Decision Support System:
Benchmark Scenario

North Coast Landscape Model

DRAFT

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Executive Summary

The North Coast Decision Support System (NC DSS) is a multi-dimensional decision system. Its purpose is to capture knowledge and to distribute information in support of the North Coast Land Resource Management Plan (NC LRMP). At its core there is a computer tool, the phase 1 NC Landscape Model (NCLM-I). The objective of phase 1 of the NCLM is to provide information in support of the NC LRMP temporal benchmark scenario. Future phases will provide the NC LRMP with scenario analysis support.

The NCLM-I consists of a collaborative temporal landscape analysis framework (Fall et al. 2000) and a set of computer based tools implemented in the SELES (Fall and Fall, 2001) modelling tool. A core modelling team works with domain experts who in turn work with the LRMP Government technical team(GTT) and the NC LRMP table to capture knowledge about landscape change and the implications for timber supply, coarse filter biodiversity and species of concern in the North Coast.

Landscape and wildlife indicators are generated by the NCLM-I and passed to the relevant domain experts. There are two domain expert groups evaluating benchmark scenario indicators the Timber Assessment group (NC TA) and the Environmental Risk Assessment group (NC ERA).

Current management was captured by the BC Ministry of Forests (MoF) following the MoF Timber Supply Branch timber supply analysis methodology (BC Ministry of Forests, 2002). The identical input data, assumptions and management regime was implemented in the SELES Spatial Timber Supply Model (SSTSM) (Fall, 2001). A timber supply alignment was done using SSTSM to match all of the output generated by MoFs Forest Service Simulator (FSSIM) timber supply model. The phase 1 implementation of the timber supply model does not use blocking, access constraints or adjacency rules, instead it applies the cover constraints identified in MoF's timber supply process. The NC TA uses this information to evaluate and verify timber supply indicators and present base timber supply to the NC LRMP table.

In phase 1 the NC ERA conducted post simulation analysis for coarse filter biodiversity, grizzly bears (*Ursus Horribilis*), mountain goat (*Oreamnos americanus*) and marbled murrelet (*Brachyramphnus marmoratus*) based on indicator reports generated by the NCLM. The species assessed were identified by British Columbia wildlife experts, the NC GTT and the NC LRMP table as species of concern and a detailed analysis was feasible for phase 1.

The NCLM-I is wrapped in a human network of domain experts, special interests, stakeholders and decision makers. The NC DSS, NC TA and NC ERA provide a system for experts to explore the decision space, they can assess the existing management regimes by evaluating indicators, conducting experiments and problem bounding. Experts gain an understanding of the landscape, wildlife and vegetation and how they would change given certain human interventions and natural processes. The critical point in this decision system is the interaction of the domain experts with the table, it is this human system that expresses the knowledge and information of the computer system to the decision process.

Phase 2 of the NCLM will be a complete spatial implementation of timber supply and include additional value indicators to do scenario analysis including variable retention. Possibly, included in the scenario analysis will be indicators for Northern Goshawk (*Accipter gentilis*). A predictive ecosystem inventory will be included and an ecosystem overstory species succession model will be implemented. An economic timber shed model will be evaluated for inclusion. A mineral assessment (NC MA) is being considered and a preliminary investigation is under way.

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Acknowledgements

The process used in developing the tools used for this project is known as collaborative modelling. This process requires input from a large number of people. Most of those listed below are domain experts that assisted with the development of conceptual models and model interpretation. To facilitate their participation a multi-disciplined team, the NC analysis team (NC A-Team) was developed. This team has expertise in data management, spatial analysis, Environmental Risk assessment, decision support systems, Timber Supply, inventory, operational forestry, operational biology and expertise in linking domain knowledge to LRMP decision making. This team is co-ordinated and integrated with NC LRMP government technical team and the NC LRMP process. It evolved over several years with a great amount effort by all involved. It has a common vision of its purpose that promotes a positive professional environment that allows the collaborative modelling framework to succeed.

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Audience

This report is intended for the North Coast LRMP table, Government Technical Team and Domain Experts.

1.0 Introduction

1.1 Background

1.1.1 The role of analyses in LRMPS

Land and Resource Management Plans establish direction for land use and specify broad resource management objectives and strategies for areas approximately 1.5 to 2.5 million hectares. All resource values are considered in the planning process, which is characterised by broad public participation, interagency co-ordination, and consensus-based decision-making.

In the broad sense, decision support systems are analytical and process-related methodologies that aim to help decision-making. Decision-making rests on the foundations of values and knowledge. LRMP support staff apply facilitated discussion and analysis techniques to help stakeholders synthesise and share the knowledge and values required to make an informed decision (Figure 1). To be complete, the decision should define management, adaptive management and monitoring strategies.

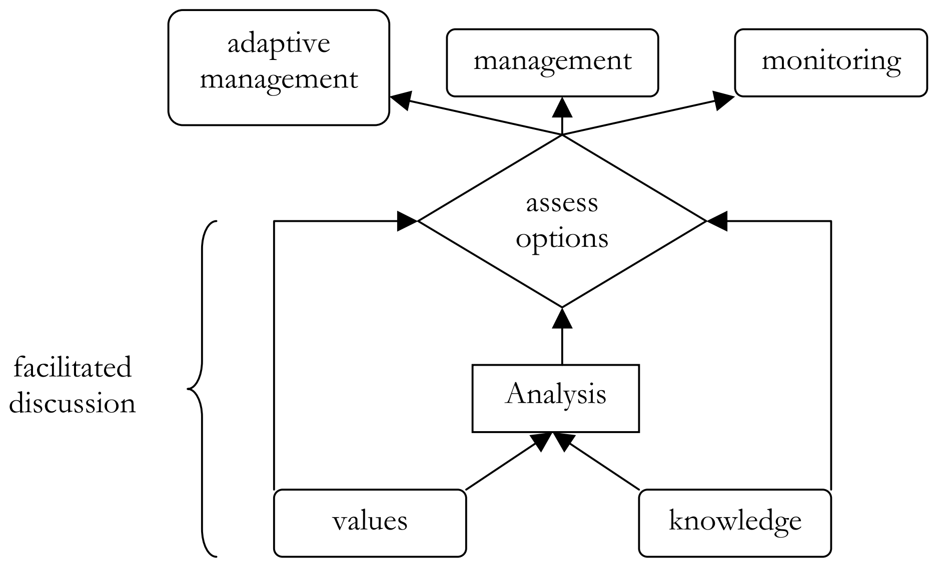

Figure 1. Decision support synthesises relevant knowledge and values using analyses (inner arrows) and facilitated discussion (outer arrows) to help stakeholders assess options and choose management, adaptive management and monitoring strategies.

Resource analyses are conducted as part of the LRMP process to provide substantive and objective information to support informed decision-making by participating public representatives and resource agencies[1]. Resource analysis is defined as **"the critical**

[1] Resource Analysis Guidelines xxxx

examination of resources and the environment so as to support planning and decision-making"[2]. Resource analysis consists of:

- gathering, examining and interpreting relevant resource-related information.
- organising and integrating this information to assist in developing land-use scenarios; and,
- assessing the impacts of proposed scenarios on resources and the environment.

Resource analysis divides into two steps. First, in landscape analysis, the basic relationships between selected biophysical features on the landscape (also referred to as planning indicators) and land management are examined. Second, in impact assessment, the impacts of changes in planning indicators on social, economic and ecological values are formally assessed.

1.1.2 Landscape Analysis Tools

Analysis "tools" or methods range from simple "back of the envelope" calculations to GIS area analysis to computer models. In land-use planning, paper or digital maps provide information for analysis.

GIS area analysis summarises the amount of land in different land classes. For example, it can calculate the total area or proportion of a biogeoclimatic subzone that falls within protected areas.

Models include data and relationships arranged (usually mathematically) to represent an idea. Typically, resource management models use equations to predict the influence of management actions on future resource conditions. The equations are often simple, but because resource management affects large areas over long time periods, the bookkeeping is difficult to do manually. Modelling has the major benefit of enforcing a more rigorous analysis of land use problems, but may be costly in time and money.

Models have been used to address a variety of issues on forest land and have become increasingly complex over time. *Timber models* have evolved from simple calculations of growth and yield through simulations of growth and harvesting to spatial simulations. *Habitat models* have expanded from simple linkages of species with forest types to include attributes of forest stands (e.g., snags, big trees) and influences of adjacent landscape features (e.g., fragmentation, roads). *Landscape models* simulate disturbance and succession and measure landscape condition (amount and pattern); they often include aspects of timber models and habitat models.

In previous LRMPs, resource analysis has consisted of aspatial timber supply analysis and GIS area analysis of ecological values. These approaches have some limitations. Because GIS area analysis only describes current ecological conditions in each land use zone, future conditions must be inferred subjectively. In contrast, landscape models explicitly predict the future conditions. In addition, landscape models can simulate more realistic harvest patterns, affecting predicted impacts on timber and the environment.

[2] ibid

1.1.3 Choosing a spatio-temporal model and an analysis framework

Many landscape modelling tools exist. Some features that distinguish models used for modelling resources are given in Appendix 1. A workshop with the Government Technical Team (Nov 6, 7, 2000) identified desirable features for a modelling tool for the NC LRMP. The model should

- produce variables needed for social, economic and environmental assessments;
- address large areas (i.e. be capable of modelling the entire North Coast Forest District to give a comprehensive landscape picture);
- be flexible and capable of modelling a variety of issues;
- have rapid turnaround time (i.e., be easily specified and modified, quickly processed and easily formatted for presentation);
- conduct scenario analysis of complete land use plans proposed by LRMP table;
- be stochastic (i.e., can model events that occur with a given probability; natural disturbance events and long-term management occur stochastically);
- be transparent (effective communication is easier when model workings are readily understood and underlying assumptions are clear).

Two further practical considerations include

- funding (the relatively small budget available essentially eliminates proprietary models and large analysis firms);
- available expertise (people supporting the North Coast LRMP have experience with SELES, Atlas/Simfor, linear programming, FSSIM, Woodstock, Forman, GIS-Forman, Facet and McGregor Model Forest's model).

Based on funding, staff expertise and the other criteria listed above, workshop participants identified SELES as a good candidate for use in the NC LRMP. In particular SELES processes models very rapidly and can thus model larger areas with reasonable resolution and speed. SELES is also very flexible.

Models built using SELES have been applied to a variety of ecological and management issues including fire and timber supply in the Invermere Enhanced Forestry Management Area (Morgan & Fall, 2000), mountain caribou habitat supply in the Columbia Mountains (Fall et al 2001), Unsalvageable loss in Robson Valley (Eng et al. 2001) and Mountain Pine Beetles in the Lakes Forest District(Fall et al 2002).

1.2 Analysis Framework

1.2.1 Collaborative Landscape Analysis

While appropriate analysis tools can generate useful information, the relationship between the decision-makers and the analysis process determines how much influence the information will have. Past resource analyses provided little opportunity for stakeholders to be involved in analysis. Generating model results and presenting them to stakeholders, however, is not sufficient to enlighten decision-making because many of the benefits of modelling come directly from participating in model development. Benefits include a better understanding of issues, ecology and economics and enhanced communication among stakeholders. In addition, model results are not usually viewed appropriately by those who were not involved in development. Uninvolved people tend to either trust or mistrust models, rather than developing a healthy scepticism based on the content of the model.

The notion that a group with appropriate expertise can combine talents to produce better models and solutions is not new (e.g., Clark et al. 1979, Holling 1978). We follow a recent framework that is familiar to LRMP analysts (Fall et al. 2000). The framework targets situations in which stakeholders have issues and questions, and conceptual models to contribute to the process, but do not wish to be directly involved in model implementation. Thus, we focus on conceptual model development, rather than model implementation (e.g., collaborative model construction), as the hub for collaboration.

The framework relies on the participation of three overlapping groups in a series of workshops and less formal discussions (Figure 2). Each group brings different talents and contributes to different phases of model development and use.

Stakeholders set project objectives, defining the issues and questions at stake. They contribute conceptual models and describe the range of potential management actions to consider. The term stakeholder is being used broadly to include those with the responsibility for making or providing advice about the decision.

- *Topic experts* provide information needed to formalise and parameterise the conceptual models. They help to interpret results. They include scientists (both local experts and topic specialists) familiar with the ecological processes involved, and land managers familiar with the local management regime.
- A *core team* (3-5 people) manages the framework. They organise and facilitate workshops and communication, gather required information, implement and test models, run simulations, analyse outputs and prepare documentation.

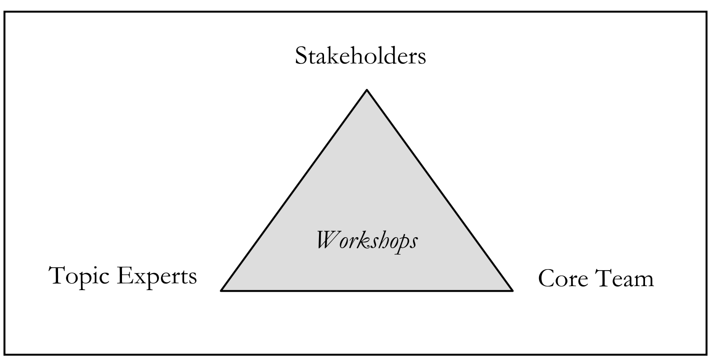

Figure 2. Collaborative modelling depends on three groups interacting through workshops.

Collaborative modelling uses an iterative model development process (Figure 1.1). The iterative process recognizes that conceptual models continue to evolve as our understanding of the modelled system and related issues increases and hence implemented models will require revision. It recognizes that not all people need or want to be involved in all phases of model development.

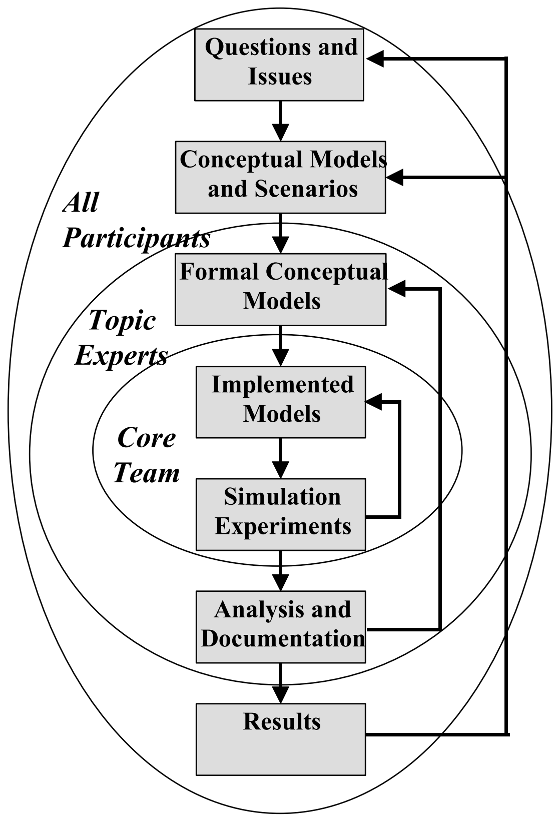

Figure 1. Nested, iterative model development process. Groups participate in all circles that surround them. All participants (stakeholders, decision-makers, domain experts, core team members) set objectives, select scenarios, develop conceptual models, and discuss model results. Domain experts and the core team develop and verify the formal models. The core modelling team is responsible for organizing workshops and communication, gathering required information, implementing models, ensuring equivalence to formal conceptual models, running simulations, analyzing outputs and documentation.

The collaborative modelling framework described above has been modified to fit better with the relatively complex LRMP process and the relatively short time period for analysis. Essentially, the GTT served as the stakeholder group during the first phase of model development before the LRMP Table convened. In subsequent model versions, Table members have more opportunities to influence analysis.

Collaborative modelling (including landscape modelling and impact assessment) provides a system for experts to explore the specific issues on the North Coast. Experts can evaluate the existing management regimes by assessing indicators, conducting experiments and bounding the problem space. Experts gain an understanding of the landscape, wildlife and vegetation and how they would change given certain human interventions and natural processes. The critical point in the collaborative framework is the interaction of the domain experts and the core modelling team with the Table. It is the human system that expresses the knowledge and information of the computer system to the decision process.

1.2.2 Current Status

The first iteration through the steps (i.e., Phase I) is complete. The GTT, topic experts and modellers defined the preliminary content of the landscape model in 2001. Data preparation, model coding and initial model testing occurred 2001 and 2002.

1.2.3 Parallel Coastal Analysis

The Coast Information Team (CIT) is an Environmental Non Government Organizations (ENGO), forest industry and provincial government funded group of international scientists and analysis experts. In addition to the North Coast LRMP analysis the CIT is co-ordinating British Columbia coast wide analysis in support of coastal decision making, including the North Coast. They have identified four different analysis approaches, the Ecosystem Spatial Analysis (ESA), Economic Gain Spatial Analysis (EGSA), Human Spatial Analysis (HAS) and a Wellbeing Assessment (WA) (Prescott-Allen, 2001). In addition spatio-temporal habitat supply modelling (STHSM) is being considered (Sutherland, 2002) which is considering the application of a similar set of decision techniques as those in the NC LRMP. The CIT conservation planning strategy identified by Noss et al. (2002) has also been applied to the 10.8 million hectares of the Greater Yellowstone Ecosystem. Their planning approach uses a combination of protection of special elements, ecological representation, and protection of critical species, identified as grizzly bear(*Ursus arctos*), wolf(*Canis lupus*), and wolverine(*Gulo gulo*) in Greater Yellowstone. To achieve this they have four goals: 1) represent ecosystems across their natural range of variation; 2) maintain viable populations of native species; 3) sustain ecological and evolutionary processes; and 4) build a conservation network that is resilient to environmental change. SITES (Andelman et al. 1999) is being used to conduct the conservation assessments and to identify sites that are of a high value for conservation objectives. It is based on a simulated annealing site-selection algorithm, combined with GIS-based biological and environmental data and static habitat suitability and dynamic population viability modelling of focal species (Noss et a. 2002).

Linkages between the NC DSS, NC ERA and NC MA and the CIT ESA/HGSA/HAS/STHSM are being developed to minimize analysis redundancy and to provide a suite of complimentary information to decision makers.

1.2.4 Overview of the North Coast Decision Support System

The North Coast LRMP analysis has a number of components. The North Coast Landscape Model (NCLM), North Coast Environmental Risk Assessment (NC ERA) and North Coast Timber Assessment (NC TA) are integrated to provide a system of spatio-temporal analysis and interpretation. There purpose is to capture knowledge and to distribute information in support of the North Coast LRMP. At its core there is a computer tool, phase 1 of the North Coast Landscape Model (NCLM-I) . The NCLM-I consists of a set of models implemented in the SELES modelling tool. A core modelling team works with domain experts, who in turn work with the LRMP Government technical team(GTT) and the NC LRMP table, to capture knowledge about landscape change and the implications for coarse filter biodiversity and species of concern in the North Coast. Phase I examines current management practices.

Landscape and wildlife indicators are generated by the NCLM-I and passed to the relevant domain experts. There are two domain expert groups evaluating benchmark scenario indicators the Timber Assessment group (NC TA) and the Environmental Risk Assessment group (NC ERA).

The NCLM-I is wrapped in a human network of domain experts, special interests, stakeholders and decision makers. The NC DSS, NC TA and NC ERA provide a system for experts to explore the decision space, they can evaluate the existing management regimes by evaluating indicators, conducting experiments and problem bounding. Experts gain an understanding of the landscape, wildlife and vegetation and how they would change given certain human interventions and natural processes. The critical point in this decision system is the interaction of the domain experts with the table, it is this human system that expresses the knowledge and information of the computer system to the decision process.

In phase 1 the NC ERA conducted post simulation analysis for coarse filter biodiversity, grizzly bears (*Ursus Horbilis*), mountain goat (*Oreamnos americanus*) and marbled murrelet (*Brachyramphnus marmoratus*) based on indicator reports generated by the NCLM. The species assessed were identified by British Columbia wildlife experts, the NC GTT and the NC LRMP table as species of concern and a detailed analysis was feasible for phase 1. In workshops, the GTT, topic experts and modellers identified planning indicators[3] for assessing impacts on biodiversity (Holt and Sutherland 2002), marbled murrelet (Steventon 2002), mountain goats (Pollard 2002) and grizzly bears (Hamilton 2002). Timber indicators mimic those used in Timber Supply Reviews (e.g., annual harvest volume). The main factors affecting each planning indicator were also discussed during these workshops.

[3] Planning indicators are elements of the landscape that link closely with the value of interest, that respond to management strategies and that can be modelled over time. Values are too general to be modelled directly.

2.0 Overview of the North Coast LRMP Area

2.1 Area Summary

The North Coast LRMP area is located on the northern coast of British Columbia (Figure 2.1).

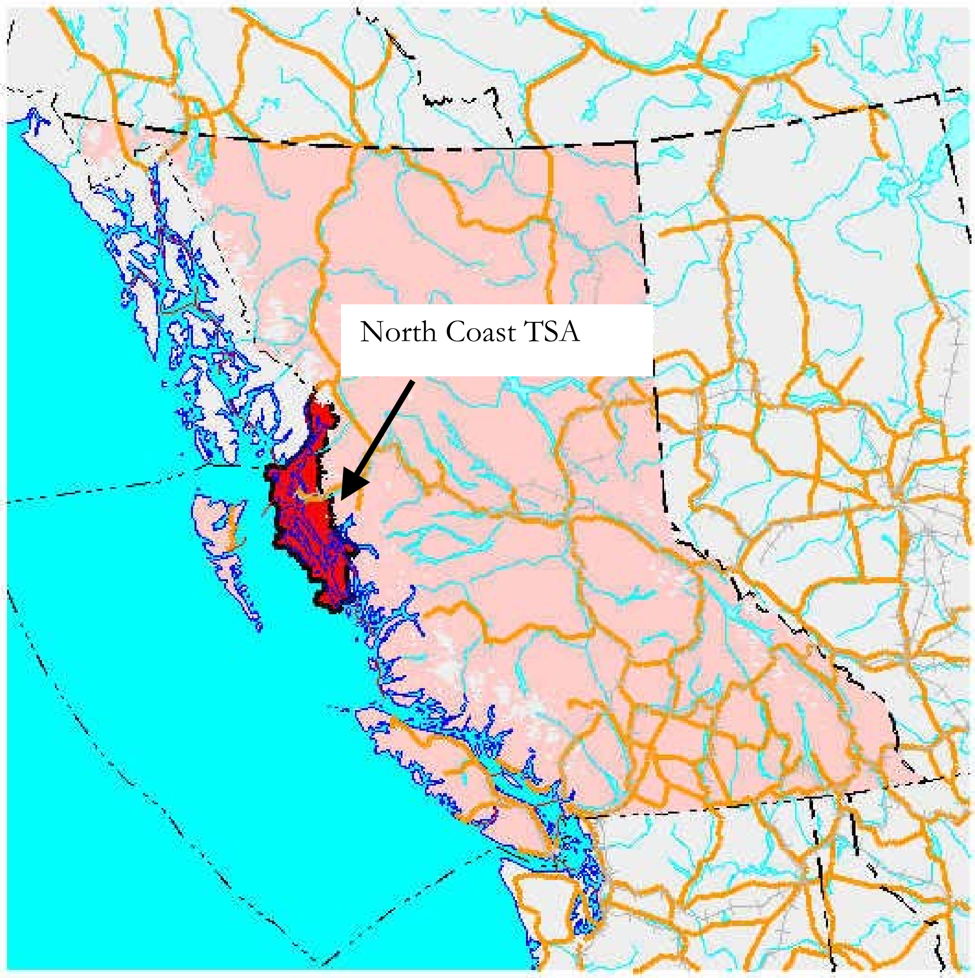

Figure 2.1. Location of the North Coast LRMP.

The North Coast LRMP area is approximately 1.6 million ha in size and includes Khutzeymateen Provincial Park. Being primarily temperate rainforest the area is of global significance. The LRMP area is dominated by stands of old growth red cedar, western hemlock, amabalis fir, spruce and cottonwood. The area includes grizzly bear, marbled murrelet, goshawks and mountain goat habitat. It has a wide variety of non-forestry land uses, including recreational, protected areas, and private land (MoF 2002).

Blow down is considered the most common disturbance in the TSA impacting approximately 8,050 m^3/year. An additional 2,034 m^3/year is disturbed due to fire for a total of 10,084 m^3/year in unrecoverable losses (MoF 2002).

Most harvesting in the North Coast LRMP area is done with a clearcut harvesting system, and restocking takes place with planting (usually after 1 to 2 years). In the recent timber supply review (TSR;MoF 2002), the AAC is presently set at 573,624 m^3/year for 60 years then stepping down to a long term sustainable harvest level of 462,000 m^3/year.

The NC LRMP landbase divides into different types of biophysical units: ecosections, subzones and subzone variants of the biogeoclimatic ecosystem classification system (BEC), broad ecosystem units (BEUs), analysis units (AUs; originally used for timber supply analysis, but also used for ecological risk assessment) and riparian areas.

2.1.1 Ecosections

The Hecate Lowlands, Kitimat Ranges and Southern Boreal Ranges cover most of the landbase (44%, 34%, 17% respectively), Meziadin Mountains covers 4% and Nass Mountains covers ¼ %.

2.1.2 Biogeoclimatic subzones

The landscape includes the CWH (68%), MH (25%) and AT (7%) zones. The CWH vh subzone is the most widespread (43%), followed by the CWH vm (18%) and MH mm (18%). The CWH wm and MH wh cover about 6 % and 7% respectively. The CWH ws covers 1%.

Each ecosection is mainly dominated by two forested subzones, with the exception of SBR (Table 1): By area, most subzones occur mainly in one ecosection with the exception of the MH mm which divides across three ecosections (Figure 1).

Table 1. Subzones that cover the majority of area in each ecosection.

Ecosection	Major Forested Subzones
Hecate Lowland (HEL)	CWH vh2, MH wh
Kitimat Ranges (KIR)	CWH vm, MH mm
Meziadin Mountains (MEM)	CWH ws, MH mm
Nass Mountains (NAM)	CWH vm, MH mm
Southern Boreal Ranges (SBR)	CWH vh2, wm, MH mm

2.1.3 Broad Ecosystem Units

Many BEUs occur almost entirely within one subzone (Figure 2). Some BEUs occur ("occur" refers to covering more than 0.5% of the subzone) in several subzones (Figure 3)[4]. Avalanche tracks occur in all subzones except the CWH vh. They are most common in the

[4] The Mountain Hemlock subzones and the Alpine Tundra zone were combined when BEUs were examined.

MH/AT zone. Rock occurs in all subzones except the CWH ws. Large and small lakes show up in the CWH vh2 and CWH vm. Bogs dominate the CWH vh2, but do not occur in the other zones. Wetlands occur in the CWH vm, ws and wm, but not in the CWH vh2 and MH/AT. Most subzones are dominated by one to six BEUs (Figure 3). The MH/AT contain all the alpine and subalpine openings and Glaciers.

Different subzones tend to have different forest types. Cedar-hemlock covers most of the non-bog CWH vh2 and about 10% of the CWH vm. Fir (amabilis)-hemlock dominates the CWH vm and ws. The CWH vm and ws contain spruce-cottonwood riparian forests (about 1% of each subzone). The CWH wm is dominated by hemlock-spruce forest. The MH/AT zone is dominated by mountain hemlock-fir and yellow cedar forests.

2.1.4 Analysis units
Analysis units describe combinations of leading species (cedar, hemlock and fir, spruce, cottonwood) and site productivity classes (SI < 15, 15 < SI < 22, SI > 22). Note that cedar leading includes red cedar and yellow cedar leading and hemlock-cedar mixes. Cottonwood is not divided into productivity classes.

Major cover
About 38% of the LRMP area is not forested (i.e., not covered with AUs). Two analysis units dominate the landbase: low productivity cedar and low productivity hemlock-amabilis fir (hem-bal). The remaining seven analysis units comprise only 6% of the landbase (see minor cover below).

Low cedar is proportionally the most abundant analysis unit in the CWH vh, vm and wm (Figure 5). The CWH ws has a high proportion of low hem-bal and of other (mainly high and medium) analysis units. The MH zone is dominated by non-forest cover; of the forest, low hem-bal makes up the highest proportion of the MH mm1 and mm2. Low cedar dominates the forested portion of the MH wh and covers part of the MH mm1.

Minor cover
Overall, medium sites are more abundant than high sites; all high sites account for less than 1% of the LRMP area (Figure 6). Hem-bal (high and medium) is more abundant than cedar or spruce. More medium cedar occurs than medium spruce, but more high spruce occurs than high cedar. Low spruce is slightly more abundant than high or medium spruce, but much less abundant than low hem-bal and low cedar.

Species dominance differs by subzone. The CWH ws is dominated by hem-bal. The CWH vh2, wm, vm1 and vm2 contain more balanced proportions of hem-bal and cedar.

The CWH ws1 has the highest proportion of high and medium sites, mainly hem-bal, but covers a small portion of the LRMP area. The CWH vm1 has the next highest proportion of high and medium sites, but contains fewer high sites and the medium sites contain approx. equal amounts of cedar and hem-bal. The MH subzones contain few high and medium sites.

2.2 Overlap of analysis units and broad ecosystem units

On the North Coast, broad ecosystem units include six forested types, two bog types, one wetland type, several non-forest types and one undefined type. On the forested part of the landbase, BEI and AU polygons overlap, both describing variation in forest cover. BEUs are a coarse-resolution inventory (1:250,000); AUs are finer (1:20,000).

BEU and AU polygons do not correlate well for cedar and hem-bal AUs, but correlate quite well for spruce and cottonwood[5]. About 75% of spruce AUs fall in the spruce-cottonwood and the wetland BEUs. About 15%, however, fall within a fir-hemlock BEU. High sites occur more frequently on the spruce-cottonwood BEU; low sites occur more frequently in the wetland BEU (and also in bogs). Similarly, about 90% of cottonwood AUs fall on spruce-cottonwood and wetland BEUs.

The cedar AUs, which include the hemlock-cedar forest type, occur most frequently on the hemlock-cedar BEU as expected, but many fall unexpectedly in the balsam-hemlock, hemlock-spruce and wetland BEUs (Figure 9). Low cedar AUs occur mainly in red cedar and yellow cedar bogs and in yellow cedar-mountain hemlock BEUs.

The hem-bal AUs, which exclude the hemlock-cedar forest type, occur most often on the balsam-hemlock BEU (as expected), but also on the spruce-cottonwood and wetland BEUs (Figure 9). High site hem-bal AUs occur most often on spruce-cottonwood BEUs. Low site hem-bal AUs occur most often on mountain hemlock – balsam and hemlock – spruce BEUs.

2.3 Streamside riparian forest

Riparian areas (defined as areas within 50m of mapped streams for this analysis) account for 5% of the total landbase (Table 3). The CWH ws contains higher than average proportions of riparian forest (about 10%). The MH subzones contain lower than average proportions (about 1%).

Of all the analysis units, the cottonwood AU occurs most commonly (36% of its area) in riparian areas followed by high, medium and low productivity spruce AUs (28%, 27% and 18% respectively; Table 3). Riparian forest in other AUs ranges from 6% to 13%. Almost half the high spruce AUs in the CWH ws fall in riparian areas. About ¼ of the high productivity hem-bal AUs in the CWH wm and ws fall in riparian.

Table 3. Percent of each ecosystem (analysis unit within subzone) falling within 50 m of a stream.

AU	AT	MHmm	MHwh	vh2	vm	wm	ws	**All subzones**
Cot	0	20	0	0	44	42	26	**36**
Cw-h	0	0	0	6	9	8	0	**7**
Cw-m	0	14	3	11	7	14	13	**10**

[5] Area of each BEU polygon was standardised to generate the probability of AU occurrence by BEU type.

Cw-l	1	3	2	7	7	7	7	**7**
HB-h	0	20	0	5	12	25	23	**13**
HB-m	0	12	5	11	13	13	12	**12**
HB-l	2	5	2	7	7	6	8	**6**
Sp-h	0	0	0	18	30	33	48	**28**
Sp-m	0	11	5	22	29	24	15	**27**
Sp-l	0	9	5	16	23	15	13	**18**
All AUs	**0**	**1**	**1**	**7**	**7**	**6**	**10**	**5**

2.4 Other riparian forest

Other riparian forest is identified directly by BEUs or occurs adjacent to BEUs (Table 4).

Table 4. Percent of NC landbase in selected BEUs.

Broad Ecosystem Unit	Percent of NC landbase
cedars – shore pine bog	16.76
estuary	0.00
large lake	0.58
small lake	0.67
slow perennial stream	0.21
Sitka spruce – black cottonwood riparian	0.40
subtidal marine	0.04
wetland	0.35
yellow-cedar bog forest	6.70

2.5 Timber harvesting landbase

The THLB is the portion of the NC landbase, that is forested, productive and operable (i.e., suitable for logging) and not constrained by other land-use designations (e.g. protected areas). Forest covers 66% of the LRMP area; productive forest covers 48%. The THLB covers only 7.4% of the LRMP area (or 15.5% of the productive forest), because much of the productive forest is technically or economically challenging to harvest.

Analysis units cover 62% of the LRMP landbase. As expected, most of the area of each analysis unit falls within the forested portion of the NC landbase (range 98% - 100%)[6]. With the exception of low productivity cedar and hem-bal, most AUs also fall in <u>productive</u> forest (range 97% - 99%, except for low cedar and low hem-bal). Twenty-six percent of low cedar and 20% of low hem-bal fall outside of productive forest. Note that low productivity AUs include stands with SI below 10, unlike analysis units defined for timber supply analysis.

Although a small proportion of the LRMP area falls in the THLB, the proportion varies by AU. In general, a small proportion of low productivity sites occur in the THLB, most low sites having less than 20% of their area in the THLB. Low hem-bal in the CWH ws and low spruce in the CWH vm have about 30% and 40% of their area in the THLB respectively. Inclusion of very low sites (SI<10) with low sites may confound interpretation (e.g., all very low sites may be outside the THLB).

[6] Analysis units, by definition, should fall on the forested landbase; GIS slivers and rasterization may account for discrepancies?

Most high and moderate sites have more than 40% of their area in the THLB, however, high and medium cedar and spruce sites in the MH zone have less than 40% in the THLB (except for high spruce sites in the MH mm). Sites with more than 60% of their area in the THLB include three high cedar sites, two medium and four high hem-bal sites and three medium spruce sites. Four high spruce sites have more than 55%, but less than 60% in the THLB.

3.0 The North Coast Landscape Model (Phase I)

This part of the document briefly describes the concepts (main assumptions) used in the Phase I North Coast Landscape Model (NCLM-1). It describes the planning indicators calculated and the ecological and management processes modelled. Appendix 3 describes model testing and the benchmark scenario. We anticipate developing a Phase II model to address new issues raised by the LRMP Table and to include important indicators and processes that were not included in the Phase I model because of time limitations, these are discussed in details in section 3.7.

3.1 Overview of the SELES Model for the North Coast LRMP

The North Coast Landscape Model was developed with SELES (Spatially Explicit Landscape Event Simulator; Fall and Fall 2001), a tool for building landscape models that supports a collaborative framework (Fall et. al 2001). It combines a simulation engine with a spatial database and a relatively simple landscape modelling language to allow rapid development of landscape simulations custom-designed for given objectives.

The SELES model constructed for the North Coast LRMP consists of a linked set of submodels. There are two classes of submodels. First, there are models of landscape change that include forest growth, forest harvesting and roading. Second, there are models that calculate and output indicators for forestry, course scale biodiversity, grizzly bears, mountain goats and marbled murrelet. The resulting integrated model is called the North Coast LRMP Landscape Model (NCLM).

The first step in the development of the NCLM-I is to calibrate harvesting and forest growth with the timber supply analysis done aspatially using FSSIM. This step ensures that the NCLM-I is accurately modelling timber supply assumptions (Fall 2002) in the North Coast LRMP area. The next step is to incorporate components specific to the LRMP needs. In the first phase, this includes making the harvesting sub-model spatial and to include road development, and to output a suite of indicators of interest for the LRMP.

The NCLM-I can be viewed most simply as an “input-process-output” system (Figure 3.1). The inputs consist of digital, raster maps describing the land base and parameter files that control model behaviour. The outputs include text files that record various aspects of the condition of the land base (e.g. growing stock, age class distribution) and raster maps of habitat patch types (e.g. young, mid-age and old forest patches) during the simulation. Output is used both to verify correct model behaviour and as indicators for values of interest. Via the user interface of SELES, the model landscape can also be viewed during model runs. The “process” portion of the North Coast Landscape Model consists of a set of sub-models that simulate ecological and management-induced change (e.g., stand ageing, harvesting). The model projects initial landscape conditions (described by input maps) forward through time, using processes represented in the sub-models (and controlled partially by input parameters) to create a model of landscape dynamics and to estimate future landscape conditions (summarised in output files and spatial maps). Users create new scenarios mainly by modifying maps of management zones and parameters affecting management and natural disturbance processes.

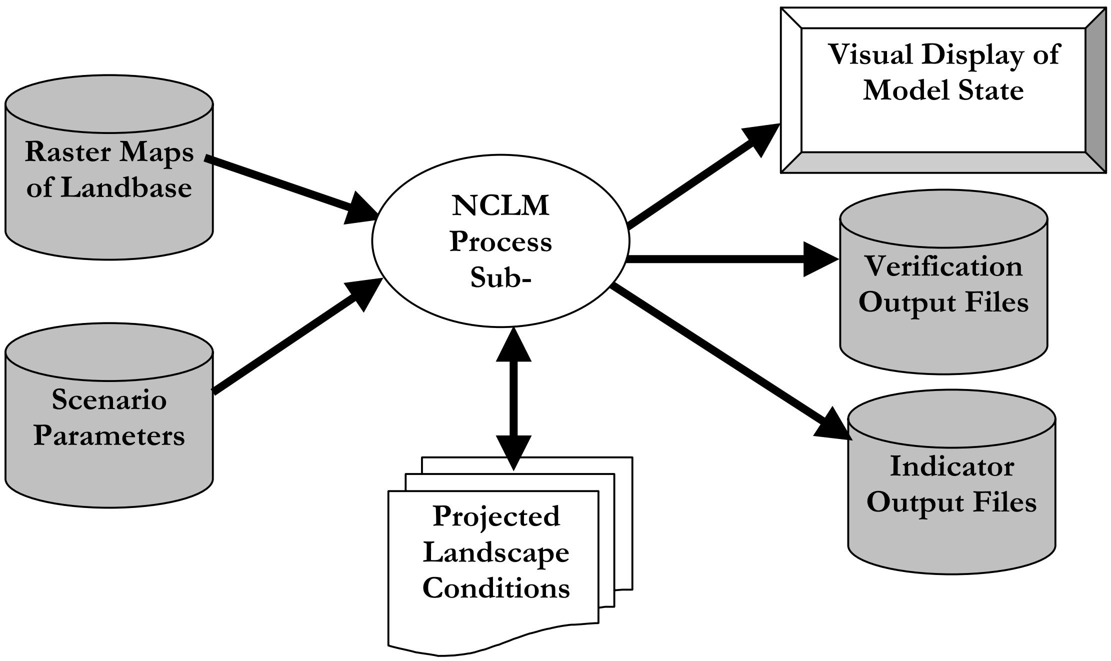

Figure 3.1. General structure of the North Coast Landscape Model. Spatial and tabular information specify the starting conditions, while scenarios set up a desired set of parameters to run. The process models project landscape conditions through time, and output is available visually and in output indicator files.

The NCLM-I simulates specified processes; it does not determine optimal solutions. The model is stochastic, generating disturbance events in space and time using probability distributions. Thus, each model run may produce different results and the model must be run several times to determine averages and ranges for each scenario modelled.

The overall model design is shown in Figure 3.2. All data layers were derived from information from the NCLRMP warehouse (See appendix 2). Management zones include landscape units, biodiversity emphasis options (BEOs), visual quality zones and resource management zones (protected areas, private land, general and management). Species are represented using forest stand type groups, based on leading species, and forest productivity groups (see section 3.3 for more details).

Succession in phase 1 of the NCLRMP implementation considers forest aging only. Phase 2 of the NCLM-I will use successional trajectories for each subzone based upon stand type and productivity group.

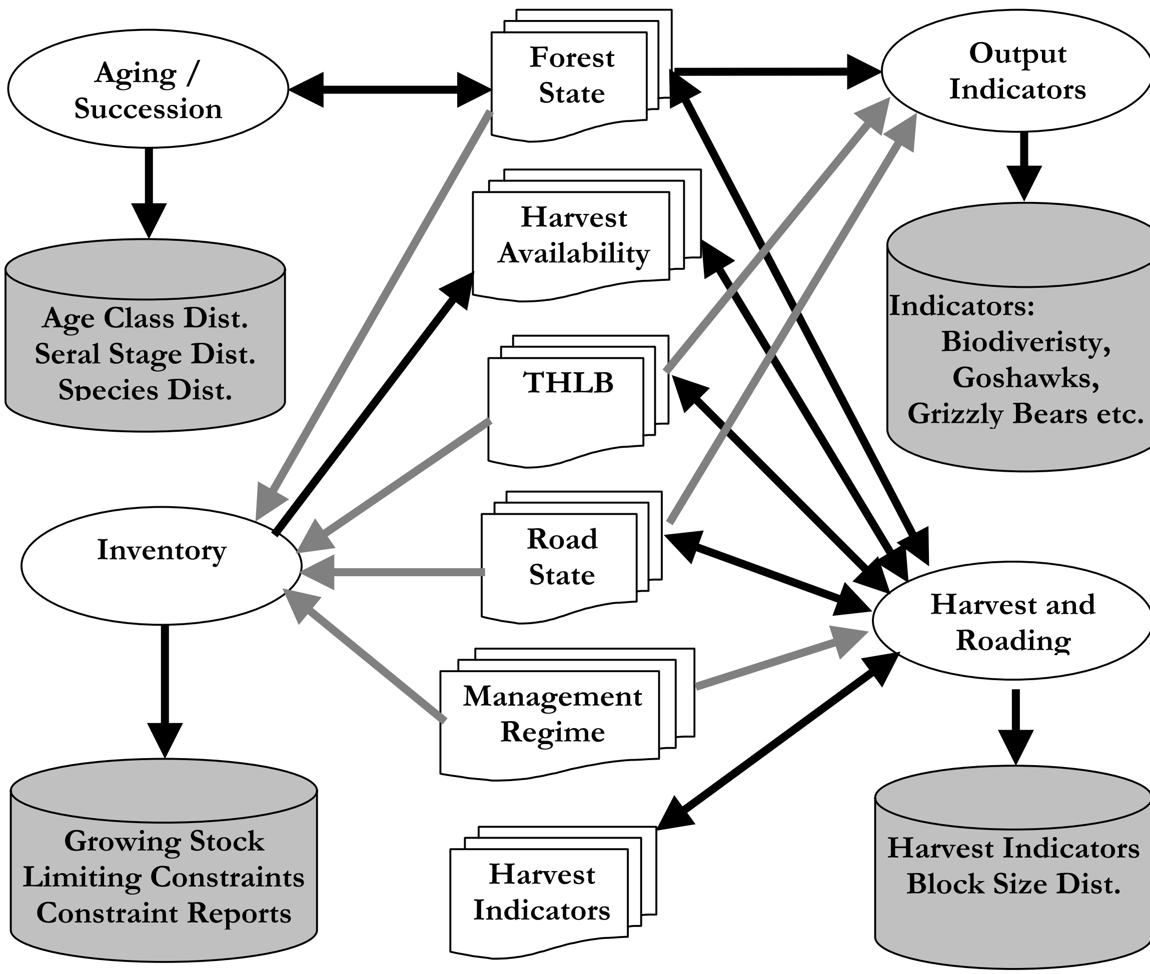

Figure 3.2. Overall conceptual design of the North Coast Landscape Model. Each main modeled process is shown as an oval, while the main parts of the landscape state (represented as spatial data layers and tables) are shown in the centre, and output files are shown as grey drums. Arcs indicate that a process depends on and/or modifies the connected landscape state

The forest is represented using species and age. Harvest availability indicates which cells are available for harvesting according to harvest policy and rules as specified in the timber supply analysis. The timber harvesting landbase (THLB) is modeled spatially as a percentage of each cell in the THLB. We computed analysis units (AUs) using the same set of rules as used in the timber supply review (TSR) and track the volume of growing stock in each cell based on input yield curves, analysis unit and stand age. The road state tracks current and developed roads.

In addition to the spatial information above, a variety of aspatial parameters and global variables are used in the NCLM. Aspatial parameters include the AAC, minimum harvest age, management objectives, and species succession probabilities. Control parameters and other variables are described in the sub-model documentation (see Appendices).

3.2 Spatial and Temporal Resolution

The NCLM-I uses 1ha cell resolution, where each cell is 100m x 100m square. Spatial entities below this resolution, such as stream buffers, are modelled as a percent of a cell. The NCLM-I models time in 1 year steps, it outputs indicator attributes at years 0, 20, 50, 100, 200 and 250. The ordering of landscape change is harvesting then forest growth. The time horizon for each run of the model is generally 250 years, but can be varied depending on the simulation objective.

3.3 Input Data

Digital maps describe land units that are used by a modelled process or that are used to create indicators. All maps came directly from or were derived from information from the NCLRMP warehouse. Digital maps describe physiography, ecology, timber values, land-use units and roads (See appendix 2 for a complete inventory list).

3.3.1 Physiography

The NCLM-I uses ocean, streams, lakes and wetlands layers. Riparian buffers are represented as a percent riparian of each cell

3.3.2 Timber Analysis Units

Timber supply analysis categorizes forest stands by site productivity class and tree species into "analysis units". These analysis units serve as the basis for modelling tree growth. The NCLM-I assigns a different growth curve to each of the analysis unit (Table 3.1). Initial analysis units are estimated using the same rules as in the TSR: stand age, planning area, site index, inventory type group, and BEC (for units that differentiate based on ESSF zones).

Table 3.1. Definition of analysis units

	Criteria	
Analysis unit	**Inventory type groups**	**Site index range (metres @ 50 years)**
1 Cedar, Hem/cedar: High	C, CH, HC ~ 9, 10, 11, 14	> 22
2 Cedar, Hem/cedar: Med	C, CH, HC ~ 9, 10, 11, 14	15-22
3 Cedar Hem/cedar: Low	C, CH, HC ~ 9, 10, 11, 14	< 15

4 Hem, Bal: H	H, HB, HS, H DEC, B, BH, BS ~ 12, 13, 15, 16, 17, 18, 19, 20	> 22
105 Hem, Bal: H <u>w</u> thinning	H, HB, HS, H DEC, B, BH, BS ~ 12, 13, 15, 16, 17, 18, 19, 20	> 22
6 Hem, Bal: M	H, HB, HS, H DEC, B, BH, BS ~ 12, 13, 15, 16, 17, 18, 19, 20	15-22
107 Hem, Bal: M <u>w</u> thinning	H, HB, HS, H DEC, B, BH, BS ~ 12, 13, 15, 16, 17, 18, 19, 20	15-22
8 Hem, Bal: L	H, HB, HS, H DEC, B, BH, BS ~ 12, 13, 15, 16, 17, 18, 19, 20	< 15
9 Spruce: H	21 - 26	> 22
10 Spruce: M	21 - 26	15-22
11 Spruce: L	21 - 26	< 15
12 Cottonwood:	AC ~ 35, 36	All
13 Pine	27-32	All
14 Deciduous	37-42	All
23 Cedar Hem/cedar: Low	C, CH, HC ~ 9, 10, 11, 14	< 15
26 Hem, Bal: M	H, HB, HS, H DEC, B, BH, BS ~ 12, 13, 15, 16, 17, 18, 19, 20	15-22
28 Hem, Bal: L	H, HB, HS, H DEC, B, BH, BS ~ 12, 13, 15, 16, 17, 18, 19, 20	< 15
30 Spruce: M	21 - 26	15-22

42 Cedar, Hem/cedar: Med	C, CH, HC ~ 9, 10, 11, 14	15-22
43 Cedar Hem/cedar: Low	C, CH, HC ~ 9, 10, 11, 14	< 15

Analysis units 42 and 42 are identical to units 2 and 3, except that they occur in marginally operable areas and harvesting by helicopter is expected.

3.3.3 Ecological Units

The following ecological units or strata are used in conjunction with stand age and height class to create indicators.

- Ecosections
- BEC Subzone Variants
- Broad Ecosystem Units
- Landscape Units
- Watersheds
- Timber Supply Analysis Units as ecosystem surrogates (Banner 2001)

3.3.4 Administrative Units

Different types of administrative units divide the landscape and influence model behaviour (Table 3.2). To be consistent with Ministry of Forests timber supply modelling logging is modelled over the TSA, however only the portion within the LRMP area is reported on. TFL 25 lies within the LRMP area but is not included in the logging model at present. In addition, the portion of the TSA on Princess Royal Island is not included in the LRMP area.

Table 3.2. Administrative units divide into four groups, each having different model assumptions.

Administrative Units	Model Assumptions
Parks	no logging, no new roads, natural age class distribution
Managed Forest-TSA	harvesting occurs within timber harvesting land base
Managed Forest-TFL	not part of analysis area
Private land & Settlement	assume not forested

3.3.5 Forest Management Zones

Management zones divide the timber harvesting land base. Zones include areas with significant non-timber values and areas to be managed primarily for timber production. Zones that emphasise management of the same forest value belong to the same "zone type" and are managed in the same way. Forest cover rules, applied to zones, limit harvesting to protect non-timber values (see below). Typical types of zones include

- VQO: visual quality objective zones
- Biodiversity: biogeoclimatic zones within landscape units - with assigned biodiversity emphasis (low, med, high)
- IRM: integrated resource management zones

- Wildlife: management zones for selected species
- Community watersheds: management zones for water supply

3.3.6 The Timber Harvesting Land base (THLB)
Forest harvesting occurs within the THLB. That is, harvesting occurs on productive forest land within the operable land base in areas not excluded from harvesting (Table 3.3). Productive forest land is capable of growing commercial tree crops. The operable land base defines, at a coarse scale, the region where harvesting is technically, environmentally and economically feasible. Steep high elevation slopes with low volumes may be defined as inoperable, for example. Within the operable land base, where finer scale terrain or economic considerations warrant or where non-timber values take precedence, an area may be entirely excluded from the THLB. Area is also excluded to account for riparian management and for road access within blocks (during simulation). All areas within the THLB may be harvested subject to the forest cover constraints (e.g. minimum old forest requirements). Area removals are modelled as a percentage of a cell that is available for harvest.

Table 3.3 summarizes the categories of areas excluded from the timber harvesting land base and shows the total area of the timber harvesting land base.

Table 3.3. Timber harvesting land base for the North Coast Timber Supply Area -- Current Conditions (Benchmark Scenario)

Land base Classification	Land base reductions (hectares)	Land base area (hectares)
North Coast TSA		**1,875,334**
Not managed by MoF	191,104	
Non-forest	833,436	
Productive forest managed by the MoF		**850,794**
Non-commercial cover	335	
Environmentally Sensitive Area	233,590	
Low growth potential	281,131	
Problem species	14,046	
Inoperable	171,554	
Existing roads	1,697	
Riparian reserve zones	11,118	
Timber harvesting land base		**137,323**

3.3.7 Roads

The NCLM-I uses maps of existing roads to identify initial conditions. It uses maps of projected roads, drawn by forest engineers and planners, to simulate future development of main roads. Spur roads and roads in unmapped areas of the THLB are built within the NCLM by connecting short segments to the mapped road network as development progresses.

3.3.8 Parameter Files

In addition to the spatial information described above, a variety of parameters are used in the NCLM. Influential parameters include tree growth curves, minimum harvest ages, annual allowable cut, and forest cover rules (See Fall, 2002 for a full list of parameter files). Along with zoning, forest cover rules provide a means of emphasising different values in different model scenarios.

Within zones, harvesting is restricted by specifying forest cover rules that require a minimum amount of old forest or of mature and old forest combined, or a maximum amount of young forest. The proportions of each forest age class required and the definitions of each age class vary among zone types.

Forest cover rules do not necessarily apply to a single zone, rather they apply to all zones of the same type within a landscape unit[7]. To the extent they are ecologically distinct, landscape units provide a logical scale for applying forest cover rules. They are typically used as a proxy for managing for coarse filter biodiversity within TSR. The size of management zones, as influenced by the applicable landscape unit and land base influences the effect of forest cover rules. Large zones potentially allow a concentrated disturbance; several smaller zones (of the same type) distribute the disturbance.

3.4 Process Models

Models of landscape change include forest growth, forest harvesting and access development. Natural disturbance processes are not presently modelled because few stand-destroying disturbances occur in the North Coast. Within-stand disturbances, caused by disease, insects and windthrow, are not explicitly modelled, however, their timber-related impacts are accounted for in estimates of volume harvested. Succession (changes in dominant tree species) is not modelled in phase 1.

Forest management strategies used in the model control the amount and distribution of logging disturbance within zones, as well as amount of location of roads developed.

3.4.1 Forest Growth

The forest growth sub-model was designed to age forested cells annually, to maintain analysis units, to update global tracking variables and to enable post-harvest planting and forest growth to be modelled. Stand ageing simply increments the age in each forested unit by one year up to a maximum age (950 years). Age is frozen at time 0 outside of the THLB in an effort to maintain forest age class distribution consistent with the historical disturbance

[7] Landscape units describe geographic regions approximately analogous to large watersheds.

regime. Because the Stagoo, Anyox and Ohl Landscape Units have been affected by historic fumekill, and their current seral stage distribution is not consistent with the disturbance regime, and hence the forested area in these landscape units is aged. This assumption change in the timber supply model was approved by BC Ministry of Forests (H. Burger pers. comm.). We assessed the impacts of this modified assumption, and found that this change had little effect on timber supply indicators (Appendix 3).

Initial analysis units are estimated using the same rules as in the TSR: stand age, planning area, site index, inventory type group, and BEC (for units that differentiate based on ESSF zones). REA zones include visual quality, and integrated resource management (IRM) zones. For most REAs, these amounts are computed for the productive forest, except for the IRM zone, which is computed over the THLB forest. Amounts for biodiversity are computed over the productive forest.

Stand volume at a given age on a given analysis unit is estimated by a yield table look-up. Planting is assumed to occur in all stands after harvest. Following their first harvest, stands move to a "managed stand" analysis unit, having a different associated growth curve. Managed stands grow faster than natural stands.

3.4.2 Harvesting Model

The harvesting sub-model was implemented using the SELES Spatial Timber Supply Model and captures the identical management regimes, assumptions and uses the same data as the base North Coast LRMP Timber Supply analysis done using FSSIM (MoF 2002). Instead of harvesting portions of analysis units, as FSSIM does, the NCLM-I implementation harvests the THLB portion of 1 hectare cells within the eligible analysis units that meet the "relative oldest first" harvest rule to achieve the harvest rate (m^3/yr) using volume yield information (curves that describe volume for different types and ages of forest). A description of the logic is given in table x. In a spatial context this would be analogous to harvesting 1 hectare cut blocks. Height is assigned to each stand based on height curves generated from the North Coast LRMP Timber Supply Analysis.

There is the potential that there will be an increase in forest fragmentation due to cell based harvesting vs cutblock based harvesting. Patch and road statistics should be interpreted cautiously.

Table 3.4. Steps used to choose cells in the logging sub-model.

1. Limit harvesting disturbance to eligible land:
    - the timber harvesting landbase;
    - eligible zones (age class structure allows harvesting; status updated with each disturbance);
    - conventional operating areas within 2 km of an existing road or the ocean;
    - helicopter operating areas within 5 km of a helicopter drop site, double line stream, ocean or an existing road;
    - stands older than minimum harvest age;
    - stands without adjacency constraints (i.e., stands not next to recently harvested stands).

2. Assign priority of <u>new</u> harvesting to each map cell based on
- stand age.
- select <u>new</u> cell location (first map cell to harvest) based on eligibility and priority:
    - if in the conventional operating area build a road from the cell to the nearest road cell (see section 3.4.4)
- harvest the cell and set stand age to zero;
- update tracking variables (e.g. annual volume harvested and seral distribution for applicable zones);
- reduce the area of THLB in the cell to account for new access roads, if in conventional operating area, and for within-block development.

In addition to logging, the NCLM-I also tracks growing stock (Appendix 3). This computes the volume and area in the various forest and management conditions (e.g. THLB, mature, available for harvest) and zones (e.g. VQOm). The logging sub-model outputs the area of THLB that is unavailable for harvest (*locked-up* or *limited*) due to maturity, access or management objectives (e.g. adjacency or BEOs) (See Fall 2002 for further discussion).

3.4.4 Road and Helicopter Access

With cutblock (1 hectare cells in this case) spread, the sub-model assumes that roads, skid trails and landings develop. Within-cutblock (cell) development (roads, skid trails and landings) reduces the net forested area and hence future volumes harvestable. In addition, a pre-defined average aerial impact of main road access is applied to each block, further reducing net forested area. Within-block development and average road impacts apply only when a natural stand is harvested the first time.

The logging sub-model explicitly connects cutblocks to the main road network. It connects "landings" by straight-line "spur" road segment to the nearest existing or future road location. The first cell of a block is considered to be a landing, and at each 40ha size threshold, another landing is created (i.e. the model assumes approximately one landing per 40ha of forest harvested). Spur roads may connect to an existing mapped road, a previously created spur road or a future mapped road. In the latter case, the future segment is then activated along with any "downstream" future roads to the nearest existing road. This method of modelling road development allows an approximation of the amount of road required to meet a harvest request, allows access restrictions to influence harvesting while harvesting reduced access constraints over time, and allows roads to be used in the computation of output indicators. In the phase 1 implementation there is a plethora of spurs that should not be included as an indicator of road development, since each block is a single cell and so a spur road is built for each hectare harvested. Phase 2 will enable spatial cut block modelling, and hence allow interpretation of spurs.

Analysis units 42 and 43 are in areas that are marginally operable and helicopter logging is expected. The NCLM-I logs these stands, but does not update the roads. These sites are assumed to be within 5 km of a helicopter drop site, a double line river, ocean or built road.

Roads are not constructed to make all heli areas accessible, although they would become accessible as the road network develops.

3.5 Output Indicators

The North Coast Landscape Model predicts changes in the values of indicators of timber, coarse filter biodiversity, grizzly bear habitat, mountain goats and marbled murrelet habitat in response to modelled processes. Many of the timber indicators are used to verify model behaviour. A detailed listing of indicator files is in appendix 4.

3.5.1 Timber

The timber model follows the SSTSM (Fall 2002). Growing stock, defined as the volume in cubic metres for certain strata in the landscape, is the primary indicator used in timber supply analysis to determine sustainable harvest projections. Secondary indicators include harvesting summaries, age class distribution and limiting constraints.

The growing stock sub-model assesses and outputs the growing stock and forest age class structure as well as updating a layer with volume/ha in each cell of the landscape based on the TSR volume tables, analysis unit, stand age and THLB. The indicators tracked include growing stock (m^3) and area (ha) for various components of the forest, including forest in and out of the THLB, Resource emphasis areas, BEC zones, and areas under various constraints.

Harvest Statistics: A range of output values that track key aspects of the harvesting process. All are means across the period and value at period

- annual volume harvested
- area treated (which equals the area harvested plus the area retained)
- area harvested
- area retained
- mean age harvested
- percent of harvest target achieved
- volume per hectare harvested
- harvest profile in terms of the proportion of harvested stands by leading species in the inventory type groups
- area and volume accounted for as non-recovered loss
- estimated kilometres of spur roads constructed

This is stratified by contributing (THLB) and non-contributing portions of the landbase. In addition, age class structure is also summarized by the main seral ages (e.g., young: $\leq$ 15 years; immature: 15 to 120 years; mature 120 to 250 years; old: $\geq$ 250 years).

Limiting Constraints: Track the area of forest unavailable for harvest due to the various objectives. This is output as net and gross values, where the net value is the incremental area constrained after preceding constraints have been accounted for, and the gross value is the total amount the would be constrained independent of the other constraints. The primary order of constraints applied is:

- minimum harvest age

- road access (if enabled)
- adjacency
- partial harvest re-entry interval
- forest cover constraints (applied in order specified in input file)

3.5.2 Coarse Filter Biodiversity
See appendix 4.

3.5.3 Grizzly Bear Habitat Effectiveness
See appendix 4.

3.5.4 Mountain Goats
See appendix 4.

3.5.4 Marbled Murrelet Habitat
See appendix 4.

3.7 North Coast Landscape Model Phase II

LRMP scenario analysis will be undertaken in phase two. Spatial rules following access constraints, block adjacency and block size distributions will be evaluated. Because the timber supply model is captured exactly in SELES the effects of the spatial rules can be easily interpreted. Without the model alignment it is challenging to isolate the spatial effects from potential model differences.

The analyst who conducted the benchmark scenario timber supply analysis will be joined by operational foresters and modellers to form a timber indicator team that will interpret the spatial timber modelling effects and to direct phase two spatial timber supply alternatives including variable retention. This group will then work with the table and other forestry and ecosystem management experts, the NC GTT and the NC LRMP table to represent forest access, operations, etc. to the NC LRMP process.

Succession in phase 2 will be implemented based on an ecological background study for the stand types and biogeoclimatic zones in the North Coast (Roberts and McLennan 2002). The report categorizes stands into stand types and into productivity groups. Site series from the PEM will be correlated to the stand types and used as productivity groups. The model runs in a one-year time step. It ages all forest stands in the landscape. It also determines post-disturbance recovery (i.e. initial species) and species changes over time (e.g. successional change from aspen to conifer types). This is done using a state-transition matrix (Markov chain) with probabilities derived from an empirical analysis of the inventory. Since analysis units are based on site index and inventory type groups, any change in the species requires an update of the analysis unit. To avoid a discontinuous change in volumes for a stand, a smooth transition between volume curves is made when the analysis unit changes.

The scenario analysis will possibly add indicators for Northern Goshawk (*Accipter gentilis*), including canopy crown closure. Crown closure is assigned to each stand based on the existing distribution of crown closure and its relationship to age class, species, analysis unit, and BEC. A predictive ecosystem inventory will be used and an ecosystem overstory species succession model will be implemented. An economic harvesting model will be considered. A mineral assessment (NC MA) is being considered and a preliminary investigation is under way.

4.0 Benchmark Management Scenario

Current management was captured by the BC Ministry of Forests (MoF) following the MoF Timber Supply Branch timber supply analysis methodology (BC Ministry of Forests, 2002). The identical input data, assumptions and management regime was implemented in the SELES Spatial Timber Supply Model (SSTSM) (Fall, 2001). A timber supply alignment was done using SSTSM to match all of the output generated by MoFs Forest Service Simulator (FSSIM) timber supply model. The NC TA uses this information to evaluate and validate timber supply indicators and present base timber supply to the NC LRMP table.

Table 2.3. Present constraints (objectives) on the land base identified in the TSR Benchmark Scenario for the North Coast (BC MoFa, 2002).

Constraint Type	*Specification*	
Minimum Harvest Age	50 – 180 years (depending on site)	
Visual resources	1-25%	< 4-7m tall
Watershed	< 5%	< 5 year
IRMP (adjacency)	<33%	< 3m tall

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Appendix 1: Comparison of Resource Modelling Approaches

Stand vs. landscape

Stand-level models can explore issues related to tree growth, succession, tree species composition, stand structure, partial cutting, commercial thinning and long rotations in an individual stand. Available knowledge limits the widespread application of process-oriented stand models.

Landscape-level models can address issues related to seral stage, road access, volume harvested and management zoning. Landscape models also use outputs from stand-level models or from the literature, expressed in the form of yield curves for example, to model stand conditions over the whole landscape (e.g., FSSIM uses timber yield curves from TIPSY).

Non-spatial vs. spatial

Non-spatial models can simulate changes in amount, but not pattern (although some aspects of pattern may be approximated). They are generally simpler and cheaper to use than spatial models. Spatial models can generate more realistic development patterns and some can measure landscape patterns.

Deterministic vs. stochastic

Deterministic models use rules to determine the time, place and characteristics of events modelled (e.g., harvesting, succession). Given the same set of conditions, the model will always project the same outcome. Such models are appropriate for modelling inherently deterministic processes such as harvesting where economic forces and management objectives largely determine development pattern, at least in the short term.

Stochastic models use probabilities to determine the time, place and characteristics of events. One set of conditions can produce different outcomes. Thus, in order to adequately characterise results, a stochastic model must be run several times to generate a mean and range. Natural disturbance is an inherently stochastic process—the timing, location and intensity of the next disturbance event is not predictable. Deterministic models typically attempt to account for natural disturbance by using an average yearly disturbance. This approach may greatly underestimate the impact of a disturbance. For example, a large beetle outbreak may overwhelm harvesting capacity and impact a significant portion of available caribou habitat, outcomes that could not be predicted by an averaging approach.

Simulation vs. optimisation

Simulation models follow a prescribed set of rules expressed as specific goals (e.g., harvest 100 m^3 each day, oldest first) and simple constraints (e.g., do not harvest more than 30 ha / day). Optimisation models determine the best solution to a more general goal (harvest as much as possible each day) given constraints (e.g., do not harvest more than 30 ha / day). Spatial optimisation models calculate near-optimum solutions rather than true-optimum solutions. Simulation models can generally include more aspects of reality than optimisation models but can consider fewer alternative solutions, (e.g., they can't assess harvesting options among time periods). Simulation models can be stochastic, optimisation models cannot.

Fixed vs. flexible

Most models are fixed. They completely define the scope of a particular problem that may be modelled. They usually have a fairly broad scope to accommodate a range of real problems. Flexible models allow information to be included and processes to be modelled that were not anticipated when the model was developed. Fixed models are generally faster to implement for a specific problem, but if a problem does not match the model's scope, the real problem must be altered, reducing the realism of the analysis. Flexible models have limits, but fewer.

Appendix 2: List of Inventories

North Coast Landscape Model: Coverages Used in SELES

Description	Coverage	Path found	Out item	Out Name
Management Zones				
landscape units	tflu_tnc	$NCLRMP/tsa	lu_name	tflu_lu
current management vqos	tvqo_tnc	$NCLRMP/tsa	vqo	tvqo_tnc
scenic areas	tsce_tnc	$NCLRMP/tsa	name	scenic
nass_partition	tnpt_tnc	$NCLRMP/tsa	nass_parititi on	tnpt_tnc
cclrmp	cclrmp_rmz	$NCLRMP/tsa	name	cclrmp_rmz
operability	hopr_tnc	$NCLRMP/tsa	oper	hopr_tnc
nc_lrmp	qlrmp_nc	$NCLRMP/admin	lrmp	qlrmp_nc
Timber Supply Analysis				
Analysis Unit	atsr_may90 2	$NCLRMP/analysis/ncb c	a_unit	thlb_aunit
age_prj	tfc_tnc	$NCLRMP/tsa	age_prj	tfc_age_prj
itg	tfc_tnc	$NCLRMP/tsa	itg	tfc_itg
type-id_pr	tfc_tnc	$NCLRMP/tsa	typid_pr	tfc_tyid_pr
thlbstat	atsr_may90 2	$NCLRMP/analysis/ncb c	thlbstat	thlbstat
thlbopct	atsr_may90 2	$NCLRMP/analysis/ncb c	thlbopct	thlbopct
thlbmpct	atsr_may90 2	$NCLRMP/analysis/ncb c	thlbmpct	thlbmpct
bec	qbec_tnc	$NCLRMP/tsa	beclabel	qbec_tnc
Spatial Modelling Additions				
Roads-existing,proposed,future	ards_tnc	$MOF/fcfd/dnc/nonstand ard/	*	*
Permanent Roads	ttrn_main_n c	$NCLRMP/forest	*	*
salt (ocean/double line)	tcst_dnc	$AL/carto	ocean-id	ocean
3rd order watersheds	lwsd_nc	$NCLRMP/fish/	gistag	lwsd_nc
Goshawk				
height class	tfc_tnc	$NCLRMP/tsa	htcl_pr	tfc_ht_cl
crown closure class	tfc_tnc	$NCLRMP/tsa	crncl_cl	tfc_cc
spc1	tfc_tnc	$NCLRMP/tsa	spc1	tfc_spc1
Grizzly Bears				
human use	ahuse_griz _nc	$NCLRMP/wildlife/	user_days	human_use
human use - settlement	tsett_nc	$NCLRMP/admin/	settlement	tsett_nc
Salmon biomas	lsalm_griz_	$NCLRMP/wildlife/	salmon_tota	salmon_bm

	nw		l	
GB populations units	qgbpu_nc	$NCLRMP/wildlife/	gbpu_name	gbpu
bei total	qbei_tnc	$NCLRMP/tsa/	qbei_tag	qbei
GB Occupancy	qgbpu_nc	$ARCLIB/nclrmp/wildlife/	status	*See gbpu
Biodiversity				
ecosection	qbei_tnc	$NCLRMP/tsa/	eco_sec	eco_sec
parks/existing protected areas	tpas_nc	$NCLRMP/protecta/	pa_name	tpas_nc
private land	town_tnc	$NCLRMP/tsa/	own	town_tnc
community watersheds	tcwsa_nc	$NCLRMP/admin/	tcws_tag	tcwsa_nc
site index	tfc_tnc	$NCLRMP/tsa/	site_idx	tfc_s_idx
rare ecosytems	trem_nc	$NCLRMP/wildlife/	rare_ss	rare_eco
rich ecosystems	lsfw_nc	$NCLRMP/fish/	RE_RANK	rich_eco
Rivers, Lakes, Wetlands	tfc_tnc	$NCLRMP/tsa/	np_descrip	np_descrip
Other Coverages				
black bear	lwsd_bb_nc	$NCLRMP/wildlife/	sutclass	lwsd_bb_nc
goat winter range	tgwr_nc	$NCLRMP/wildlife/	confidence	tgwr_nc
deer winter range	tdwr_ncfd_g1	$NCLRMP/wildlife/	hab_class	tdwr_nc_g1
mamu	thsimamu_nc	$NCLRMP/wildlife/	hsi_rank	thsimamu_nc
moose winter range	lmwr_nc	$NCLRMP/wildlife/	confidence	lmwr_nc
DEM-resampled to 100m	tdem	$MOF/fcfd/dnc/dem/tdem	tdem	tdem_100
Slope	tdem	$MOF/fcfd/dnc/dem/tdem	slope percent	slope
Aspect	tdem	$MOF/fcfd/dnc/dem/tdem	aspect degree	aspect

Appendix 3: Timber Supply Review Alignment using the SELES Spatial Timber Supply Model

Introduction

The North Coast Landscape Model (NCLM) is a base component of decision support for the North Coast LRMP. A first step in is to ensure that the harvesting assumptions and policies applied in NCLM match those used in the recent timber supply analysis. This is done by ensuring that the NCLM implemented in SELES (Fall and Fall 2001) can replicate the Timber Supply Review (TSR) results derived using FSSIM for the North Coast Timber Supply Area (TSA). We call the process of matching indicators produced by these two models *TSR alignment*. Where indicators match closely, the assumptions and data used by the two models are likely to match as well. Where differences appear, then either the assumptions or data inputs differ in some undocumented or unexpected way, and further investigations may be required.

We have undertaken a detailed review of the TSR assumptions and data requirements applied in the North Coast TSR, and adapted and calibrated the NCLM to match as closely as possible the TSR results. This document describes the results of the TSR alignment, including an assessment of the effects of dynamically computing analysis units (to support a future succession sub-model), of applying an area-based vs. volume-based annual allowable cut target, and of freezing stand aging in the non-contributing land-base. The benchmark scenario analysis is aspatial. The next step of the NCLM will assess the effects of incorporating space (block sizes, access restrictions).

Methods

We first need to define what we mean by model *alignment*. First, model inputs must be the same, in particular the timber harvesting landbase. Second, the behaviours and assumptions (explicit or implicit) of the two models must match. Lastly, model outputs (growing stock, harvest volumes and areas, mean age and volume harvested, etc.) should match. The following sections are organized to match the structure of the TSR analysis report. The first three sections correspond to Appendices 2 to 4 in (B.C. Min. of Forests, 2002), respectively. The results section compares the output graphs from the two analyses.

(a) Model inputs: zones and analysis units

We used the same set of management zones and analysis units as in the TSR. These were provided as input layers to the NCLM, and included zones for visual quality (preservation, retention, partial retention and modification), integrated resource management, community watersheds, and landscape level biodiversity.

(b) Model inputs: THLB

A spatial timber harvesting landbase layer was provided as input to the NCLM. Some netdowns remove entire cells (e.g. protected areas, inoperable areas), while others remove only a portion (e.g. environmentally sensitive areas, riparian zones). Hence, each cell in this layer denoted the percentage of the cell covered by THLB. The primary differences between the THLB used in the NCLM and that using the timber supply analysis is due to rasterization (since the NCLM is a grid-based model while the timber supply analysis was polygon-based).

The THLB used in the model started at 137,376.3ha (vs. 137,323ha in the TSR), and declined to approx. 131,892ha over a 400-year simulation due to road construction. In the TSR model, a road reduction of 8.4% was applied to stands currently ≥ 50 years the first time they are cut. To match more closely this reduction, in the NCLM we applied a road reduction of 6% to previously unharvested stands.

(c) Forest management assumptions

We now describe how we captured the forest management assumptions in the NCLM.

(i) *Utilization levels:* N/A (captured in volume tables).

(ii) *Volume exclusions for mixed species stands:* N/A (deciduous leading stands except cottonwood were excluded from the THLB. Exclusion of deciduous secondary components was captured in volume tables).

(iii) *Minimum harvest age:* same as in TSR report.

(iv) Site productivity estimates for management stands: same as in the TSR report.

(v) Harvest scheduling priorities: harvest order

Harvest order has a critical impact on model results. The TSR used a *relative oldest first* ordering. Each analysis unit has a minimum harvest age (MHA). Using this rule, stands are harvested in a decreasing order based on (*StandAge – MHA*). That is, stands that are the most number of years older than their MHA have highest priority.

(vi) *Silviculture systems:* assumed to be clearcut, as in the TSR

(vii) Unsalvaged losses

Non-recoverable loss (NRL) is specified as a constant volume loss annually in the North Coast TSR. NRL is added to the annual harvest request. To be consistent with area-based harvesting and to facilitate natural disturbance sub-models, the AAC is specified as a curve of total annual volume or area to remove, including NRL (hence it may be more accurate to call it *annual allowable disturbance*). As in standard TSR documents, the AAC does not include the NRL volume, but the graph showing mean area harvested does include the NRL area. The total NRL for the North Coast TSR was 10,084 m^3 (2,034 ^{3} for fire, and 8,050 m^3 for blowdown).

(viii) *Managed stand regeneration assumptions:* After harvesting, an analysis unit-specific regeneration delay of one or two years was applied, and a regenerated analysis unit is assigned to the cell.

(ix) Immature plantation history

Stands initially younger than 40 years assumed to have been controlled for density and are placed on managed yield curves.

(x) Not satisfactorily restocked areas

We identified the NSR areas based on type id. Due to differences in the THLB, the amount of NSR differs somewhat between the NCLM and the TSR (Table 1). The number of years assumed before reestablishment of backlog NSR was 10 years. The main reason for the discrepancy is that we didn't account for the 2,345ha assumed to be restocked.

Table 1. NSR differences between TSR and NCLM.

Backlog NSR in THLB	
NCLM	*TSR*
1,227	1,259

(xi) Forest cover requirements – visual quality, integrated resource management, water quality, and landscape level biodiversity

Forest cover constraints were applied as in the TSR, and shown in Table 2 and Table 3.

Table 2. Forest cover constraints (except for landscape level biodiversity).

Resource emphasis	Maximum allowable disturbance (%)	Green-up (metres or years)	Land base to which constraints apply
Integrated resource management	33	3m	TLHB
Water quality	5	5 years	TLHB
VQO – Inside Passage - preservation	1	7m	Productive forest
VQO – Inside Passage - retention	5	7m	Productive forest
VQO – Inside Passage - partial retention	15	7m	Productive forest
VQO – Skeena R. Corridor - preservation	1	7m	Productive forest
VQO – Skeena R. Corridor - retention	5	7m	Productive forest
VQO – Skeena R. Corridor - partial retention	15	7m	Productive forest
VQO – Portland/Work – modification	25	4m	Productive forest
VQO – Douglas/Gribbell – modification	25	4m	Productive forest

Table 3. Forest cover constraints for landscape level biodiversity (applied to productive forest).

		Minimum retention by decade (%)		
Biogeoclimatic Unit	**Minimum age (years)**	**1**	**7**	**14**
CWHvh2	250	9.7	11.65	13.6
CWHvm	250	9.7	11.65	13.6
CWHvm1	250	9.7	11.65	13.6
CWHwm	250	9.7	11.65	13.6
CWHvm2	250	9.7	11.65	13.6
MHmm1	250	14.2	17.05	19.9
MHmm2	250	14.2	17.05	19.9
MHwh1	250	14.2	17.05	19.9
CWHws1	250	6.7	8.1	9.4
CWHws2	250	6.7	8.1	9.4

(xii) *Riparian management zones:* same as in TSR: reduce volumes by 4.2%.

(xiii) *Identified wildlife management strategy:* same as in TSR: reduce volumes by 1%.

(xiv) *Volume and height tables*: same as used in TSR.

(xv) *Adjacency:* Cutblock adjacency should not be explicitly modelled, but is addressed indirectly through surrogate cover constraints as in the TSR.

(d) Model outputs
The NCLM outputs a range of indicators:

(i) *Age class*: hectares in 10-year age classes, stratified by whether THLB/non-THLB.
(ii) *Seral stage distribution*: hectares in different seral stages (young, immature, mature, old) stratified by THLB, operable excluded, and inoperable.
(iii) *Zone thresholds*: hectares and proportion above and below the threshold age or height specified for each forest cover constraint. This is output for the entire zone and by reference subzone (e.g. biodiversity constraints are output by BEC variant and by BEC variant/landscape unit). This is useful to verify that the model is respecting the zone forest cover constraints.
(iv) *Growing stock*: standing volume and area stratified by THLB, mature, available, and availability according to the constraints (e.g., forest cover; accessibility).
(v) *Harvest record*: volume and area harvested, mean volume per hectare harvest, mean harvest age, proportion of harvest in different zones, harvest profile, NLR area and volume, proportion of harvest in old, thrifty and managed AUs.
(vi) *Limiting constraints*: amount of THLB constrained by minimum harvest age, access, adjacency, and cover constraints. This is computed both in the order of rule application (e.g. if a stand is too young to harvest, then it is irrelevant if it is too far from a road to harvest) and overall. In the former, the sum of all constrained areas (which represents the total constrained portion of the THLB) shows the *actual* impact of a constraint. In the latter, cells with overlapping constraints contribute to more than one entry, identifying the *potential* impact of a constraint.

For the TSR alignment, we are primarily interested in the age class, growing stock and harvest record indicators.

(e) Simulations
The TSR analysis was conducted using a 10-year time step. The NCLM can be driven either by a volume-based or an area-based AAC. The former is how the TSR analysis is done. However, the latter has different stability properties, which may be useful for comparing different land-use scenarios. If models are completely aligned, then the area-based and volume-based approaches should give identical results. We present the volume-based results first, followed by the area-based results. For the area-based harvesting scenarios, the annual area targets were taken from the mean area harvested in the TSR analysis. We also ran

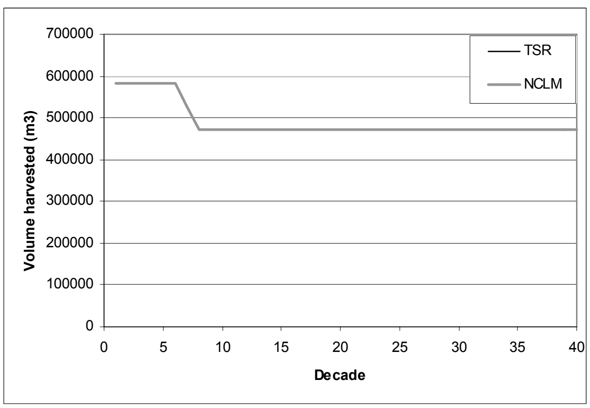
scenarios that "froze" aging in the forest outside the timber harvesting landbase (i.e. did not increment stand ages in non-contributing forest, reducing the difficulty of making ecological risk assessments due to "perpetual aging" of stands), and in which the model computed analysis units rather than using a provided input map. All scenarios were run 10 times for 40 decades.

Analysis of the first set of volume-based and area-based results showed that the variability between runs was close to 0 (since the logging sub-model is mostly deterministic). We ran single-replicate simulations of 40 decades for each scenario.

Results

(a) Volume based Results

Figure 2 shows the volume and area harvested by the two models. As designed, the volume matches the TSR exactly, and the area harvested is on average just under 5 hectares/decade (~0.8%) more in the NCLM than in the TSR. This was due to an average of 5.4 m^3/ha (~0.7%) less in the NCLM than in TSR (Figure 3). Mean age harvested (Figure 3) is very close between the two models, with a mean difference of about 2 years.



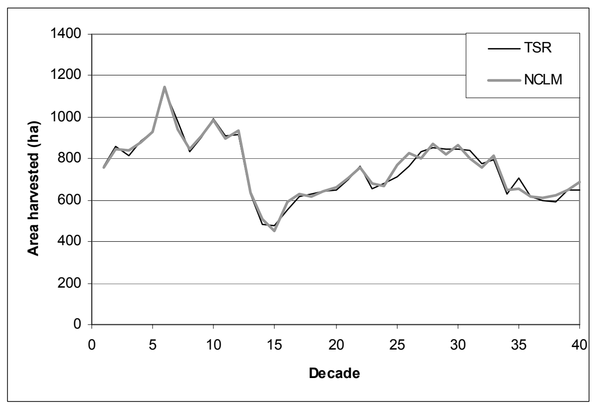


Figure 2. Volume and area harvested each decade by NCLM and TSR.

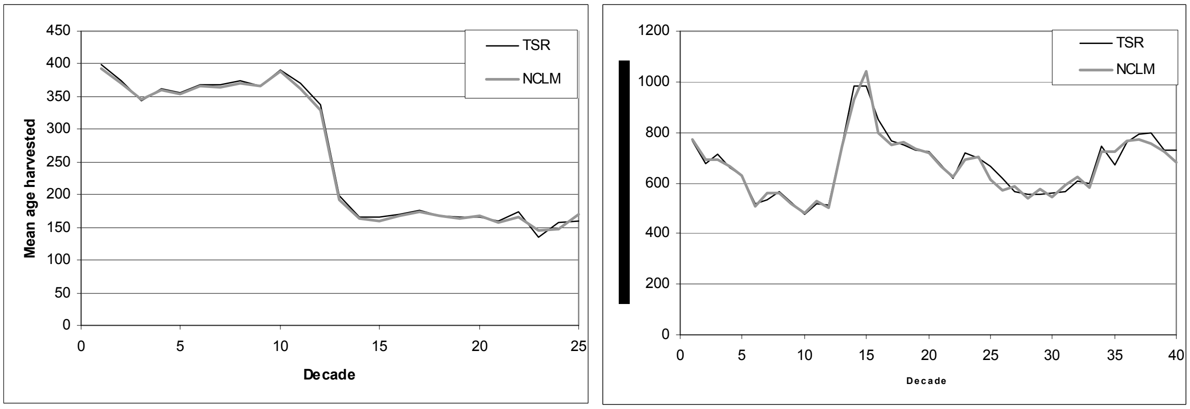


Figure 3. Average age and volume/hectare of harvested stands each decade by NCLM and TSR.

The NCLM has an almost identical match of growing stock as the TSR model (Figure 4).

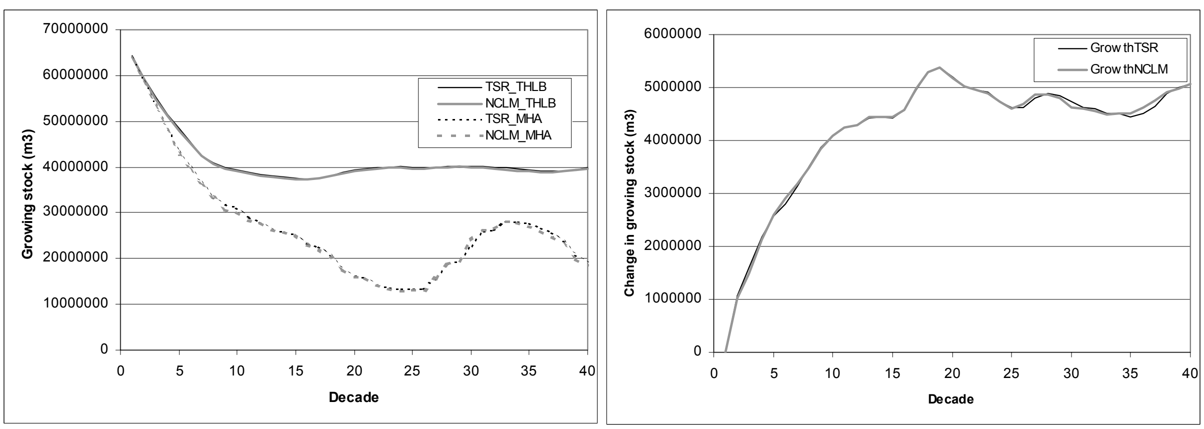


Figure 4. Growing stock for THLB (Total) and merchantable (mature) stands (left) and change in growing stock (right) in the NCLM and TSR models.

To explore the growing stock in more detail, I analysed the growth rates in the two models, where growth is defined as the change in growing stock between two decades plus the volume harvested. The overall growth increments each decade are shown in Figure 4. The two models are very closely aligned over the entire period. The results follow the same trend, with a low growth early in the horizon and increasing over time to a maximum around decade 19.

(b) Area based Results

The results from the volume-based and area-based scenarios are comparable. Figure 5 shows the volume and area harvested by in the TSR and NCLM models. In this case the NCLM matches the area harvested in TSR precisely. The volume harvested by the models is quite close, although the NCLM model predicts slightly lower volumes. On average, the NCLM predicted 0.3% less volume harvested than TSR (approximately 1,400 m^3/year). The other indicators are virtually identical to the volume-based case.

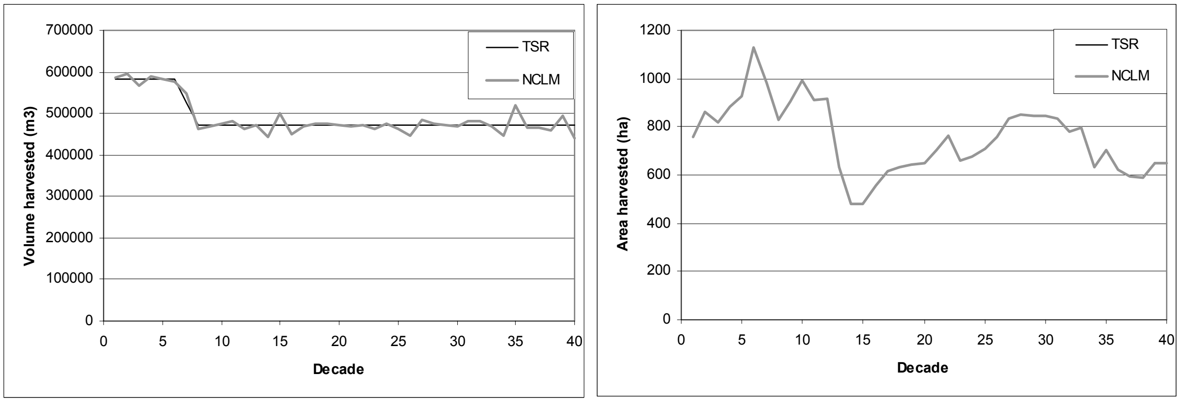


Figure 5. Area and volume harvested each decade by NCLM using an area-based target and TSR.

(c) Effects of modified assumptions used in the benchmark scenario

The effects of the assumptions applied in the NCLM benchmark scenario that differed from the FSSIM model can be summarized as follows:

(a) Freezing aging in non-contributing forest: Keeping stand ages static outside the timber harvesting landbase had a very minor effect on the timber supply indicators, although there was a slight increase in area harvested (to a mean of 9ha/year more than in the TSR) due to a slight decrease in volume/ha (just under 10m3/ha less than in the TSR).

(b) Dynamically computing analysis units: Computing analysis units within the NCLM model (based on stand species, site index, etc.) little effect on the timber supply indicators compared to the above results.

(c) Combined effects 1: TSR benchmark scenario: Combining the dynamic computation of analysis units and freezing aging in the non-contributing led to little change from that noted for these two options separate. This combination is what was used as the aspatial benchmark scenario for the NC LRMP analysis, and so it is key that the results are very comparable to the TSR analysis.

Conclusions

The NCLM parameterized to match the assumptions of the TSR results in a very close alignment of outputs. This gives some confidence that the NCLM, when run in aspatial mode, has captured the essence of the North Coast timber supply analysis. The sensitivity analysis of the results to dynamic computation of analysis units and freezing aging in the non-contributing landbase show that these features can be included in the main NCLM aspatial benchmark scenario with only a minor effect on timber supply projections.

With an area-based AAC target, under the benchmark scenario assumptions, the results are virtually the same as with a volume-based target. However, an area-based method may become important when we assess the effects of spatial blocks and access restrictions.

For the NC DSS, our goal is not to perform a full timber supply analysis for a spatial harvest flow. Rather, we wish to assess the impacts various land-use scenarios on timber supply and ecological indicators. Hence the timber supply indicators produced in this analysis are to be used as benchmarks for comparing changes under various land-use scenarios.

Appendix 4: NCLM Phase I Indicator Files

The output indicators for the NCLM are output as a set of files either in a pre-processing step, directly during simulation runs, or after a post-processing step. Each file is a tab-separate file of columns, with the first row giving column headings. The first columns identified as "strata fields" specify the units to which the "result" fields apply.

Static Indicators

I. *StaticIndicators.txt* - static info for various strata

Strata Fields:
AU: Base analysis unit (1-14), where 1-12 are as in the TSR, 13 is for decid (other than cottonwood) and 14 is for Pine leading.
BEC: 1-13
BECName: BEC zone name
LU: 1-59
LUName: landscape unit name
Watershd: watershed id
Ecosec: Ecosection (0-6)
EcosecNm: ecosection name
BEU: BEU habitat type (0-27)
BEUMod: BEU Modifier (0-6)

Result Fields:
Area: Total area of strata (ha), including non-forest
Forest: Forested area of strata (ha)
Productive: Area of productive forest in strata (ha)
InoperableForest: Area of inoperable foreest in strata (ha)
OperableForest: Area of operable forest in strata (ha)
initialTHLB: amount of timber harvest landbase in strata at present (ha)
Settlement: amount of settlement in strata (ha)
PermRds: amount of permanent road in strata (km)
Riparian: amount of riparian area in strata (ha)
MeanElevation: average elevation in strata (ha)
MeanSlope: average slope in strata (ha)
Dist2Ocean0-4: amount of total area in strata in various distance classes from ocean:

0: < 100m
1: 101-200m
2: 201-500m
3: 501-1000m
4: 1km+

Dist2Road0-4: amount of total area in strata in various distance classes from current active roads:

0: < 100m
1: 101-200m
2: 201-500m
3: 501-1000m
4: 1km+

II. StaticWSIndicators.txt - static info for watersheds

Strata Fields:
Watershd: watershed id

Result Fields:
Area: Total area of strata (ha), including non-forest
Forest: Forested area of strata (ha)
Productive: Area of productive forest in strata (ha)
InoperableForest: Area of inoperable foreest in strata (ha)
OperableForest: Area of operable forest in strata (ha)
initialTHLB: amount of timber harvest landbase in strata at present (ha)
Settlement: amount of settlement in strata (ha)
PermRds: amount of permanent road in strata (km)
Riparian: amount of riparian area in strata (ha)
MeanElevation: average elevation in strata (ha)
MeanSlope: average slope in strata (ha)
Dist2Ocean0-4: amount of total area in strata in various distance classes from ocean:

0: < 100m
1: 101-200m
2: 201-500m
3: 501-1000m
4: 1km+

Dist2Road0-4: amount of total area in strata in various distance classes from current active roads: same classes as for Dist2Ocean

Indicators from Main Model

NOTES:

(1) Height class is only changed for harvested stands because the height estimates from the yield tables differ dramatically from the inventory height class
(2) Age is only incremented in the THLB and in the Anyox, Olh and Stagoo landscape units.
(3) Canopy closure class is not currently updated
(4) The total amount of productive forest declines slightly over time due to loss of forest from road construction
(5) Spur roads cannot be interpreted for aspatial scenarios, since a spur will be constructed to each "single-cell block".

I. BiodiversityDetails.txt – Detailed indicators for biodiversity analysis

Strata Fields:
Year: output year
isLRMP: 1 if stratum is in LRMP area; 0 if stratum is in TSA outside LRMP area
AU: Base analysis unit label
BEC: biogeoclimatic zone label
LU: landscape unit label

Watershd: watershed id
Ecosec: Ecosection label
AgeClsB: age classes for biodiversity analysis: 1-12 (0-20, 21-40, 41-60, 61-80, 81-100, 101-120, 121-140, 141-180, 181-250, 251-350, 351-500, 500+)
LandStat: Land status: 0: thlb, 1: protected area; 2 – other crown forest

Result Fields:
NumCases: number of hectares in stratum

II. *RareEcosystemDetails.txt* – Detailed indicators for rare ecosystems

Strata Fields:
Year: output year
isLRMP: 1 if stratum is in LRMP area; 0 if stratum is in TSA outside LRMP area
AU: Base analysis unit label
BEC: biogeoclimatic zone label
LU: landscape unit label
Watershd: watershed id
Ecosec: Ecosection label
AgeClsB: age classes for biodiversity analysis: 1-12 (0-20, 21-40, 41-60, 61-80, 81-100, 101-120, 121-140, 141-180, 181-250, 251-350, 351-500, 500+)
RareEcosystem: rare ecosystem type (0-83)
LandStat: Land status: 0: thlb, 1: protected area; 2 – other crown forest

Result Fields:
NumCases: number of hectares in stratum

III. *MamuDetails.txt* – Detailed indicators for marbled murrelet analysis

Strata Fields:
Year: output year
isLRMP: 1 if stratum is in LRMP area; 0 if stratum is in TSA outside LRMP area
AU: Base analysis unit (1-14)
BEC: 1-13
LU: 1-59
Watershd: watershed id
AgeClass: standard forest service age classes 1-9 (0-20, 21-40, 41-60, 61-80, 81-100, 101-120, 121-140, 141-250, 251+)
HtCls: 1-9
CCCls: Canopy closure class (0-10)
LandStat: Land status: 0: thlb, 1: protected area; 2 – other crown forest

Result Fields:
mOldEdge: number of metres of edge between old forest ($\geq$ 140 years) adjacent to forest under 40 years. NOTE: to compute edge, each cell is classified according to its dominant land status (THLB, protected area, or other crown forest).

NumCases: number of hectares in stratum

IV. WatershedSummary.txt - Third order watershed summary indicators

Strata Fields:
Year: output year
Watershd: watershed id

Result Fields:
AreaFor: size of forested portion of watershed
ProdFor: amount of productive forest
THLB: amount of thlb
LocAct (m3): volume harvested in watershed since last output period
LocActTS (m3): volume harvested in watershed in last decade (i.e. timestep)
TotAct (m3): volume passing through watershed on road network since last output period
TotActTS (m3): volume passing through watershed on road network in last decade
kmOldEdge (m): length of between old (> 250 years) and young (<= 40 years) forest. NOTE: to compute edge, each cell is classified according to its dominant land status (THLB, protected area, or other crown forest).
AgeDiv: Shannon's diversity index for age class diversity (where the proportion in each class is the proportion of the total watershed area covered by forest in that age class)
TotRds (km): total number of active roads
MaintRds (km): cumulative number of active roads visited (maintained) each decade since last output period. This includes the amount of permanent roads, whether they were accessed for harvest or not. Note that a road may contribute for each decade in which it is visited.
MaintRdsTS (km): total number of active roads visited (maintained) in last decade. This includes the amount of permanent roads, whether they were accessed for harvest or not.
NewRds (km): number of proposed roads built since last output period
NewRdsTS (km): number of proposed roads built in last decade
Spurs (km): number of spurs built since last output period
SpursTS (km): number of spurs built in last decade
RdInRip (km): amount of roads within 50m of a stream
StrCross: number of stream crossings on mainlines built since last output period
StrCrossTS: number of stream crossings on mainlines built last decade
SpurStreamCrossings: number of stream crossings on spurs built since last output period
SpurStreamCrossingsTS: number of stream crossings on spurs built in last decade
SerStg1-4: not currently used
CCCls0-10: canopy closure class distribution
HtCls1-8: height class distribution
AgeCls1-9: age class distribution

V. GBSummary.txt – Summary indicators for Grizzly Bear analysis

Strata Fields:
Year: output year

Watershd: watershed id

<u>Result Fields</u>:
AreaFor: size of forested portion of watershed
ProdFor: amount of productive forest
THLB: amount of thlb
LocAct (m3): volume harvested in watershed since last output period
LocActTS (m3): volume harvested in watershed in last decade (i.e. timestep)
TotAct (m3): volume passing through watershed on road network since last output period
TotActTS (m3): volume passing through watershed on road network in last decade
TotRds (km): total number of active roads
MaintRds (km): cumulative number of active roads visited (maintained) each decade since last output period. This includes the amount of permanent roads, whether they were accessed for harvest or not. Note that a road may contribute for each decade in which it is visited.
MaintRdsTS (km): total number of active roads visited (maintained) in last decade. This includes the amount of permanent roads, whether they were accessed for harvest or not.
NewRds (km): number of proposed roads built since last output period
NewRdsTS (km): number of proposed roads built in last decade
Spurs (km): number of spurs built since last output period
SpursTS (km): number of spurs built in last decade
HtCls1-8: height class distribution
StrStg1-4: structural stage (age class) distribution (0-20, 21-60, 61-140, 141+)
RdDens1-4: Road density class distribution

VI. GBDetails.txt – Detailed Indicators for Grizzly Bear analysis

<u>Strata Fields</u>:
Year: output year
isLRMP: 1 if stratum is in LRMP area; 0 if stratum is in TSA outside LRMP area
AU: Base analysis unit label
BEC: BEC label
BECZone: BEC zone label
BECSubZone: BEC sub-zone label
BECVariant: BEC variant
LU: landscape unit label
Watershd: watershed id
Ecosec: ecosection label
BEU: BEU label
BEUMod: BEU modifier label
StrStg: structural stage (age class) 1-4 (0-20, 21-60, 61-140, 141+)
isDecid: 1: deciduous forest; 0: coniferous forest
LandStat: Land status: 0: thlb, 1: protected area; 2 – other crown forest

<u>Result Fields</u>:
NumCases: number of hectares in stratum

VII. GoatWRIndicators.txt – Mountain goat winter range summary indicators

Strata Fields:
Year: output year
LU: Landscape unit label

Result Fields:
AreaFor: size of forested portion of landscape unit
ProdFor: amount of productive forest
THLB: amount of thlb
TotRds (km): total number of active roads
MaintRds (km): cumulative number of active roads visited (maintained) each decade since last output period. This includes the amount of permanent roads, whether they were accessed for harvest or not. Note that a road may contribute for each decade in which it is visited.
MaintRdsTS (km): total number of active roads visited (maintained) in last decade. This includes the amount of permanent roads, whether they were accessed for harvest or not.
NewRds (km): number of proposed roads built since last output period
NewRdsTS (km): number of proposed roads built in last decade
Spurs (km): number of spurs built since last output period
SpursTS (km): number of spurs built in last decade
RdDens: Road density in landscape unit (km roads/ha)
Hab1: amount of goat winter range habitat type 1
Hab2: amount of goat winter range habitat type 2
Hab1NrRd: amount of goat winter range habitat type 1 within 300m of a road
Hab2NrRd: amount of goat winter range habitat type 2 within 300m of a ro

Indicators from Post-Simulation Spatial Analysis

Folder: statsAC: landscape metrics based on age-class patch definition:
Type 1: 0-40 years
Type 2: 41-250 years
Type 3: 251+ years

Folder: statsHC: landscape metrics based on height-class patch definition:
Type 1: height class 4+

I. ClassStats.txt

This files contains a variety of metrics for different patch types. The following are the key metrics.

Strata Fields:
Year: output year
Replicate: replicate or map number

Type: patch type

<u>Result Fields</u>:
A: Area (ha)
PCTLAND: percent of the forest cover by the patch types
LPI: largest patch index (% of landscape occupied by larges patch)
LargestPatch: in hectares
SmallestPatch: in hectares
NP: Number of Patches
PD: Patch density (number per 100 ha)
MPS: mean patch size (ha)
PSSD: patch size standard deviation (ha)
TE: total edge (metres): length of cell edges between two different types of cell)
ED: edge density (m/ha)
LSI: landscape shape index: amount of edge relative to amount of edge if class was a single square patch. Computed as: total perimeter/4 divided by the square root of the total area. If a patch is square, the value will be 1.
MSI: mean shape index: amount of edge relative to amount of edge if each patch in the class was a square patch. Computed for each patch as: patch perimeter /4 divided by the square root of the patch area. If all patches are square, the value will be 1.
AWMSI : area-weighted mean shape index. Same as MSI, but instead of dividing by the number of patches to get the mean, the sum of per-patch shape values is divided by the total area covered by the class.

II. ClassStatsC.txt

This files contains a variety of metrics computed using patch centroids (location representing patch centre of balance).

<u>Strata Fields</u>:
Year: output year
Replicate: replicate or map number
Type: patch type

<u>Result Fields</u>:
CCE: connectivity between patch centroids: Mean interaction between patch pairs, where interaction is defined as the product of patch size divided by the square of distance between their centroids. Low values indicate small patches that are far apart, while large values indicate larger, closer patches.
MaxCCE: max connectivity between patch pairs
CD: mean distance between centroids (in metres)

III. ClassStatsNN.txt

This files contains a variety of metrics related to nearest neighbours (edge-to-edge links between patches).

<u>Strata Fields</u>:

Year: output year
Replicate: replicate or map number
Type: patch type

<u>Result Fields</u>:
MNN: Mean nearest neighbour distance (m)
MinNN: Minimum nearest neighbour distance (m)
MaxNN: Maximum nearest neighbour distance (m)
NNSD: nearest neighbour standard deviation (m)
meanMST: mean length of edges in the miminum spanning tree (in metres). The MST is the set of n-1 shortest edges to join n patches together. All nearest neighbour edges are in the MST, plus additional edges required to connect patch components.
tMST: total length of edges in the miminum spanning tree (in metres). This is equivalent to meanMST * (NumPatches-1).
meanMPG: mean length of edges in the minimum planar graph (in metres). The MPG is the set of shortest edges to create a maximum size (maximum number of edges) planar graph. A planar graph is a graph where no two edges cross (i.e. it can be drawn on a plane without crossing edges). All edges in the MST are in the MPG plus additional edges. This creates a graph that is similar to a Delaunay triangulation.
tMPG: total length of edges in the minimum planar graph (in metres).
nMPG: number of edges in the minimum planar graph.

IV. ***PatchSizeDistDetails.txt***: patch size distribution details

<u>Strata Fields</u>:
Period: output period (generally: 1 = 0 years, 2 = 20 years, 3 = 50 years, 4 = 100 years, 5 = 200 years, 6 = 250 years)
Replicate: replicate for Monte-Carlo runs
Type: patch type
AU: Base analysis unit (1-14)
BEC: 1-13
LU: 1-59
Watershd: watershed id
Ecosec: Ecosection (0-6)
BEU: BEU habitat type (1-27)
BEUMod: BEU modifier
LandStat: Land status: 0: thlb, 1: protected area; 2 – other crown forest
SizeCls: patch size class
 0: <= 20 ha
 1: 21-50 ha
 2: 51-100 ha
 3: 101-200 ha
 4: 201-500 ha
 5: 500+ ha

Result Fields:
NumCases: number of hectares in stratum

V. ***EdgeDistDetails.txt***: distance from edge distribution details

Strata Fields:
Period: output period (generally: 1 = 0 years, 2 = 20 years, 3 = 50 years, 4 = 100 years, 5 = 200 years, 6 = 250 years)
Replicat: replicate for Monte-Carlo runs
Type: patch type
EdgeType: type of patch at nearest edge. This will be –1 if the edge is at the study area boundary and 0 for an edge adjacent to a non-classed type within the study area (e.g. non-forest)
AU: Base analysis unit (1-14)
BEC: 1-13
LU: 1-59
Watershd: watershed id
Ecosec: Ecosection (0-6)
BEU: BEU habitat type (1-27)
BEUMod: BEU modifier
LandStat: Land status: 0: thlb, 1: protected area; 2 – other crown forest
DistCls: Distance from edge class
- 0: < 100m
- 1: 101-200m
- 2: 201-500m
- 3: 501-1000m
- 4: 1km+

Result Fields:
NumCases: number of hectares in stratum