561.92	$498,256.19	$866,008.49

Table 13: Carbon Additionality and Revenue for each scenario at $US 20.30

Appendix

Appendix I: Trends of the Carbon Market Chart

	2003	2004	2005	2006	2007	2008
tCO2e	78	110	374	1745	2984	4811
Approx billion $US	0.3	0.5	2.7	31	63	126

*Figures from World Bank: State and Trends of the Carbon Market (2003-2008)

Appendix II: Break Even Analysis Chart

Number of Hours	Fixed Cost	Variable Cost ($13/hr)	Total Cost	Total Revenue ($100/hr)	Total Revenue (150/hr)	Total Revenue (200/hr)
0	17938.563	0	17938.563	0	0	0
100	17938.563	1300	19238.563	10000	15000	20000
200	17938.563	2600	20538.563	20000	30000	40000
300	17938.563	3900	21838.563	30000	45000	60000
400	17938.563	5200	23138.563	40000	60000	80000
500	17938.563	6500	24438.563	50000	75000	100000

Appendix III: Office Space

Price : **$68,000**

Address : 148 BORLAND ST

Williams Lake, British Columbia V2G 1R1 (ICX.ca, 2010)

Appendix IV: Monthly Cash Flow Analysis

Monthly Forecast		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sales													
	Consulting Base Fee	$12,600.00	$12,600.00	$12,600.00	$12,600.00	$12,600.00	$12,600.00	$12,600.00	$12,600.00	$12,600.00	$12,600.00	$12,600.00	$12,600.00
	5% of Net Revenue	0	$ 2,076.07	$ 2,076.07	$ 2,076.07	$ 2,076.07	$ 2,076.07	$ 2,076.07	$ 2,076.07	$ 2,076.07	$ 2,076.07	$ 2,076.07	$ 2,076.07
		assume that first month have no 5% net revenue											
	Total Sales	$12,600.00	$14,676.07	$14,676.07	$14,676.07	$14,676.07	$14,676.07	$14,676.07	$14,676.07	$14,676.07	$14,676.07	$14,676.07	$14,676.07
Variable Costs													
	Utilities												
	Natural Gas	$ 74.58	$ 74.58	$ 74.58	$ 74.58	$ 74.58	$ 74.58	$ 74.58	$ 74.58	$ 74.58	$ 74.58	$ 74.58	$ 74.58
	Hydro	$ 60.00	$ 60.00	$ 60.00	$ 60.00	$ 60.00	$ 60.00	$ 60.00	$ 60.00	$ 60.00	$ 60.00	$ 60.00	$ 60.00
	Travel, fuel	$ 719.96	$ 719.96	$ 719.96	$ 719.96	$ 719.96	$ 719.96	$ 719.96	$ 719.96	$ 719.96	$ 719.96	$ 719.96	$ 719.96
	Total Variable Costs	$ 854.54	$ 854.54	$ 854.54	$ 854.54	$ 854.54	$ 854.54	$ 854.54	$ 854.54	$ 854.54	$ 854.54	$ 854.54	$ 854.54
Fixed Costs													
	Telephone/Internet	$ 78.00	$ 78.00	$ 78.00	$ 78.00	$ 78.00	$ 78.00	$ 78.00	$ 78.00	$ 78.00	$ 78.00	$ 78.00	$ 78.00
	Advertising	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ 2,500.00
	Vehicle Insurance	$ 250.00	$ 250.00	$ 250.00	$ 250.00	$ 250.00	$ 250.00	$ 250.00	$ 250.00	$ 250.00	$ 250.00	$ 250.00	$ 250.00
	Building Insurance	$ 300.00	$ 300.00	$ 300.00	$ 300.00	$ 300.00	$ 300.00	$ 300.00	$ 300.00	$ 300.00	$ 300.00	$ 300.00	$ 300.00
	Salary	$13,333.33	$13,333.33	$13,333.33	$13,333.33	$13,333.33	$13,333.33	$13,333.33	$13,333.33	$13,333.33	$13,333.33	$13,333.33	$13,333.33
	Repair and Maintainance	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00
	Mortgage Payment	$ 324.23	$ 324.23	$ 324.23	$ 324.23	$ 324.23	$ 324.23	$ 324.23	$ 324.23	$ 324.23	$ 324.23	$ 324.23	$ 324.23
	Vehicle Payment	$ 653.00	$ 653.00	$ 653.00	$ 653.00	$ 653.00	$ 653.00	$ 653.00	$ 653.00	$ 653.00	$ 653.00	$ 653.00	$ 653.00
	Total Fixed Costs	$17,938.56	$17,938.56	$17,938.56	$17,938.56	$17,938.56	$17,938.56	$17,938.56	$17,938.56	$17,938.56	$17,938.56	$17,938.56	$17,938.56
Total Costs		$18,793.11	$18,793.11	$18,793.11	$18,793.11	$18,793.11	$18,793.11	$18,793.11	$18,793.11	$18,793.11	$18,793.11	$18,793.11	$18,793.11
Net Income before taxes		-$ 6,193.11	-$ 4,117.04	-$ 4,117.04	-$ 4,117.04	-$ 4,117.04	-$ 4,117.04	-$ 4,117.04	-$ 4,117.04	-$ 4,117.04	-$ 4,117.04	-$ 4,117.04	-$ 4,117.04
Corporate Tax (10.5%)					-$ 432.29	-$ 432.29	-$ 432.29	-$ 432.29	-$ 432.29	-$ 432.29	-$ 432.29	-$ 432.29	-$ 432.29
Net Income		-$ 6,193.11	-$ 4,117.04	-$ 4,117.04	-$ 3,684.75	-$ 3,684.75	-$ 3,684.75	-$ 3,684.75	-$ 3,684.75	-$ 3,684.75	-$ 3,684.75	-$ 3,684.75	-$ 3,684.75
Debt to Income Ratio		0.49151646	0.28052746	0.28052746	0.25107207	0.25107207	0.25107207	0.25107207	0.25107207	0.25107207	0.25107207	0.25107207	0.25107207

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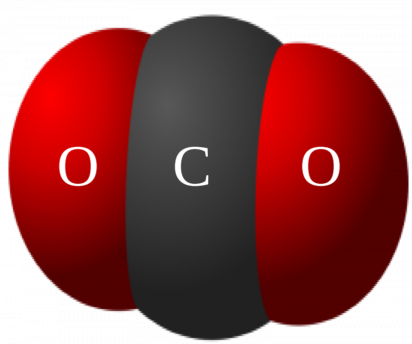
Management Plan

April 28

2010

A Forest Management Plan Exploring the Potential of a Carbon Sequestration Project in the Alex Fraser Research Forest prepared by C-Quest



Felix Capitulo, Graham Cameron, Martin Lewynsky, Timothy Hsu

Executive Summary

In this management plan, our objective is to provide Alex Fraser Research Forest with recommendations on possible management strategies to generate additional revenue from carbon sequestration. Various management scenarios will be proposed and assessed to determine the best management strategy. Our management scenarios include the base case at year 2007, afforestation, and forest management practices such as fertilization and improved seed stock. Criteria and indicators will be used to compare between the various management scenarios. Six criteria and indictors will be used and these include: research, sustainable forest management, revenue, education, social values, and range lands. The scenarios will be modeled using the Carbon Budget Model and FPS-Atlas in order to forecast the carbon additionality that can be achieved over time.

From the results of scenario ranking and financial analysis, fertilization, improved seed stock, and reducing harvest levels provide the most increase in carbon sequestration. Afforestation offers only slight increases to carbon sequestration due to the small area attributed to it. Other forest management practices such as increasing buffer also provide carbon sequestration opportunities. It is recommended that management strategies be implemented based on local site conditions and stand structure. For Knife Creek, it is recommended that afforestation be conducted to sequester carbon. For Gavin Lake, reducing harvest levels and extending rotation age are recommended.

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1.0 Introduction

1.1 Significance of the Project:

The Greenhouse Effect is a natural process that enables the surface of a planet to be heated. It does this through the use of various gasses within the atmosphere. The gasses in the atmosphere are able to absorb and release infrared radiation. As infrared radiation is trapped within the atmosphere and its gasses, it results in the heating of the Earth. The main gasses involved in the Greenhouse Effect are Carbon Dioxide, Methane, and Nitrous Oxide. Out of the three, carbon dioxide is recognized as the main contributor to the effect, about 76%, due to its abundance in the atmosphere; Methane, although 20x more powerful than Carbon Dioxide, contributes to about 13% of the effect; Nitrous Oxide at about 6%.

The effects of Greenhouse Gasses on the Earth's climate have become a major issue on a global scale. Since before the 1930's, scientists have observed that global warming was occurring and was due to increased levels of Carbon Dioxide (Weart 2008). In 1997, the United Nations adopted the Kyoto Protocol; a protocol whose goals were to reduce the global carbon emissions and reduce the amount of carbon dioxide in the atmosphere. The Kyoto Protocol states an agreement between multiple countries, including Canada, that they would reduce their 1990 emission levels by 5% by the year 2012 (United Nations Framework Convention on Climate Change 2010).

In 2004, Canada reported an increase of CO_2 emissions of about 27% higher than the 1990 emission levels. Two major factors contributing to this increase include Alberta's oil production and the Mountain Pine Beetle outbreak that devastated a significant amount of Canada's forests. Due to these causes, Canada would not be able to meet its agreement with the Kyoto Protocol (Government of Canada 2006). Instead, the country has made its own national goals to drastically reduce its carbon emissions. For the province of British Columbia, it has set its target goal of a reduction of 33% below 2007's carbon emission by 2020 (Government of Canada 2006).

The University of British Columbia has taken an active role in planning and facilitating projects to reduce its emissions. The university has set its own targets, in addition to BC's provincial goals, which include reducing emissions by 10% by 2015, 33% by 2020, and 100% by 2050. In an effort to reach these targets, the University of British Columbia has recognized the great potential of carbon sequestration in its research forests. This project will focus on the Alex Fraser Research Forest and the opportunity it provides the university to achieve its targets.

1.2 Location and Biogeoclimatic zone

The Alex Fraser Research Forest (AFRF) is located near the town of William's Lake in the Central Cariboo Forest District. The research forest is comprised of two blocks; the Gavin Lake block, located on the northern slope above Beaver Valley and the Knife Creek block located to the south between Knife Creek and Jones Creek. The Gavin Lake block is the larger of the two at 6315 ha while the other covers an area of 3487 ha (Day 2007). Both forests are easily accessed by main highways. A series of dirt roads within the forests provide access to most areas during the summer months.

The research forest is important for commercial harvesting and wildlife habitat. The close proximity to Williams Lake means that there are many mills that have access to the timber available. The Knife Creek block is in an area that is important for mule deer winter range. The large old-growth Douglas-fir (*Pseudotsuga mezeii*) trees in the area provide shelter from the snow for the mule deer that dwell in the area during the winter months.

The two blocks cover in several biogeoclimatic zones and subzones. The subzones give important information about local growing conditions and productivity. The Gavin lake block is primarily located in the SBSdw1 and also has a large section in the ICHmk3. The SBSdw1 contains a variety of different species. The species mix includes Douglas-fir (*Pseudotsuga mezeii*), Lodgepole Pine (*Pinus contorta*) and Trembling Aspen (*Polulus tremuloides*). Douglas-fir and Lodgepole Pine are the key commercial species in this area. While trembling aspen is a commercial species in some areas, in the Gavin lake block they are fairly sparse making them unfavourable as a targeted commercial species. Dead aspen trees are commonly used by many cavity nesting species. Since aspen is not common in the forest, it provides important habitat for many species and is generally retained in wildlife tree patches during harvest operations. The ICHmk3 is in a slightly wetter area and for this reason the species composition is different. Western red Cedar (*Thuja plicata*), Hybrid Spruce (*Picea engelmanii var glauca*) and Subalpine Fir (*Abies lasiocarpa*) make up the majority of the species composition. Western Hemlock (*Tsuga heterophylla*), Douglas-fir (*Pseudotsuga mezeii*) and Black Cottonwood (*Populus deltoids*) are also important species in this area. The moist climate in the ICHmk3 means that fire disturbances are less frequent in this subzone. This has resulted in stands of fairly old trees.

The Knife Creek block is in a dryer area. The western portion of the block is located in the IDFdk3 subzone with a smaller portion in the IDFxm. Both of these blocks are comprised mainly of Interior Douglas-fir. The IDFdk3 also contains Lodgepole Pine while the IDFxm does not. The eastern portion transitions into the SBPSmk subzone which is dominated by Spruce and Lodgepole Pine. Figure 1 shows the provincial view of Williams Lake while Appendix 1 shows a more detailed layout of Alex Fraser Research Forest.

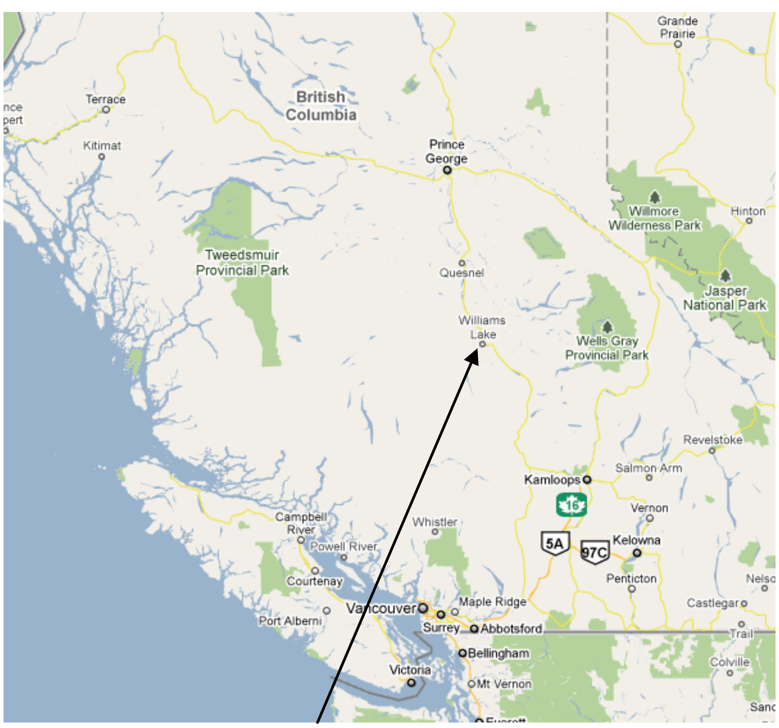

Figure 1: William's Lake (Provincial View)

1.3 History

The two blocks that comprise the Alex Fraser Research Forest have had various natural and human disturbances over the years and should be examined separately due to their different spatial, climatic, and stand conditions. Both areas have been host to many visitors over the decades, shaping the forest through different management activities for wildlife, cattle grazing, trapping, hunting, fire suppression and harvesting for timber. The history contained in this document stems directly from the Management and Working Plans for the forest.

1.3.1 Knife Creek

The Knife Creek block is located within the Jones River Valley and has been used by local bands for various purposes long before early European settlement. There are indications in their oral history that these bands used fire as a tool to open up grassland areas, encouraging hunting prospects, and to reduce the risk of fire overtaking their camps. The early stands were often subjected to unrestricted wildfire, creating uneven age structures throughout the area. However, as fire suppression technology and knowledge grew in scope and efficiency, the stands came to be denser with an even aged understory (Day, 2007).

Around the late 1800's early settlers rushed to the site as gold was found in Northern BC. The event led to the construction of the Cariboo Wagon Road around 1860. Along the way, road houses and ranches sprang up to supply travellers, which increased pressures on forests near the road as they were being cut down for buildings, fence lines, and rail ties. Ranchers relied heavily on local grasslands for grazing during the summer months and for hay stocks during winter months (Government of BC 2008). The fields were expanded over the years with the implementation of irrigation ditches to accommodate for the increasing population in the area (Day 2007).

Intensive logging began in the early 1940's to supply for an increasing demand of rail ties and saw logs to the growing economy. Fir was highly sought after by the bush mills that began operating in the area during the 1960's. This led to a fairly even age class distribution of fir and pine due to the low operational means of harvesting available at the time (Day 2007). By 1980, logging practices had changed to a faller-selection method aimed at removing 50% of the volume from merchantable age classes and leaving the best trees to regenerate openings. Although this method of harvesting was closer to the natural, stand maintaining fire cycles that had historically occurred within the forest, little logging was done within the next decade due to growing conflicts with mule deer winter range interests (Day 2007).

In 1987, the Alex Fraser Research Forest was established and it's first Resident Forester, Ken Day, was employed to help develop and manage the disturbed stands. Financial backing from UBC for research and development allowed silvicultural initiatives to be undertaken with the intention of improving the condition of disturbed stands. Small scale salvage operations of fir were increased and changed to pine in 1998 with the outbreak of the Mountain Pine Beetle. . By 2004, the salvage operation was complete and 247ha of Beetle infested pine forest had been cut and approximately 85% of large diameter stems were recovered ([1]Day, personal communication). Since then, reforestation efforts have been underway but the declining price of lumber has limited the amount of material cut from the forest to such a degree that in the winter of 2009 – 2010, not a single tree is expected to be harvested ([2]Day, personal communication).

1.3.2 Gavin Lake Block

The Gavin Lake Block is situated on the north slope of Beaver Valley, West of Quesnel Lake. Although it is not on the Cariboo Wagon Road, it still became a rest stop for the long trip north to the Barkerville gold fields in the mid 1800's (Government of BC 2008).

Logging became active in the area in the 1950's with the opening of a number of bush mills. By the early 1960's operations had increased with the establishment of a permanent camp located at Gavin Lake. Early logging focused on removing fir and spruce, but as tenures got passed to new operators over the years, the large cedar vets became economically viable to

[1] Day K., personal communication. March 22, 2010. M.F., RPF, Alex Fraser Research Forest Manager, 1987 - present. kday@forestry.ubc.ca.
[2] Day K., personal communication. January 11, 2010. M.F., RPF, Alex Fraser Research Forest Manager, 1987 - present. kday@forestry.ubc.ca.

harvest and were harvested between 1977 and 1984 (Day 2007). As early as 1972, plantations of Douglas-fir and spruce occurred using seed stock of unknown genetic makeup and untested silvicultural techniques. During this period, blocks were cut in a checker-board pattern, approximately 80 ha to an opening with 300 m wide reserves in between for wildlife considerations. By the end of the Cedar operations, the forest was losing financial productivity. In 1987, the Alex Fraser Research Forest was established in the name of UBC. Small scale salvage harvests, single tree selection, and variable retention cuts have been employed in recent years to bolster stand conditions and the available amount of winter range for mule deer (Day 2007). As with the Knife Creek block, a large salvage operation was carried out to combat the Mountain Pine Beetle; however no harvesting is expected to take place over the winter of 2009 – 2010 due to poor economic conditions (Day 2010).

In 1926, a large fire reportedly started on the north shore of Prouton Lake and burned a large section of forest to the east. Fire, combined with logging and silvicultural practices extending back into the 1950's, have produced many mid-seral and mature stands of fir and spruce which provide an excellent opportunity to manage these stands for mule deer range initiatives (Day 2007).

1.4 Purpose/Objectives

To develop a baseline carbon stock for the Alex Fraser Research Forest and examine through use of various modelling techniques the amount of carbon sequestered in the forest. In doing so, we will determine whether the forest is a carbon source or sink. This document will examine various management scenarios and quantify their impact on the changing carbon stock so that recommendations can be made for generating revenue through carbon sequestration.

1.5 Players and Culture:

Several Parties are associated with the Research Forest. Any actions and/or activities that are to be applied into the forest must first be accepted by the different groups. These groups form the “players” of the research forest and are as follows:

1.5.1 UBC members:

The Alex Fraser Research Forest is one of the 3 research forests managed by the University of British Columbia. As such, it is used as a place to conduct long term experiments concerning environmental studies. Researchers, professors, and students of the universities are able to use this facility as a valuable resource for education and information development. The following are derived from the AFRF Management and Working Plan #3 (Day 2007).

1.5.2 Government and Industry

The Research Forest is part of the Crown land of British Columbia. It has a continued tenure agreement with the government for research purposes and for operational purposes. Under these conditions, the forest is managed according to the legislation and regulations of the province of British Columbia and of Canada. Members of the Forestry Industry also share an interest with the research forest as a source of information.

1.5.3 Communities

The Research Forest is found within the Cariboo Regional District. Several communities of this district are situated relatively close to the Research Forest. Williams Lake, Horesefly, and Likely are only some of the areas highly affected by the environmental impacts of any operational activities done in the forest. The communities also use the forest for educational, recreational, and cultural purposes.

1.5.4 First Nations

The T'exelc people and Xats'ull/Cmetem' people (Williams Lake Band and Soda Creek Band, respectively) are two of the First Nations people that have land claims in the Alex Fraser Research Forest. Archaeological, cultural, and historical sites have been identified within the Research Forest. Currently in stage 4 of a 6-stage treaty process, these two bands have major interests in the management plans for the forest. The bands are also integrated in the cultural education of students and faculty members.

1.6 Legal Issues/Constraints

The Research Forest is Crown Land held under tenure by the University of British Columbia. Two documents are needed to provide legal access for the University to the Research Forest and forms the framework within which all activities must occur. One of the documents is the Special Use Permit which is a permit that designates the land area of the Research Forest, and requires that the forest resources are to be managed according to an approved Managed and Working Plan. Under the Forest Act, the Management Plan is a plan approved "which specifies proposed management to establish, tend, protect, and harvest timber resources and conserve other resource values." The content of the Management Plan must comply with the content requirements for a Management Plan written for a Tree Farm License. The second document needed is the Two Licenses to Cut, which are L42641 for Knife Creek Block and L42502 for Gavin Lake Block (Day 2007). With this document, the Research Forest is authorized to harvest timber and perform forest management activities within approved operational plans.

The management activities of the Research Forest must comply with the regulations described in the Forest and Range Practices Act (FRPA) and the Caribou Chilcotin Land Use Plan. With FRPA, the Research Forest is required to achieve the Government's objectives and desired outcomes. The government's objectives and desired outcomes are given and the Research Forest will propose results or strategies to reflect the goals. Under FRPA, the Research

Forest submits one comprehensive plan, the Forest Stewardship Plan, for approval before receiving a cutting permit to authorize harvesting. The Forest Stewardship must be consistent with local land use plans, specifically the Caribou Chilcotin Land Use Plan (CCLUP). A forest tenure holder must meet all the requirements of FRPA and the Forest Planning and Practices Regulation. The tenure holder is required to follow the government's objectives of protecting values including soil, timber, wildlife, water, fish, biodiversity, and cultural heritage resources.

The Research Forest is required to comply with CCLUP timber targets. CCLUP divides the land base into three Resource Development Zones: Enhanced, Special, and Integrated. The CCLUP "presents the overall framework for land use, conservation, and economic development. It is used to provide direction for the management and allocation of public lands and resources over a defined area." (Day 2007). In the CCLUP, it outlines the vision and approach for achieving sustainable land management and expresses the goals and objectives for using and managing Crown land. It also provides certainty on the land base for Alex Fraser Research Forest to access and utilize resources, protects sensitive areas, and reduces conflict between alternate resource users.

Regarding cultural values, the Knife Creek and Gavin Lake blocks fall within lands claimed by the William's Lake Band and by the Soda Creek Band respectively (Day 2007). Since there are First Nations occupying in the Research Forest, there are constraints as to the area of land that can be utilized. Negotiations and agreements are needed to be made between the parties to allow both the Research Forest and the First Nation to benefit from each other. The Research Forest will also manage development activities to prevent physical damage to cultural sites and features, in accordance with the Heritage Conservation Act.

2.0 AFRF Criteria and Indicators List

For the carbon sequestration project in the Alex Fraser Research Forest six criteria have been chosen. The chosen list of criteria closely resemble those already in place for operations in the forest listed in *UBC Alex Fraser Research Forest Management and Working plan #3*. The only addition for a carbon sequestration project is the revenue produced from selling carbon offsets added to the total revenue for the forest.

2.1 Research

The forest license for the AFRF is a special license since the forest is designated as a research forest. The main goal of the forest is research itself as this is the reason for the forest's use permit. The knowledge acquired from research on the forest can be used to improve management practices throughout the province. Research performed on the forest directly benefits educational opportunities in the forest.

2.1.1 Criteria Goal

Activities on the forest that are not related to research must not disturb research projects or impede the needs of researchers. We will strive to provide and maintain an optimal environment for research.

2.1.2 Indicators

Table 1: Research C&I

Indicator	Target
Disturbed research projects	No Disturbance
Important areas Changed or lost	No Disturbance

2.1.3 Management

Preventative measures will be taken prior to work commencing in an area. Research activity in the area will be located and the rest will be assessed by importance of research. Steps will then be taken to prevent the disturbance of these areas.

2.2 Sustainable Forest Management

Sustainable forest management covers a wide variety of forest functions and attributes that need to be taken into consideration while managing a forest. Managers of the Alex Fraser Research Forest strive to practice sustainable forest management to the highest standards. There are many steps that are taken in doing this.

2.2.1 Criteria Goals

- **Abide by laws and regulations**: Laws and regulations for the area will be understood and followed closely.
- **Sustain or enhance fish and wildlife habitat:** These areas will be left intact and when operations are able to improve or enhance fish and wildlife habitat it will be done.
- **Water quality:** Water is used by both people and wildlife in the area. Its quality and volume will be maintained.
- **Visual quality:** Visual quality will be taken into consideration at all times and be maximized.
- **Biological diversity:** No net loss of biodiversity in areas under management.
- **Protect from catastrophic losses from fire as well as pest and pathogen outbreak:** Take necessary steps to protect from these losses when possible.
- **Grow and harvest quality timber:** Wood grown and/or cut will be done at the highest standard.

- **Conduct activities in a way that provides a safe, healthy and secure working environment:** Work in the forest will be performed in a manner that minimizes safety risks to workers.

2.2.2 Indicators

Table 2: Sustainable Forest C&I

Indicator	Target
Net loss of fish and wildlife habitat	No Changes
Water quality	Maintained
Loss of biodiversity (%)	0
Catastrophic losses from natural disturbance	Current level maintained
Timber quality	Enhanced
Safety incidents	0 Incidents

2.2.3 Management

- **Abide by laws and regulations**: Become familiar with the laws and regulations for the area and abide by them
- **Sustain or enhance fish and wildlife habitat**: Heavy machinery will not be used in riparian areas and areas where erosion into water ways is of high risk. If fertilizers are to be used it will not be applied in riparian areas or where seepage into waterways could be an issue. Current mule deer habitant management will be followed.
- **Water quality**: The management strategies regarding heavy machinery and fertilization from the last point will also consider water quality
- **Visual quality**: Carbon sequestration management sites will maintain or enhance visual quality. This should not be an issue.

- **Biological diversity**: Prior to work in an area the negative affects to species in the area will be reviewed. If it is realized that biological diversity will be lowered as direct result of carbon management the project will not be employed.
- **Protect from catastrophic losses from fire as well as pest and pathogen outbreak**: If a fire break can be worked into a carbon project without additional costs. For planting, the use of mixed seed stock and a variety of species could help lower the severity of pest and pathogen outbreaks.
- **Grow and harvest quality timber**: Harvesting quality timber is not part of a carbon sequestration project, though growing timber is. Commercial species will be used for planting stock.
- **Conduct activities in a way that provides a safe, healthy and secure working environment**: Standard work safety gear will be a requirement on the job site.

2.3 Revenue

The Alex Fraser Research Forest is not funded by the university. Operations on the forest are self-funded so money must be generated by the managers of the forest. Managing the forest for carbon to be sold as carbon credits is an option that will produce revenue for the forest.

2.3.1 Criteria Goal

The costs of managing the forest for carbon will not be greater than the revenue produced by the sale of carbon credits. This includes the opportunity costs of not cutting to produce carbon.

2.3.2 Indicators

Table 3: Revenue C&I

Indicator	Target
Profit compared to profit lost from not logging	= or >

2.3.3 Management

Managing the land base for producing timber is already a well understood practice. Managing for carbon credits is a less understood practice which involves additional risks. Carbon credits will only be managed for if there is reasonable certainty that they will produce equal or greater revenue.

2.4 Education

Providing a quality atmosphere for education is a very important part of the research forest. Learning opportunities range from elementary school students to university professors. The forest is a great place for students to learn about the field work involved. Ongoing research in the area also provides excellent learning opportunities for teaching students. Introducing new carbon sequestration projects into the management of the forest can provide additional learning opportunities. Selling carbon credits is a new concept that is not well understood by most. A carbon program at the research forest could double as a research project and as a learning tool to better understand both the market and the operations.

2.4.1 Criteria Goal

Carbon projects will not negatively impact educational opportunities in the research forest. Management activities will provide an optimal environment for learning.

2.4.2 Indicators

Table 4: Education C&I

Indicator	Target
Area of education degraded	0 areas degraded
Create new educational opportunities	1 per implemented project

2.4.3 Management

In areas commonly used for educational purposes carbon sequestration projects will not be performed if it is determined that they will have a degrading impact on education. Projects will be implemented in a way that provides educational opportunities when possible.

2.5 Social Values

There are many important social values the forest has for both the First Nations and local communities in the area. The lakes and trails in the area are used by recreationists. Recreational activities in the forest include sport fishing, canoeing, and hiking. The AFRF is located on land that had been traditional used by two aboriginal bands. There are parts of the forest that hold historical importance for these peoples.

2.5.1 Recreation Criteria Goal

To maintain and to not disturb recreational opportunities in the forest.

Table 5: Recreational C&I

Indicator	Target
Number of visitors to the forest	Same as prior

2.5.2 First Nations Criteria Goals

To protect and to not disturb sites with traditional, cultural, and historical importance.

Table 6: First Nations C&I

Indicator	Target
Area of culturally important sights negatively affected (%)	0
Satisfaction of local First Nations groups (%)	Same as prior
Archeological surveys performed	Prior to work commencing in an area

2.5.3 Management

Areas of high historical importance such as ceremonial sites will be left untouched. Other areas of interest to local native bands such as places for potential berry picking and gathering will be managed differently. These sites will remain in the management area but will be managed separate from the carbon sequestration management objectives. Prior to work commencing in a new area a survey will be done to locate these places. The important areas will then be managed as guided by the local native bands.

2.6 Range Lands

The Alex Fraser Research Forest sits on land that is also used as domestic range. The range lands are used by local ranchers for live stock grazing. In areas developed for forest management and also used as range lands, complications can occur. Development can at times result in temporary loss of grazing area. Furthermore, live stock can cause damage to young seedlings. A good relationship with the ranchers thus becomes an important goal.

2.6.1 Criteria Goal

- Avoid degrading grazing quality in areas under management that are also used as range land.
- Maintain a good relationship with range land users.

2.6.2 Indicators

Table 7: Range Lands C&I

Indicator	Target
Area of quality grazing land	Maintained
Satisfaction of ranchers	Same as prior

2.6.3 Management

The management practices for range lands in the management and working plan #3 will be followed for carbon sequestration projects in the research forest.

3.0 Risk Assessment

3.1 Mountain Pine Beetle

The most publicized forest health issue currently facing the Cariboo-Chilcotin is the mountain pine beetle (*Dendroctonus ponderosae* Hopk.) epidemic (Robins 2008; Siddle 2009; Hamilton 2010) which has affected over 13 million hectares in British Columbia alone (Raffa et al., 2008). Being cold blooded, the lifecycle of mountain pine beetle is entirely dependent on temperature fluxes which dictate brood emergence, cold-hardiness, mass flight, and a number of other biological processes (Carroll 2003). Beetles spend the majority of their life under the bark of its host feeding on phloem as the larvae develop through four instars, until they emerge as adults in mass flight to new hosts (Carroll and Safranyik 2003). Typically, a full life cycle is completed in one year, however when summer temperatures are conducive, an additional brood can be produced or it could take an additional year for the cycle to complete (Amman et al. 1985).

The limitation of beetle range expansion is determined by seasonal temperature fluxes and the timing of the beetle life cycle to those fluxes. Under bark temperatures below -40^{0}C can kill up to 100% of the larval population overwintering under the bark of the host species. Alternatively, temperatures below -20^{0}C in the fall or spring preceded by a period near 0^{0}C can be damaging to populations as they may have not developed adequate cold hardiness or could be in the preliminary stages of spring awakening after hibernation (Amman et al., 1985; Carroll et al., 2003; Government of Alberta, 2009). These temperature fluxes restrict the spatial distribution of bark beetle habitat not only in latitude, but also in elevation. The susceptibility of a forest lessens further north, as well as with increasing elevation since higher and more northern sites are subjected to colder temperatures (Shore and Safranyik, 1992).

The preferred host of mountain pine beetle populations are densely stocked stands of pine (750-1500 stems/ha), between the age of 80 and 100 years, with an approximate DBH >20 cm. These trees are usually attacked first due to the low vigour associated with densely stocked, old individuals. They provide ample habitat for bark beetles to develop a foot-hold in a stand and produce a productive and prolific brood for further colonization in the area (Amman et al., 1985; Whitehead et al., 2003; Safranyik and Carroll, 2006). As the population grows over subsequent years of infestation, smaller diameter individuals are attacked and overwhelmed, causing the production of indicative pitch tubes and frass accumulations near the base of the stem (Amman et al., 1985).

Management options can include both direct and indirect efforts. Small scale application of insecticides can help to control the spread of recent outbreaks, however large scale application is not economic or socially desirable (Amman et al., 1985). Alternative direct approaches can include single tree selection harvest, fall and burn, or debarking, but as with pesticide use these choices are limited by economics and application on large scale. Instead, preventative maintenance of susceptible stands through thinning can help boost vigour and resource availability for residual stems, allowing for increased growth and carbohydrate allocation to defensive chemicals within the tree (Axelson et al., 2009). Warring and Pitman (1984) found an almost linear relationship between annual wood production per square meter of foliar area and thinning, and showed that trees exhibiting annual growth rates >100 g of wood/m2 foliage were vigorous enough to fight off all but the most overwhelming beetle attacks.

3.2 Douglas-fir Beetle

A naturally occurring pest in the interior forests of British Columbia is the Douglas-fir beetle (*D. pseudotsugae* Hopk.). The insect has reached epidemic levels of infestation in recent years and has affected approximately 93,000 ha of interior forest, almost half of the area within the Cariboo-Chilcotin (Ebata, 2009). Outbreaks typically last between 2 and 4 years and occur primarily in overstocked stands with a large component of over-mature large diameter trees. At endemic levels, beetles attack small groups of weakened trees, patches of windfall, and/or trees injured by various abiotic and biotic stresses (Schmitz and Gibson, 1996).

Research exploring the role of semiochemical in beetle-host relationships has expanded our understanding of potential approaches that forest managers have at their disposal to cope with this pest. External stress factors such as drought or fire damage that affecting host species can facilitate the production of monoterpenes which can attract beetles to a host (Furniss et al., 1981). Female beetles also emit pheromones to attract mates and help concentrate the infestation in an attempt to overwhelm the host and aid in a successful attack. Understanding both host and pest physiological response during an attack has allowed for the development of control methods, including trap tree sites and chemical baiting, to draw beetles into desired sites before cleansing through debarking and processing of the trap logs (Furniss et al., 1981; Schmitz and Gibson, 1996).

3.3 Western Spruce Budworm

Currently a pest of great interest to the Forest Health arm of the MOFR’s Practices Branch, western spruce budworm (*Choristoneura occidentalis* Freeman) is an indigenous defoliator that has reached epidemic levels of infestation in the interior regions of British

Columbia. In 2009, over 419,000 hectares of forests had experienced some level of attack, much of which occurred within the Cariboo Region (BCMoFR, Aerial Overview Data, 2009). Attacks can last up to ten years and have been recorded in the IDF as far back as the early 1900's (Alfaro et al., 1982; Harris et al. 1985). Damage is often dependant on attack timing with budburst, precipitation levels through winter and spring, and host vigour and species (Alfaro and MacLauchlan, 1992), with large infestations leading to reduced growth or mortality (Campbell et al., 2005).

Environmental conditions can play an important factor in the susceptibility of a host to pest attack. Periods of extended drought, especially over the winter and in early spring can lead to increased stress and greatly limit the ability of a host to respond to infestation. Large energy expenditures during budburst occur in the spring while carbohydrate allocation is emphasizing root and shoot growth at the expense of foliar allelochemicals (Campbell et al., 2005). If budworm emergence coincides closely with that early growth, the loss of vigour may be too great for the tree and reduced apical growth is resultant.

Management of this pest by the Forest Practices Branch has been ongoing for the last 13 years in the Cariboo though aerial spraying application of *Bacillus thuringiensis* var. kurstaki (Btk). Btk is a microorganism that acts as a highly specific biological insecticide which only affects the larvae of Lepidoptera (moths and butterflies) while they feed. In June 2009, nearly 80,000 ha of forest in the Southern Interior Region was treated with Btk, of which almost 35,000 ha was located within the Cariboo. Since the extent of infestation has become so wide spread and Btk application is a control not a solution, focus has been placed on the most highly susceptible stands with the intent to slow the spread and allow host species an opportunity to recover ([3]Rankin, personal communication).

[3] Rankin L., personal communication, March 4, 2010. [Forest Entomologist, Southern Interior Region, Williams Lake Forestry Centre, Williams Lake, BC. (250) 398-4352.

3.4 Fire Management

Wildfire is the primary means of stand replacement and maintenance in many dry forest

ecosystems and it is influenced by three factors: weather, topography and fuel. Ecosystem functions are often driven by the frequency, severity, intensity and size of wildfires, however increased emphasis on suppression has led to changes in the regimes that develop the forest systems (Covington, 2000). Studies conducted by Feller and Klinka (1998) and Iverson et al. (2002) have identified a decrease in the frequency of fire intervals in the past half century and this shift has led to an increase in small diameter stems, reduced diversity, and increased availability of fuel within the forest.

Topographical features can greatly affect fire behaviour through variances in local climatic conditions. Changes in elevation will cause different types and quantities of precipitation to fall, affect melt rates, and fuel curing rates (Beck et al., 2005). Vegetative communities will be dictated by moisture regimes which largely depend on slope and aspect of various topographical features. For example, a south facing feature with a 30^{o} slope will receive much more solar radiation than a north facing feature with 10^{o} slope because of the trajectory that the sun takes as it travels east to west across the sky. Other features, such as canyons and draws, can have a funnelling effect on wind as parcels of air are forced to follow contours over the landscape (Beck et al., 2005).

Weather not only brings precipitation, wind, and temperature fluctuations, but is also the source of lightning which is attributed as the leading cause of non-anthropogenic source of ignition for wildfire (Klenner et al., 2008). Relative Humidity (RH) is a term used to describe the amount of moisture found in a parcel of air at a certain temperature. Atmospheric molecules at a higher temperature will have more space between them and so can hold more water (Beck et al., 2005). Low RH values increase the rate at which fuels dry since higher moisture levels in the fuel will be drawn out into the dryer air. This usually happens during periods of high temperature and low RH values, also increasing the ambient temperature of the fuel and lessening the amount of energy required before combustion can take place. Summer months reach peak daily temperatures between July and August, accompanied by low RH values, which precipitates the formation of storm cells through convective heating (Beck et al., 2005). These cells are the source of lighting which acts as a primary ignition source in the Cariboo, causing an average of nearly 9600 strikes annually between 2000 and 2009 ([4]Meyer, personal communication) resulting in 319 confirmed lightning starts in 2009 ([5]Bardossy, personal communication).

Fuel is anything that a fire will consume during combustion and can be in the form of ground, surface, or aerial fuel, either dead or alive. Ground fuels include grasses, leaves, limbs, roots and duff found on or in the forest floor. Surface fuels include larger diameter woody debris and low vegetation such as small trees or shrubs. Aerial fuels account for all aspects of the forest crown, such as snags, moss, lichens, branches and leaves (Beck et al., 2005). Successful suppression efforts in the past half century have altered forest characteristics, increasing the amount of fuel found on the forest floor, the density of stands, and abundance of understory vegetation creating a situation that favours larger, more intense, severe wildfires with an increased chance of catastrophic aerial or crown fire (Iversen et al., 2002). Day (2007) suggests that the occurrence of a crown fire would have a devastating effect on the structure of mule deer winter range, and could potentially cause significant damage to local property.

Part of the northwest corner of the Knife Creek block is contained within the community fire plan developed by the Williams Lake and Area Interface Fire Committee (2005) and is designated as partly the core area, and partly buffer area. The core area contains a large number of buildings and infrastructure values, whereas the management area is where much of the fuel management and interface planning is focused (Day, 2007). According to the Management and Working Plan 3 developed by Day (2007), most of the forest contained within the Knife Creek Block is classified as moderate, high, or very high fire hazard based on local stand structure.

[4] Meyer E., personal communication. March 30, 2010. Superintendent, Fire Weather, BC Wildfire Management Branch, Victoria, BC. (250) 387-8744.
[5] Bardossy R., personal communication. April 12, 2010. Senior Protection Officer, Cariboo Fire Centre. BC Wildfire Management Branch, Williams Lake, BC. (250) 989-2675.

The management and working plan put forward three activities to focus upon in the Knife Creek Block to help reduce fire-hazard risk:

- maintain a low-fuel zone between the Big Meadow Road and the Rodeo Drive subdivision, to reduce the risk of a wildfire destroying private property or a backyard fire destroying stands on the Research Forest;
- reduce stand density and fuel ladders by harvesting and thinning;
- investigate methods to reduce surface-fuel accumulations after treatment
    - gradual re-introduction of low-intensity surface fires
    - whole tree harvest methods
    - other burning and mechanical treatments (Day, 2007)

3.5 Climate Change and Pest-Fire Interactions

There is no longer an argument regarding whether or not our global climate is changing. Increasing CO2 concentrations have been widely documented and both atmospheric and ocean surface heating from the increased greenhouse effect is expected to continue (Dickenson and Saunders, 2002; David Suzuki Foundation, 2009). Climate envelope modelling conducted by Hamann and Wang (2006) suggest that tree species with a northern range limit in BC could potentially expand approximately 100 km per decade; key conifer species could lose much of their suitable habitat and sub-boreal and montane climatic regions can be expected to disappear rapidly.

Pest expansions and increasing levels of epidemic infestation will lead to increased mortality and greater fuel accumulation in the forest. Mountain pine beetle has been noticed expanding into areas that were previously unsuitable for habitation (Carroll et al., 2003), indicating that the warming temperatures are allowing historic range distributions to expand to the north, east, and in higher elevation. Changing weather patterns are bringing shorter winters and dryer summers (Bhaumik, 2009) which can have a direct effect on fire behaviour and budworm emergence timing (Alfaro and MacLauchlan, 1992). With increasing temperature and reduced RH, fuels dry much faster and have a lower energy requirement before combustion can occur, enabling fires to burn with increased ease, vigour, and scale.

Although we cannot directly combat the effects of climate change, managers can take a proactive approach towards management for future stand characteristics and make choices today that will reflect the altered environmental conditions expected to come. Seed and species selection incorporated with alternative thinning and harvesting strategies can be implemented in preparation for changing climatic conditions. This can also help in the mitigation of pest and fire concerns that would jeopardize the desired growth rates and stand structure. Any development of carbon sequestration projects must account for and expect these instabilities in anticipation of the impact they may have on sequestrations levels. Since we cannot directly predict exact levels of disturbance, a buffer pool should be established as an offset so we can ensure the integrity of any carbon credits sold into the marketplace.

4.0 Management Scenarios

4.1 Introduction to the Modeling Programs Used

To predict the potential outcomes of our scenarios they were modeled using a number of computer programs. A brief description of each of the programs is given below.

4.1.1 TIPSY 4.1

TIPSY (Table Interpolation Program for Stand Yields) is a forest modeling and database program for the interior and coastal regions of British Columbia. The program is able to create growth and yield models for forest stands. It does this by simulating the growth responses of a stand by inputting different geographical and silvicultural factors involved in a managed stand. The program then retrieves and interpolates the yield tables it has in its database to be able to produce the proper models desired (Government of BC 2007). With this program, our team has generated forest stands that are aimed at growing fast while still being biologically diverse.

4.1.2 FPS-ATLAS

FPS-ATLAS is a harvest simulation program for forest-level management. FPS-ATLAS models the forest stand spatially and temporally according to the various factors placed upon the forest. The program takes into account harvest levels, riparian buffers, silvicultural practices, road systems, growth and yield models of a specific polygon, and many others in projecting harvest scenarios. The program is able to report any changes that occur within the forest in each time-step that is specified. This allows for a modeling of a harvest schedule that would reach the target harvest level (Nelson 2003). Using this program, our team has been able to integrate the CBM-CFS3 results to it allowing us to project the carbon stock model throughout the Alex Fraser Research Forest.

4.1.3 CBM

CBM (Carbon Budget Modeling) is an aspatial, stand- and landscape-level modeling framework to simulate the dynamics of all forest carbon stocks required under the Kyoto Protocol (i.e. aboveground biomass, belowground biomass, litter, dead wood and soil organic carbon). The model uses much of the same information that is required for forest management planning supplemented with information from the national ecological parameter databases (Natural Resources Canada 2009).

4.2 Scenario One: Base Case

At the Alex Fraser Research Forest, managers have been continually improving the methods in which all aspects of forestry are carried out in the forest. Harvesting methods as well as silvicultural techniques have changed quite significantly over the years. These improvements may have resulted in a greater volume of carbon stored in the forest. If this is the case then this carbon may be available for sale as vintage credits. We will look at the results of using both 1990 as well as 2007 for the baseline years. Using the 1990 baseline, credits will only qualify for sale on the voluntary market. If the 2007 baseline is used, credits may also qualify for sale in the compliance market where they will likely fetch a higher price.

4.2.1 Base year 1990

Using the 1990 baseline year only allows for sale on the voluntary market. The annual allowable cut for the forest in 1990 was 5,435 m^3. The projected carbon stock levels based on the practices of 1990 are displayed in Figure 1.

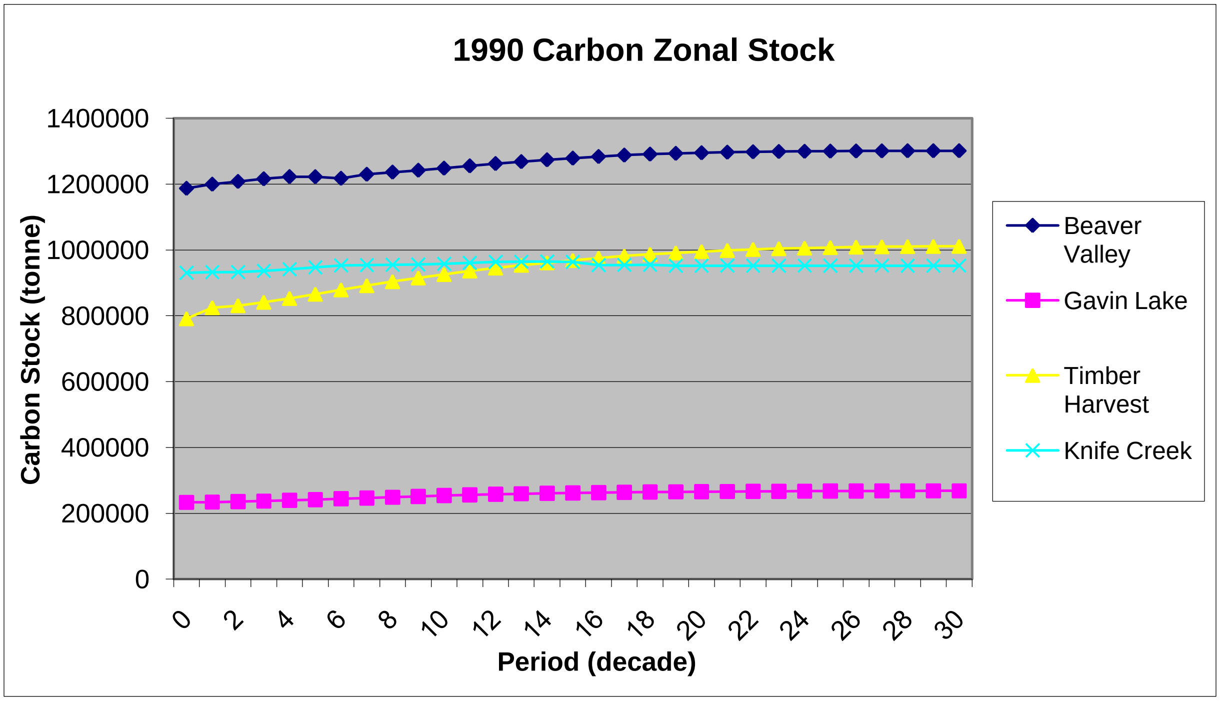

Figure 2: Carbon Ronal Stock using 1990 operations projected over 300 years.

4.2.2 Base year 2007

Using the 2007 base year to calculate additional carbon stored allows for credits to be sold on the compliance market. Credits sold on the compliance market are considered to be of a higher standard and will fetch a higher price. The annual allowable cut during 2007 was 14,000 m^3.

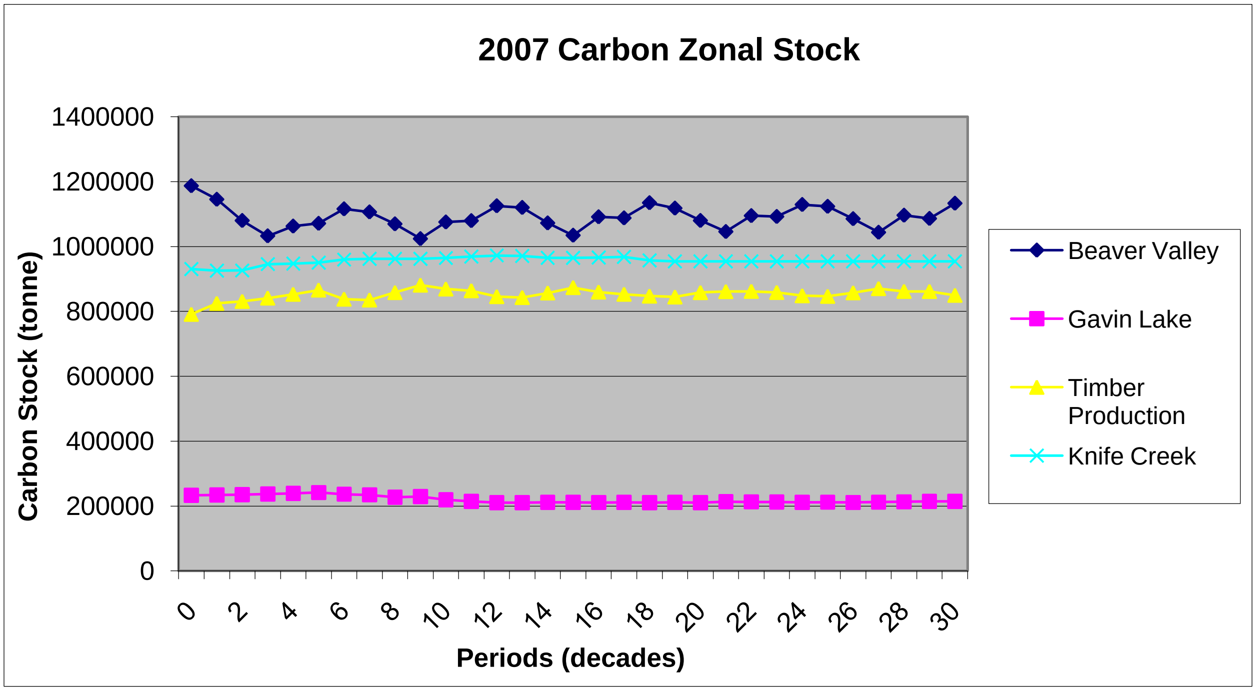

Figure 3: Carbon Zonal stock using 2007 operations projected over 300 years.

Based on the modeling, if operations were to continue as they were in 1990 then a greater volume of carbon would be stored than if operation from 2007 were to continue. This can be seen in table 1 for all zones except Knife Creek. Features such as buffers and reserves have been increased, though increased harvesting is likely the reason for lower sequestration. Harvesting in the Knife Creek block has been reduced to nearly nothing in recent years which explains why projections show greater carbon here for the 2007 baseline.

Table 8: Baseline carbon tonnes sequestered over the next 300 years

	Gavin Lake	Timber Harvest	Knife creek	Beaver Valley
1990	7,957,846	29,290,825	29,505,118	39,222,022
2007	6,808,715	26,413,703	29,290,825	33,846,545
Difference	1,149,131	2,877,122	-116,068	5,375,477

4.3 Scenario Two: Afforestation

Afforestation is the practice of planting an area for it to return to a forest structure. For carbon sequestration, it is an area that has not been forested for a period of ten years prior to the base year. At the Alex Fraser Research Forest the land base has been managed to very high standards. As a result there is limited opportunity for producing carbon credits through afforestation. Afforestation projects will focus on old roads and landing sites. Roads and landings are often left untreated after logging operations. If these areas meet the size and time requirements and are no longer needed for access or harvesting they are eligible candidates for afforestation projects.

4.3.1 Area Potential

The Knife Creek block is best suited for and will likely be the main focus for an afforestation project. Harvesting has slowed down significantly in this area and it is not likely to pick up soon. Reclaiming roads and landing sites no longer used would be quite costly. An afforestation project on these areas could fund their restoration and potentially turn a profit. In the Knife Creek block of the AFRF there are 9 kilometres of road that have been deactivated and left to regenerate naturally (Day 1997). These road sections along with decommissioned landing sites will be looked at for carbon sequestration. The roads alone provide about 18 ha of area for afforestation.

Modelling Input Data

Table 9: Input data used for modelling afforestation in Tipsy.

Afforestation Tipsy Input Data					
Zone	**Stocking composition**	**Stocking density**	**Site Index**	**Fertilization intervals**	**Seed stock genetic Gain**
IDFdk3	75% Pl and 25% Fd	3200stmstm/ha	20.5	(yr 25) and (yr25+yr35)	10%

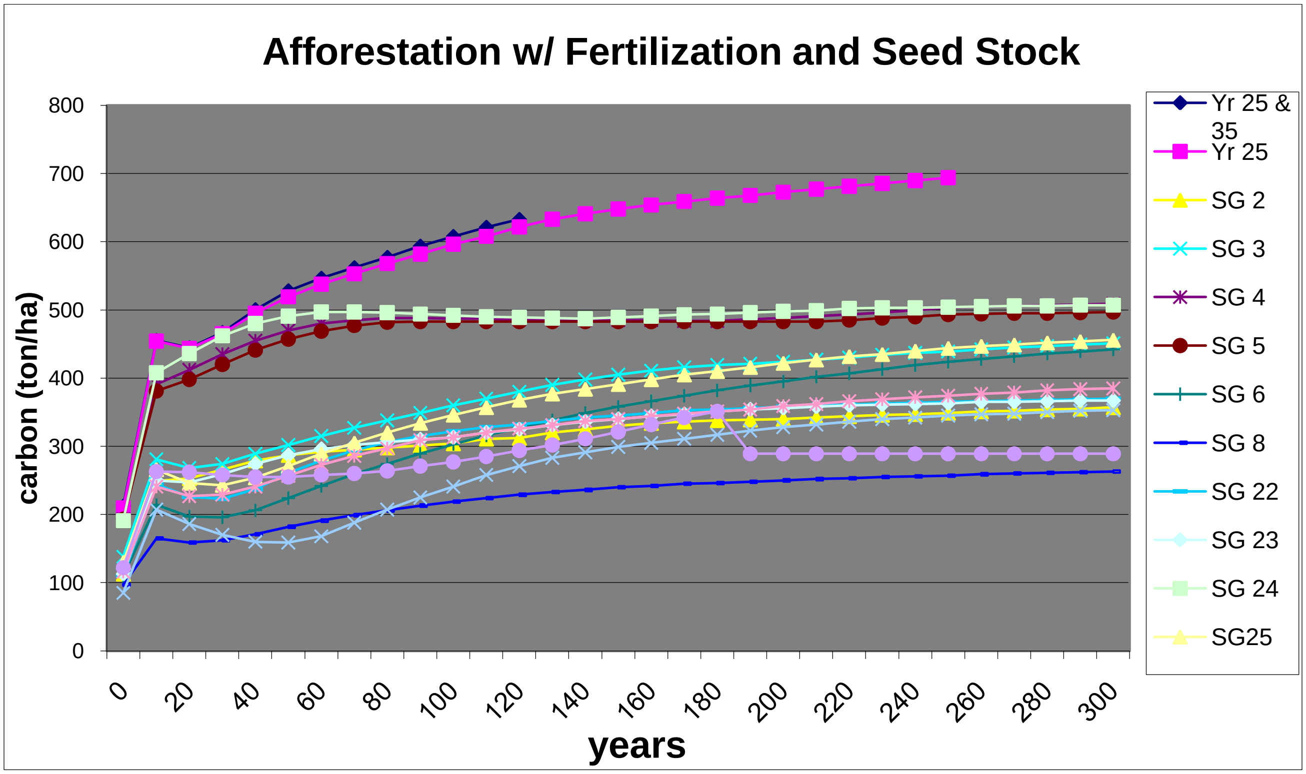

Figure 4: Carbon sequestered for Afforestation vs. Baseline Stand Groups (SG)

The amount of carbon that could be sequestered through afforestation on the available sites is displayed on the graph in figure 3. The amount of additional carbon comes to about 14,780 tonnes over the first 100 years. Since afforestation projects are on previously un-forested land all sequestered carbon is available to be sold as carbon credits.

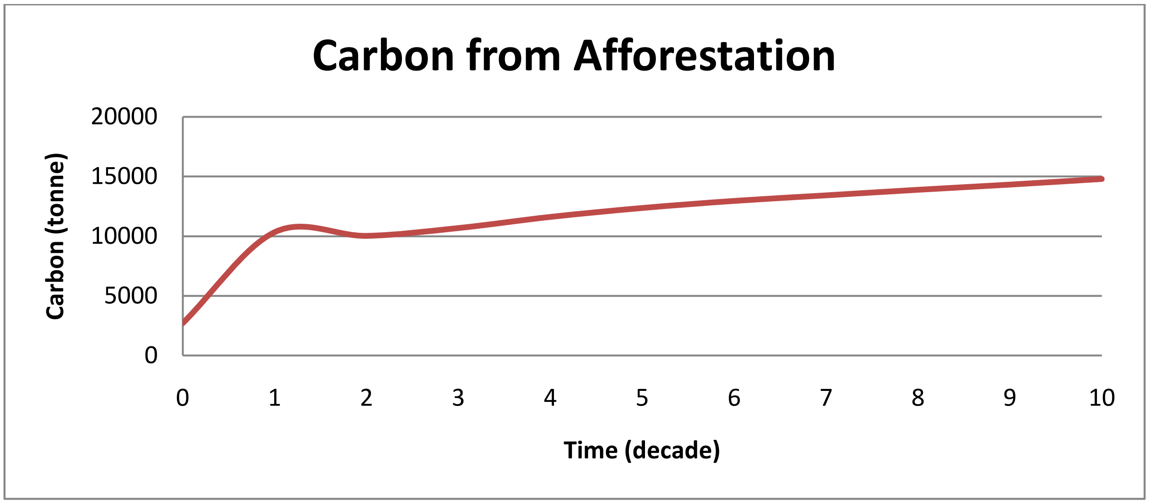

Figure 5: Projection of potential amount of carbon sequestered through afforestation.

The greatest amount of growth occurs in the first decade then over time the growth rate slowly decreases. This is a good situation if short term contracts are desired.

4.3.2 Operations

Afforestation is a fairly straight forward process, though it can be combined with other parts of silviculture to increase growth and carbon storage. Site preparation will be the first and potentially the most difficult step in the process. Roads and landing sites generally have high degradation in terms of growth potential for seed stock. This is a result from soil loss and heavy compaction. Heavy machinery will be required for the site prep process. An excavator would be the best choice for the job as it is the most versatile. The roads would first be ripped up then the soil removed during construction would be put back into place. Slash from logging could then be spread over the site. Once the site prep is complete seed stock would be selected for planting based on the locations and site conditions. Planting stock will likely consist of a mix of lodgepole pine and Douglas-fir. Appendix 3 shows the projected additionality gained from the afforestation project.

4.4 Scenario Three: Additional Management

Forest growth can be increased with different management techniques known as silviculture. Increasing the growth potential of the forest will sequester carbon at a greater rate. There are multiple management practices that can be done to improve forest growth. Practices include but are not limited to fertilization, planting improved seed stock, and brushing. Fertilization is more effective in areas of medium to high productivity (FPC, 1995). Areas of lower productivity are generally limited by moisture and not nutrients. Fertilization has minimal effects in areas that are limited by moisture. The Knife Creek block is a dryer low productivity site. For this reason we will focus on the potential of the Gavin Lake Block for additionality of carbon through additional silviculture practices.

4.4.1 Modelling Input Data

Table 10: Input data used for modelling management scenarios in Tipsy.

Management Tipsy Input Data					
Zone	**Stocking composition**	**Stocking density**	**Site Index**	**Fertilization intervals**	**Seed stock genetic Gain**
SBSdw1	55% Pl 35% Fd 10% Sw	2800stm/ha	21	(yr 25) and (yr25+yr35)	10%
ICHmk3	55% Pl 35% Fd 10% Sw	2800stm/ha	23	(yr 25) and (yr25+yr35)	10%

4.4.2 Fertilization

Tree growth always has a limiting factor. Limiting factors can include not enough moisture, certain nutrients, or sun light. Increasing sunlight isn't possible and increasing moisture would be very difficult and costly. One factor that can be increased is nutrient level done through fertilization. Research throughout the B.C. interior has shown that lodgepole pine is consistently nutrient deficient (Thomson, Brockley, Saini, 2009). There are multiple methods and strategies that can be used for fertilization: inorganic or organic fertilizers can be used and can be applied at different time intervals. Inorganic fertilizers are made with measured portions of the key nutrients for plant growth. These are generally the most affective making them the most popular. Using store bought inorganic fertilizer for forest application is quite costly so other organic ones can be a cheaper alternative. Many different organic wastes can be used for fertilization. Usable organic wastes include sewage sludge, pulp sludge, fish silage and ash. These substances can be used alone or in combination. Sewage and pulp sludge are likely the most plentiful of these substances in the William's Lake area. Sewage sludge has been found to be more affective so it would be the best option for an organic fertilizer at the Alex Fraser Research Forest (McDonald, Hawkins, Kimmins, Prescott, 1993).

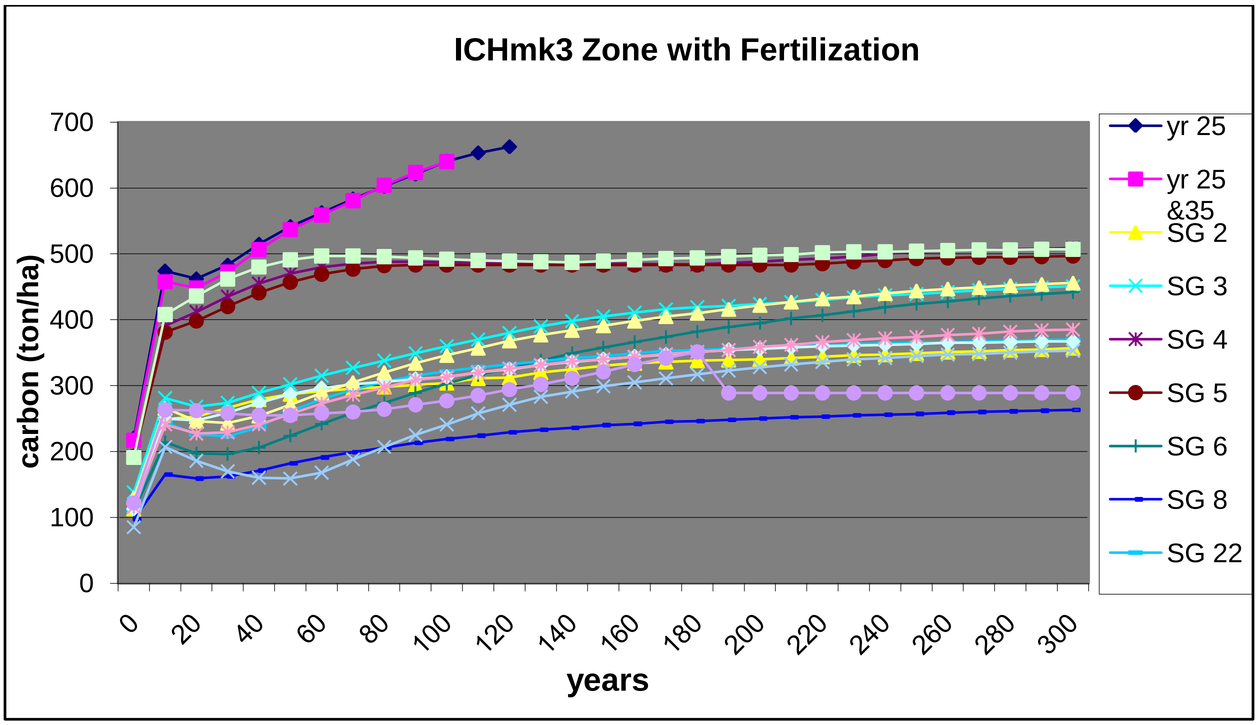

Figure 6: Fertilization at Yr 25 and at Yrs 25 & 35 vs baseline Stand Groups

In figure 5, the lines for fertilization only go to years 100 and 120. This is due to limited information in the programs used for modeling. As can be seen in the graph, the use of fertilization resulted in greater growth than all stand groups.

4.4.3 Improved Seed stock

For reforestation after logging there are different types of seed stock that can be used. It is common to use stock from the area of harvest, though this can be done in multiple ways. Trees can be left in the block to naturally seed the area. Seed can also be collected from trees in the area, germinated, then brought back to the site and planted. Tree breeding programs in BC are providing an ever increasing supply of genetically improved seed for reforestation (Brown, 1997). Improved seed stock can be created by selecting for resistance, faster growth, and desired stem form. Using seed stock selected for faster growth would be ideal for increased carbon sequestration. Higher resistance to pest and pathogen would also help to keep carbon stored for a longer period of time. There are four seed orchards that produce seed that can be used in the forest. The available improved seed stock has an estimated genetic gain up to 18% over natural stocking (FGCBC 2007). Faster growing stock is not only good for faster carbon sequestration, it can also reduce costs in that less brushing may be required.

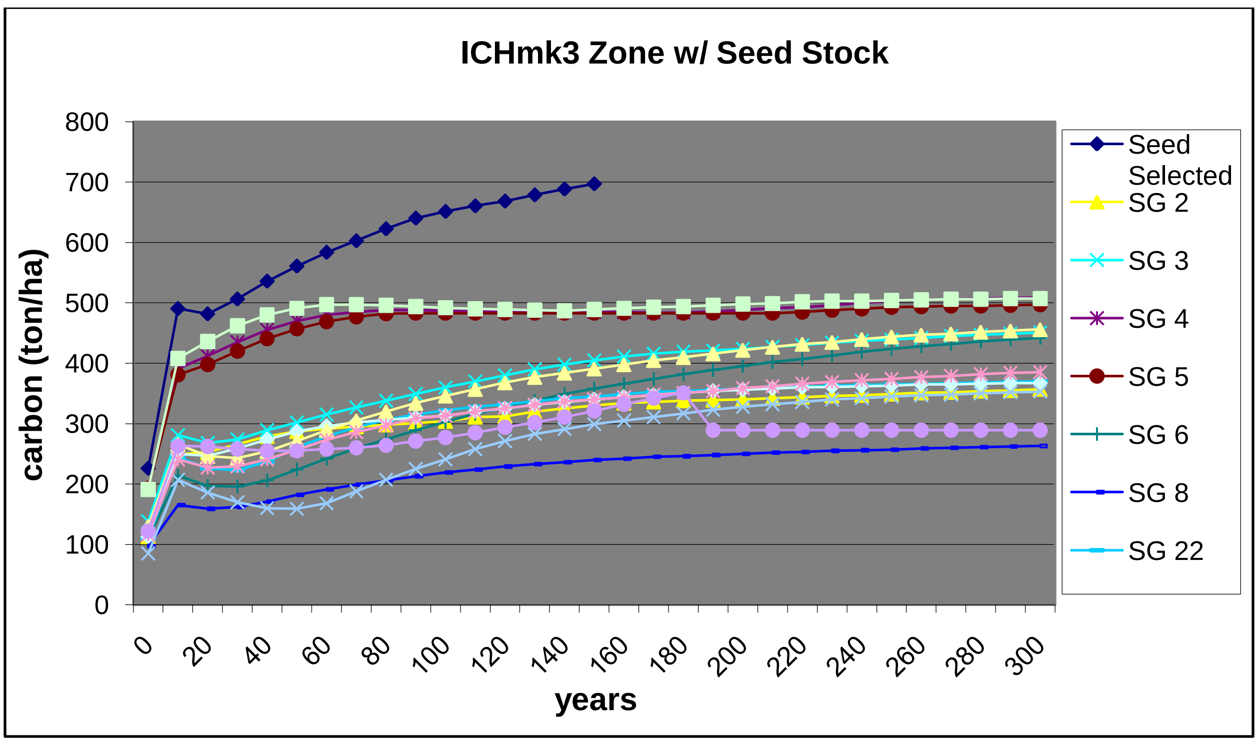

Figure 7: Advanced seed stock compared to baseline Stand Group growth.

Carbon levels for advanced seed stock are only projected to year 150 in figure 6 due to limitations of information in the program used. The genetic gain used in the modeling was set to an average of 10%. This is a conservative number as there are seed stocks available for the area that has gains of less than 10%. It can be seen in the graph that using this level of genetic gain gives greater sequestration than natural stock in all of the stand groups.

4.4.4 Additional practices

In addition the fertilization and the use of improved seed stock there are other steps that can be taken to increase growth for carbon sequestration. Non-desired species that compete with planted trees can be removed through brushing or herbicide spray. Removing the competing vegetation leaves all resources such as light, moisture and nutrients to be utilized by the desired species.

Commercial thinning is commonly done in stands where high value timber is desired on a shorter rotation. Thinning will increase individual tree growth, though MAI will decrease. This procedure prematurely removes stored carbon and leaves fewer trees to sequester carbon. Allowing trees to self thin keeps the carbon stored and leaves more trees for a greater overall growth. Though, this will result in individual trees growing slower and potentially poorer wood quality.

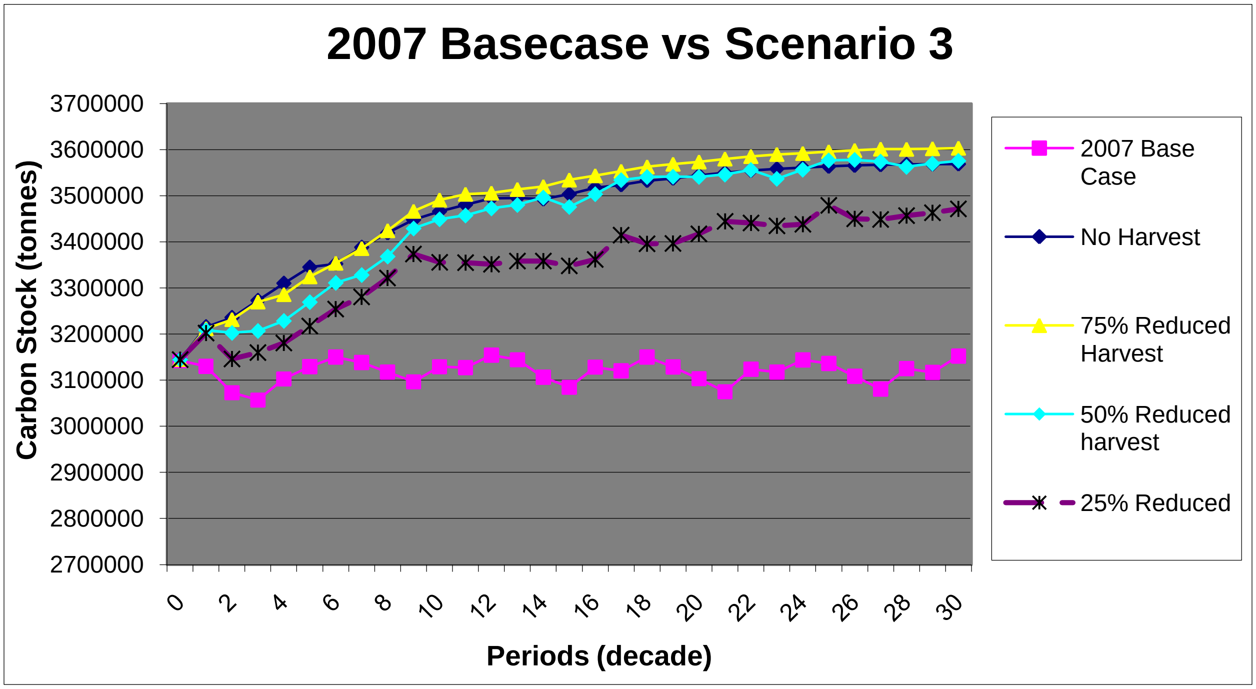

Figure 8: 2007 Base case carbon levels compared to other harvesting scenarios.

Determining the harvest volume is also a part of silviculture. A few different harvest levels are compared to the 2007 baseline in figure 3. Four different harvest volume scenarios differing from the baseline were modeled. These included no harvest, 25% reduced harvest, 50% reduced harvest, and 75% reduced harvest. The reduced harvest scenarios also had their rotations extended by 50 years. These were projected over a 300 year period. Even reducing the cut by only 25% with the 50 year rotation extension shows a significant increase in the amount of carbon sequestered. After a 100 year period there is already 219,101 tonnes more of carbon. Appendix 2 shows how each 25% reduction of the 2007 harvest level results in an averaged increase of 320,000 m³ for the growing stock.

4.5 Scenario-Criteria Analysis

The scenarios were ranked based on a few selected values to determine which are best suited for the forest. Scenarios and sub-scenarios were ranked by level of acceptance for the chosen values. Each value was ranked on a scale of 1-5 for each scenario or sub-scenario. A rank of 1 being the most accepted and a rank of 5 being the least accepted. Once values were assigned, the ranked criteria were totalled for each scenario and sub-scenario to give values that could easily be compared. Although the base cases were modeled for baseline comparison and were not intended as options, they were presented and included in the analysis.

Table 11: Ranking Key.

Acceptability Values						
Good	1	2	3	4	5	**Poor**

Table 2 above shows the key that was used in ranking the acceptability of the likely outcome for each of the values. Table 3 below displays all of the assigned ranking values as well as the totals.

Table 12: Scenario overview based on the Criteria

Values	Base case 1990	Base Case 2007	Afforestation	Fertilization	Improved seed Stock	Reduced Harvests
Research	4	2	1	2	3	3
Education	4	2	1	2	3	3
Recreation	3	3	3	4	2	2
Cultural values	4	3	3	4	4	2
Abide by laws and regs.	3	2	1	2	1	1
Water quality	4	3	1	4	2	2
Visual quality	3	3	1	4	2	2
Biological diversity	4	2	3	4	4	1
Timber	3	2	1	1	1	4
Safety	3	2	2	3	2	2
Revenue	3	5	2	2	2	3
Range lands	3	3	4	3	3	3
Totals	**41**	**32**	**23**	**35**	**29**	**28**

Since the scenarios can be implemented at the same time they are not alternatives to one or the other. For this reason it did not make sense to rank them against each other. Instead they were judged individually by comparing their score totals to the best, middle, and worst scores possible. Scores close to or greater than then the medium should be looked at more closely. The only scenario that was over was the 1990 base case which was modeled for reference only so it does not matter. Fertilization was the only other that came close to the medium score

Table 13: Acceptability table.

Acceptability Table	
Very good	6
Medium	36
Very bad	60

4.5.1 Research and Education

Afforestation has the lowest rank in this section. Since afforestation projects would occur on unused roads and landings research would likely be unaffected. As well, these projects could be used for research. The 1990 base case was given the highest rank as changing practices to back to how they were in 1990 would likely have a negative impact on current research. Values for education ended up being identical to those for research. This was not surprising as education is closely tied to research.

4.5.2 Recreation

Fertilization had the highest ranking for recreation. Sewage sludge and other organic fertilizers would likely smell bad and would not be pleasant for outdoor recreation. Reduced harvests and improved seed stock have the lowest rank for recreation. Part of outdoor recreation is enjoying the natural landscape so reduced harvesting and faster growing trees would be more aesthetically pleasing.

4.5.4 Cultural Values

Improved seed stock and fertilization were both given a rank of four. Using improved seed stock is not a natural process in the forest so it would likely be less culturally accepted. Fertilization could have an effect on understory plants that hold cultural significance. Reduced harvest was assigned the lowest value as less harvesting would mean less impact on sights of potential cultural importance. Additionally, more forest would be left natural.

4.5.5 Abide By Laws and Regulations

The 1990 base case had the highest ranking as laws and regulations have changed since that point in time. Going back to these old practices may be against new regulations. All of the other scenarios were given a lower ranking as abiding by laws and regulations should not be a problem.

4.5.6 Water Quality

The 1990 base case and fertilization were given the highest rankings for water quality. Since 1990 there have been improvements that would increase water quality so eliminating these improvements would decrease water quality. Fertilization would be kept at a safe distance from streams, though there is always the chance of leaching into ground water. Afforestation was given the lowest ranking as these projects involve reclaiming old roads which could potentially result in drainage problems.

4.5.7 Visual quality

Fertilization was given the poorest value for visual quality. When the fertilizer is first applied, it is likely that it will be visible and will not look appealing. Afforestation had the lowest rank as reclaiming old roads and landings as forest would probably be considered an aesthetic improvement by most.

4.5.8 Biological Diversity

There were three scenarios that were given a 4 for biodiversity. These were the 1990 base case, fertilization, and using improved seed stock. Improvements for biological diversity have been made since 1990 so eliminating these practices would be a step back. Fertilization will likely favour certain species more than others. Species that have a higher reaction may choke out other species potentially resulting in species loss in fertilized areas. Improved seed stock would likely compete with trees that have naturally regenerated. Multiple species may have seeded naturally and these trees would have greater variation within a single species. Reduced harvesting had been given a 1 for biological diversity. Reducing harvest would leave more natural forest intact which would on average have greater diversity than managed stands.

4.5.9 Timber

Reduced harvest had the highest ranking for timber since less stands would receive management. When stands are management for harvesting steps are taken to improve timber quality. Aside from the 1990 base case all of the other scenarios received lower rankings as all had beneficial attributes towards timber quality.

4.5.10 Safety

None of the scenarios seemed to have significant safety risks associated with them. The 1990 base case was given a medium rank as improvements to safety may have occurred since then. Fertilization also received a medium rank as too much exposure may have affects on certain individuals.

4.4.11 Revenue

The 2007 base case received a 5 as the poorest rating. Though, in a better market the forest would likely have been more profitable. Afforestation, fertilization, and using improved seed stock were all given a two as these scenarios are designed to improve carbon storage and wood production to produce revenue.

4.5.12 Range Lands

All of the scenarios were given a medium rank of 3 except for afforestation. The old roads and landings which are the proposed sites for afforestation projects are likely areas of good grazing for live stock.

5.0 Conclusion and Recommendations

5.1 Limitations and Additional Opportunities

In developing this management plan we ran into several limitations, the largest being time. As a result there are additional areas to explore that are not included in this plan. With the continuing change in climate, it is predicted that the migration of BEC zone boundaries will occur. The effects of migrating BEC zones could have a large impact on carbon sequestration. Exploring this would be beneficial and strongly recommended for larger scale projects. Alternatives to the pile and burn method of forest waste and fuel management would be good to look into as well for reducing emissions. In the Knife Creek block, commercial harvest has been significantly decreased and mule deer habitat is a large focus in the area. It may also be beneficial to look into making it into a permanent reserve. For harvesting operations, decreasing the amount of area converted into roads could also be beneficial to carbon sequestration and would be worth exploring.

5.2 Recommendations

The differing forest structure and history have led us to divergent recommendations for the two blocks that make up the Alex Fraser Research Forest. An afforestation project in the Knife Creek block showed great potential. Focus was on roads that have already been deactivated, though other roads that are no longer needed could also be incorporated. Although this project has a limited area, the scenario would serve as a self funded restoration project even if it were only a break-even financially. Fertilization along with the use of improved seed stock could also be incorporated into an afforestation project for additional gains.

When returning to harvest at the Gavin Lake block, there are multiple options that will differ based on the log and carbon prices. Increasing rotation ages along with reducing harvests showed large gains for carbon sequestration. When harvesting less than the baseline, we recommend establishing a sequestration project for additional revenue. This will result in a steady revenue stream as revenue could then be generated through both harvesting and not harvesting.

All of the financial projections are based on the trends of the ECX. For this reason we recommend selling on the ECX if a carbon sequestration project were to be implemented within the next year. In a year from now policy will likely be ratified in BC and the PCT may be a better market at that point. When policy becomes fully erect in BC, a comparison of the markets should be performed once again so that the best can be chosen.

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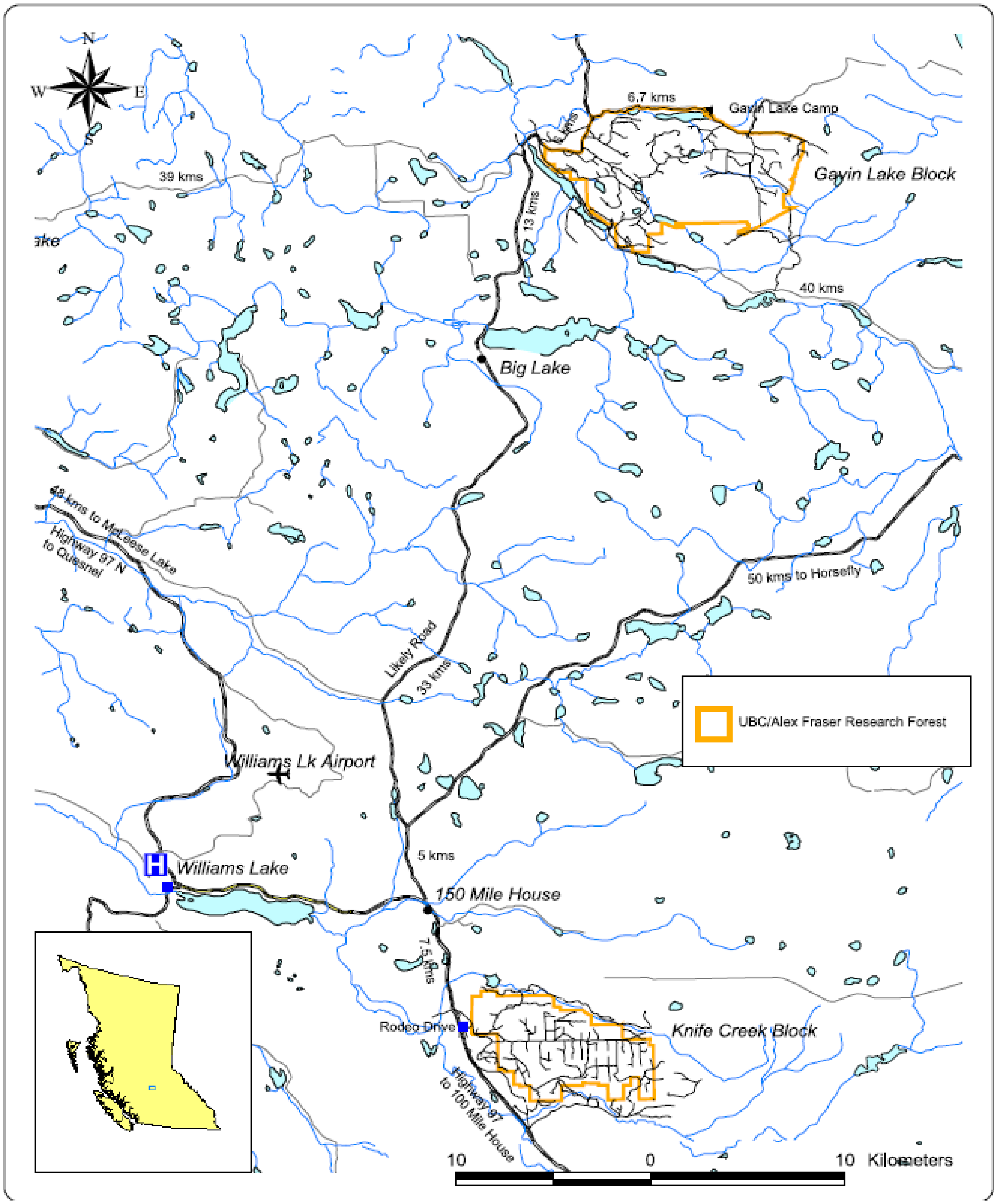
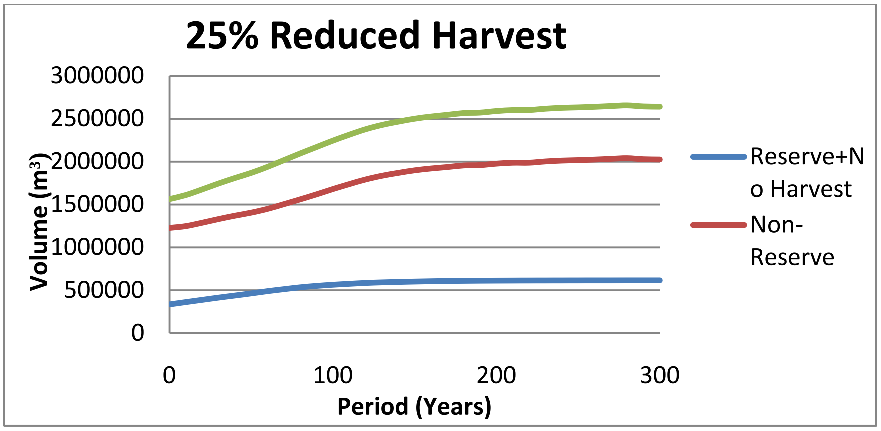
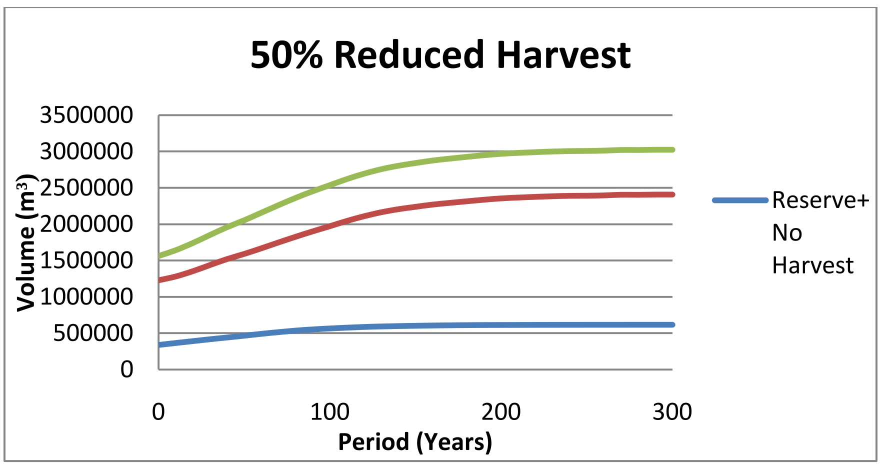
Appendix 1: Alex Fraser Research Forest Map

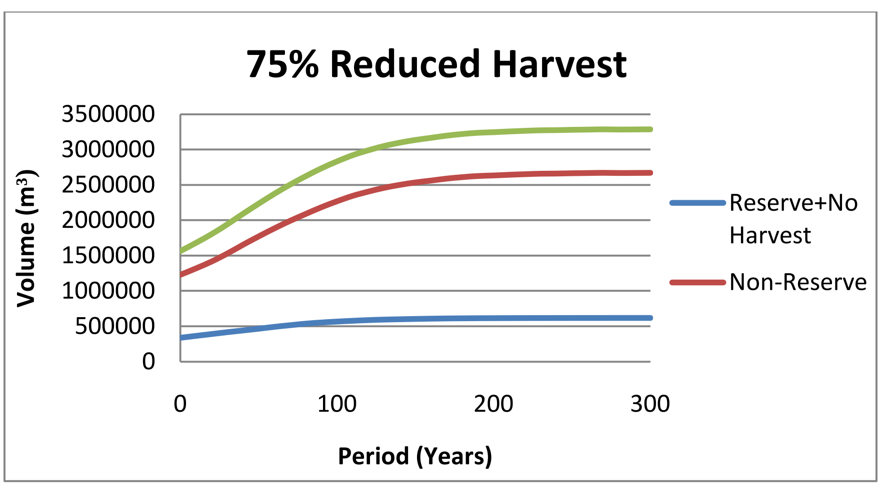
Overview of Knife Creek and Gavin Lake Blocks



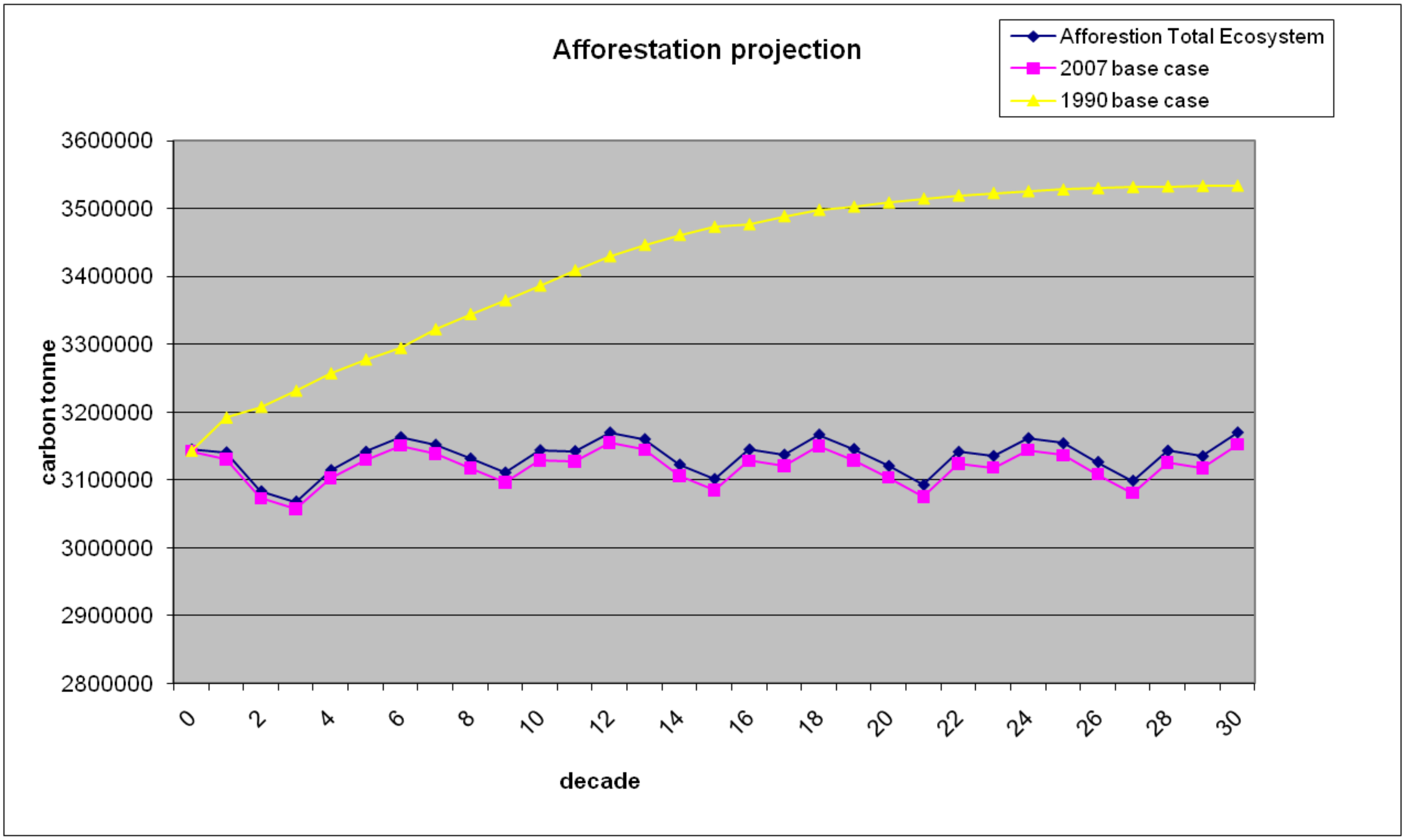
Appendix 2: Growing Stock Volume



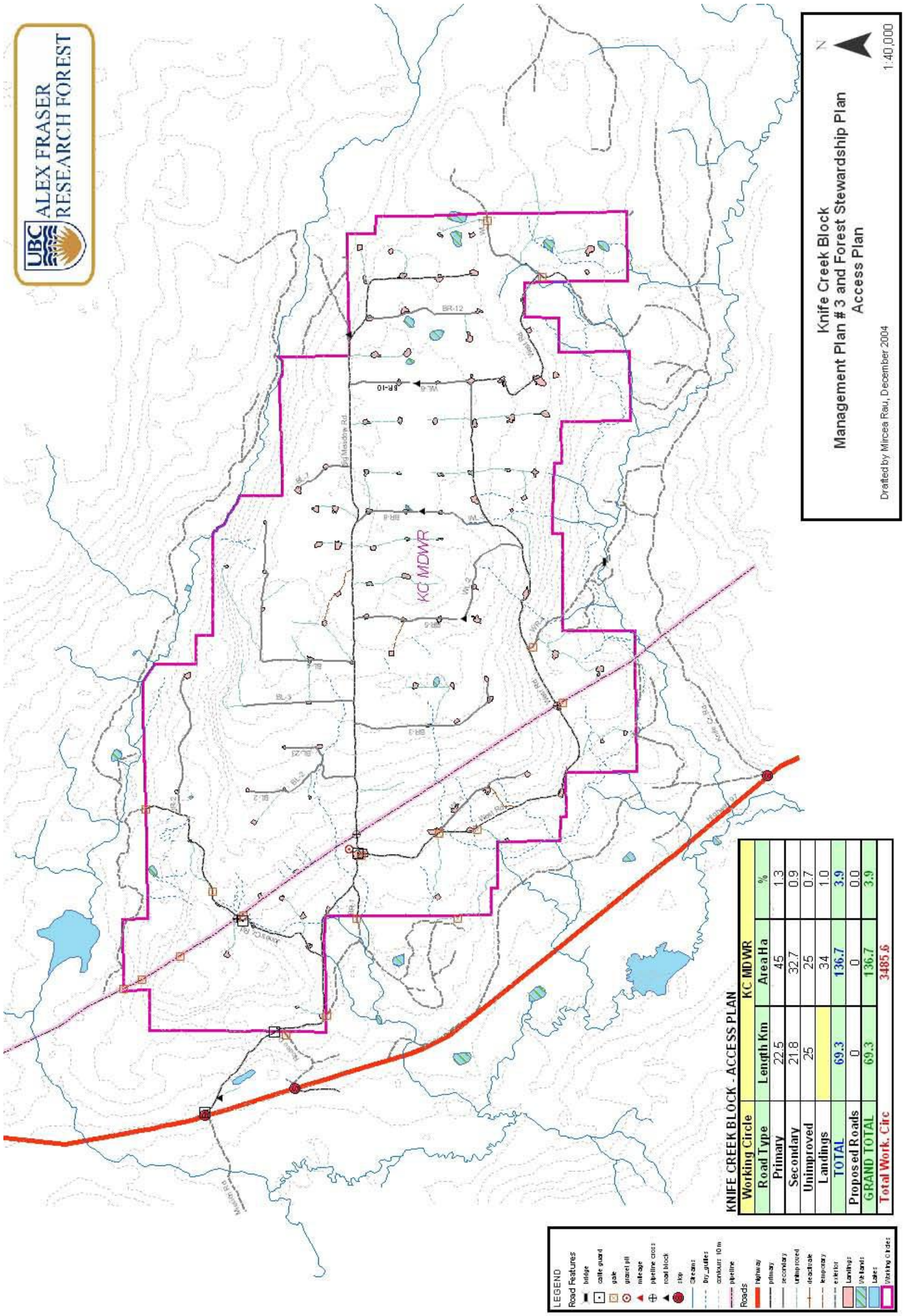




Appendix 3: Afforestation Comparison to Baselines 2007 and 1990

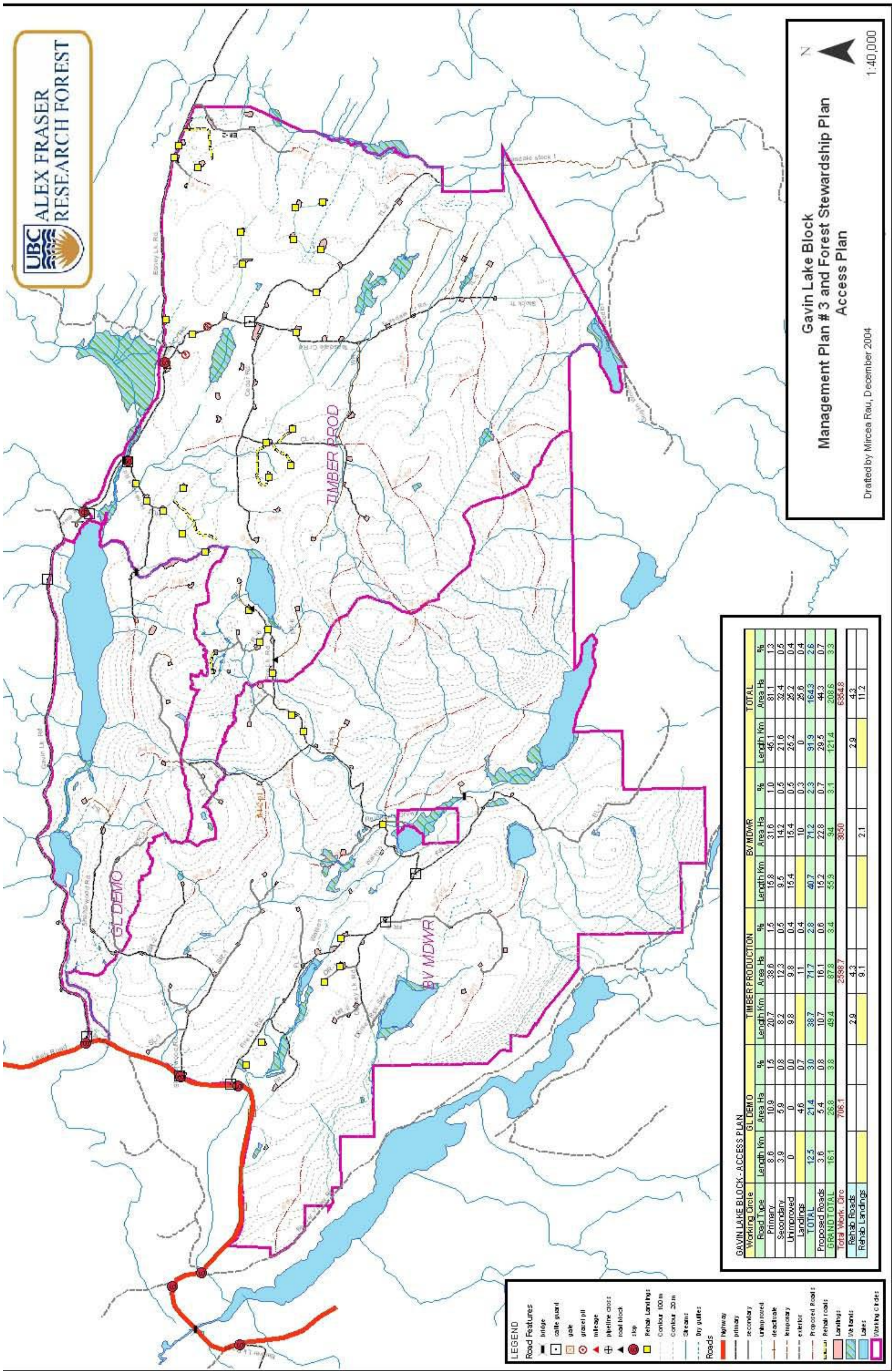


Appendix 4: Knife Creek Access Plan



KNIFE CREEK BLOCK - ACCESS PLAN			
Working Circle	KC MDWR		
Road Type	Length Km	Area Ha	%
Primary	22.5	45	1.3
Secondary	21.8	32.7	0.9
Unimproved	25	25	0.7
Landings		34	1.0
TOTAL	69.3	136.7	3.9
Proposed Roads	0	0	0.0
GRAND TOTAL	69.3	136.7	3.9
Total Work. Circ		3485.6	

Appendix 5: Gavin Lake Access Plan



Appendix 6: List of Assumptions

1. Carbon Standards Used:
   a. CSA-ANSI
      i. ECX follows Kyoto protocol and therefore we will use the national standards for carbon sequestration
   b. Standards will not change significantly from Draft-form used to final ratification of standard

2. ~18ha of Road area for Afforestation Roads
   a. existing in 1990 were 20m width
   b. In 1997 roads made were 15m width

3. 10 yr contracts are the standard contract length
4. Scenarios projected assume a model without a catastrophic natural disturbance
5. Scenario criteria analysis
   a. Fertilization will be in a visible form
   b. Carbon sequestration projects will be of interest to researchers and educators
   c. Areas used as range lands are subject to implantation of all the scenarios