J. W. GOTTSTEIN MEMORIAL TRUST FUND

The National Educational Trust of the Australian Forest Products Industries

FOREST ESTATE MODELLING OF MULTIPLE-USE FOREST MANAGEMENT

MIKE McLARIN

2005 GOTTSTEIN FELLOWSHIP REPORT

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Joseph William Gottstein Memorial Trust Fund

The Joseph William Gottstein Memorial Trust Fund was established in 1971 as a national educational Trust for the benefit of Australia's forest products industries. The purpose of the fund is *"to create opportunities for selected persons to acquire knowledge which will promote the interests of Australian industries which use forest products for the production of sawn timber, plywood, composite wood, pulp and paper and similar derived products."*

Bill Gottstein was an outstanding forest products research scientist working with the Division of Forest Products of the Commonwealth Scientific Industrial Research Organization (CSIRO) when tragically he was killed in 1971 photographing a tree-felling operation in New Guinea. He was held in such high esteem by the industry that he had assisted for many years that substantial financial support to establish an Educational Trust Fund to perpetuate his name was promptly forthcoming.

The Trust's major forms of activity are:

1. Fellowships and Awards - each year applications are invited from eligible candidates to submit a study programme in an area considered of benefit to the Australian forestry and forest industries. Study tours undertaken by Fellows have usually been to overseas countries but several have been within Australia. Fellows are obliged to submit reports on completion of their programme. These are then distributed to industry if appropriate. Skill Advancement Awards recognise the potential of persons working in the industry to improve their work skills and so advance their career prospects. It takes the form of a monetary grant.

2. Seminars - the information gained by Fellows is often best disseminated by seminars as well as through the written reports.

3. Wood Science Courses - at approximately two yearly intervals the Trust organises a week-long intensive course in wood science for executives and consultants in the Australian forest industries.

Further information may be obtained by writing to:
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Mike McLarin is a Senior Forest Resource Planner with Forestry Tasmania, based in Hobart. In this role he undertakes strategic forest estate modelling, encompassing all of Tasmania's eucalypt native forest and plantations on State forest, to demonstrate where the wood is coming from for the next century. His interest is in modelling multiple objectives, including wood and non-wood products, and linkages between strategic and tactical planning.

Mike trained as a forester with the New Zealand Forest Service and at the University of Canterbury in Christchurch in the 1980s. Prior to moving to Tasmania in 2001, he worked in the Central North Island for NZFP Forests and Carter Holt Harvey Forests in a variety of operational, technical and planning roles, including a year on secondment with the Ministry of Forestry in Wellington.

Acknowledgments

First I would like to thank my family, particularly my wife Brenda, who gave me the go-ahead to pursue the idea of gaining a Gottstein Fellowship, and my subsequent time away from home undertaking the study tour and preparing this report.

Second, thanks to my employer, Forestry Tasmania, who supported my Gottstein Fellowship application, both in terms of time away from work, and financially.

And a sincere thankyou to the Gottstein Memorial Trust Fund for the opportunity to seek out alternative approaches to forest estate modelling in North America, for the benefit of Australia. The Trust's activities were commented on most favourably, even enviously, a number of times during the study tour.

Finally, thanks to my hosts in North America, each and every one of you (too many to name individually). Your hospitality and willingness to share experiences and ideas really made the study tour for me. I hope we meet up again.

Executive Summary

Forest estate modelling is the generic term used to describe the process by which forest resource planning specialists address the characteristics of their forest of interest at the macro-scale. Forest estate models can take many forms, from the very simplistic woodflow, to the most complex non-wood values. In this way, forest estate modelling can represent multiple-use forest management.

North America is the source of most of the forest estate modelling software used in Australia. For this reason, the study tour involved attending a number of events and visiting a large number of organisations to understand North America's approach to forest estate modelling of multiple-use forest management. The goal was to seek out alternative approaches to forest estate modelling. The various examples of forest estate modelling encountered during the study tour are classified as optimisation, simulation or heuristic models, and discussed.

Australian forestland managers are generally on par with most forestland managers visited, in terms of their use of forest estate modelling, and in particular traditional wood supply analysis. However, Australian forestry organisations are relatively weak at incorporating non-wood values into traditional wood supply analysis.

Remsoft's Spatial Planning System is considered an industry standard, both in North America and Australia. There are other tools available for forest estate modelling, particularly for incorporating non-wood values into wood supply analysis. However, all alternative tools require an investment of time (and often money) to utilise. It is important to remember that all tools have their advantages and disadvantages, which are often not discovered until the tools are implemented.

Table of Contents

Introduction

Forest estate modelling is the generic term used to describe the process by which forest resource planning specialists address the characteristics of their forest of interest at the macro-scale. Traditional stand and tree growth models, which operate at the unit area level, are assembled along with a total area and attribute statement for the forest. Forest management strategy, incorporating an organisation's policies and goals, along with area and yield estimates, form the basis of any forest estate model.

Forest estate models can take many forms, from the very simplistic, to the most complex. Forest estate models can be aspatial, with a long term strategic view, or incorporate spatial and tactical implementation issues. Output from forest estate models can be used to inform operational forest management decision-making. Decisions often supported by forest estate modelling include silvicultural regime selection and harvest location, timing and method. Output from forest estate models in the past has focussed mainly on woodflow. Although this is still the main use of forest estate models today, other forest non-wood values are sometimes included as well. In this way forest estate modelling can represent multiple-use forest management.

Forest estate models can be classified as optimisation, simulation or heuristic models. Optimisation is a mathematical method of determining the maximum or minimum value of an objective function, given a set of constraints. Simulation involves representing a given course of action, with simple selection priority rules. A heuristic is pseudo-optimisation. The mathematical method here attempts to improve the objective function value on every iteration, by learning from previous iteration outcomes. This classification of forest estate modelling has been used to group the various examples of forest estate modelling encountered during the study tour, for further discussion in the report.

Purpose of Study

The purpose of the study tour to Canada and the United States was to understand some North American organisations' forest management situations and their processes for generating, and using, decision-support forest estate models. Of particular interest was modelling of non-wood products and multiple objectives, and linkages between strategic and tactical planning.

In conjunction with this study tour there was the opportunity to attend a number of events, where forest resource specialists gathered to share experiences and ideas, and learn from each other. These events were:

Canadian Council of Forest Ministers' Workshop
Canadian Inter-provincial Resource Analysts Meeting
Remsoft Users Group Meeting
United States Forest Inventory and Analysis Symposium

Forestry organisations in Australia take a variety of approaches to their forest estate modelling. The study tour aimed to see what others' approaches are outside the Australian forest industry. North America was selected as the destination because it is the source of most of the forest estate modelling software used in Australia. The study tour sought alternative approaches to forest estate modelling of multiple-use forest management for Australian forestry organisations.

Locations

Locations visited during the study tour of North America included:

Northeast – New Brunswick and Maine

Forest Landscape near Mt Carlton in New Brunswick

Southeast – Florida, Georgia, North and South Carolina

Southern pines in Florida

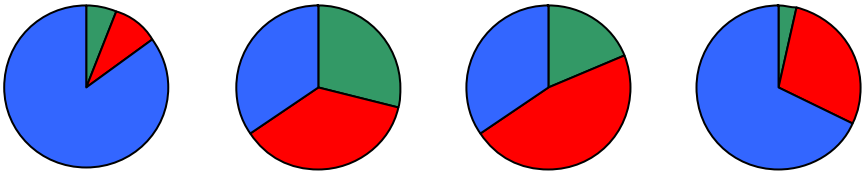
Saskatchewan

Mature black spruce stand north of Prince Albert

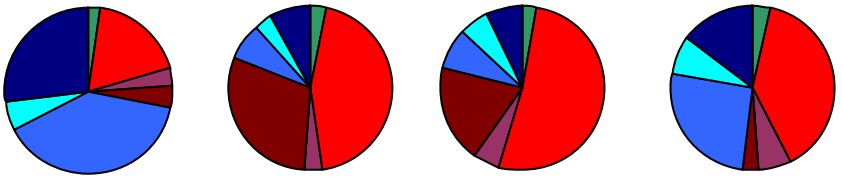
Pacific Northwest – Oregon, Washington and British Columbia

Forest Landscape near Hoquiam in Washington

A simple comparison of the countries visited with Australia, and States/Provinces visited with Tasmania, in terms of population, land area and forestry activity follow:



Country	Population (M)	Total Land Area (M ha)	Total Forestland Area (M ha)	Annual Wood Production (M m^3)
Australia	20	768	164	26
Canada	32	979	402	194
United States	294	916	302	464
State/Province				
Tasmania	0.5	6.8	3.4	5.6
British Columbia	4.2	95.0	64.0	65.0
New Brunswick	0.8	7.3	6.2	10.4
Saskatchewan	1.0	65.0	24.0	5.0
Georgia	8.8	15.0	9.9	42.7
Maine	1.3	8.0	7.2	12.5
Washington	6.2	17.2	8.9	24.5



Sources:

Australia – Australia's Forests at a Glance (www.daff.gov.au/nfi)

Canada – The State of Canada's Forests (www.nrcan.gc.ca/cfs)

United States – An Economic Overview of the United States Solid Wood Industry (www.fas.usda.gov/ffpd/economic-overview/overview.html)

Although all three countries are a similar land area, the United States stands out in terms of population and annual wood production (upper pie graphs). Australia and Canada are most similar in terms of extensive forest management, although Canada's industry is somewhat larger than Australia's. Similar trends are apparent in the selection of States and Provinces from the three countries (lower pie graphs). British Columbia dominates all but the population statistic.

Events

Canadian Council of Forest Ministers' Workshop

This Canadian Council of Forest Ministers Workshop, an initiative of the Technical Sub-committee on Reporting Wood Supply within the National Forestry Database Program, was held from 17-18 October 2005 in Saskatoon, Saskatchewan. The workshop was titled "Risky Business – Supplying Forest Values in the Face of Uncertainty".

The workshop included presentations from academics across Canada. They addressed modelling approaches and analysis of uncertainties associated with forest management. In summary, although reasonable methods were presented, an ability to re-plan in a timely manner when an event actually occurs is the author's favoured approach to modelling uncertainty. However, these uncertainties should not be forgotten when preparing a harvest schedule. There is a need to look for robust strategies that will work well across a variety of unknown futures.

Also included were presentations on forest estate modelling in New Zealand and Tasmania, and practitioners' modelling work in North America. Of particular note was new development of Remsoft's Spatial Planning System (RSPS) to incorporate a fire simulation model, integrated with the existing system. This involves converting the vector shapefile to a rastor coverage within Spatial Woodstock.

The workshop provided time for discussion of issues and was an excellent networking opportunity within a large continent.

Canadian Inter-provincial Resource Analysts Meeting

This periodic meeting between Canada's provincial government forest resource analysts was held from 20-21 October 2005 in Prince Albert, Saskatchewan. It was an informal gathering attended by all provinces except Quebec, New Foundland, Nova Scotia and Prince Edward Island.

Attendees heard from British Colombia on their current mountain pine beetle epidemic, Alberta about their use of the Canadian Carbon Budget Model, Ontario about their forest inventory initiatives and New Brunswick on crown land forest management, including a new taskforce to review wood supply.

Again this meeting provided an excellent networking opportunity and was most enjoyable, hosted superbly by Saskatchewan.

Provincial representatives from west to east

Remsoft Users Group Meeting

A Remsoft User Group Meeting was held on 29 September 2005 in Fredericton, New Brunswick. There were about 30 attendees, mostly from the Northeast of North America, including experienced and novice Remsoft users (the later having undertaken training earlier in the week).

The day included presentations from Remsoft staff on software developments, both immediately available and those coming soon. There was an opportunity to provide Remsoft with feedback from users, and to hear Remsoft's plans for the future.

And there were user presentations – one from Ian Prior from FORSight Resources LLC, based in Bangor, Maine, and one by the author on Forestry Tasmania's use of

RSPS. Ian's presentation described a project investigating how forest managers implement a strategic plan, by comparing the optimal solution with alternative implementations in terms of area and volume cut, and net present value.

The networking opportunity with other forest resource planning specialists and their uses of RSPS is very valuable. At the very least it confirms your current approaches are used elsewhere, and there is potential to gain insight into new approaches to resource planning problems.

United States Forest Inventory and Analysis Symposium

The Forest Inventory and Analysis Symposium was held the week 3-7 October 2005 in Portland, Maine. The author attended the third day of the symposium. Papers were presented on a wide variety of forest inventory related topics, both on the collection and use of this measurement data.

A feature of the symposium (the seventh of its type, organised by United States Forest Service (USFS)) was the number of overseas attendees, with representatives from France, Finland, New Zealand and Australia, as well as Canada and America.

Organisations

The following is a complete list of all organisations visited during the study tour, with website addresses. The study tour itinerary is attached as Appendix 1.

Government Forest Land Managers

British Columbia Ministry of Forests and Range	www.gov.bc.ca/for
Florida Division of Forestry	www.fl-dof.com
New Brunswick Department of Natural Resources	www.gnb.ca/0078
Saskatchewan Environment Forest Service	www.se.gov.sk.ca/forests
Suwannee River Water Management District	www.mysuwanneeriver.com
United States Forest Service	www. fs.fed.us
Washington State Department of Natural Resources	www.dnr.wa.gov

Non-government Forest Land Managers

Canadian Forests Products Ltd.	www.canfor.com
Cascadia Forest Products Ltd.	www.cascadiafp.com
Hancock Timber Resource Group	www.hancocktimber.com
International Paper Company	www.internationalpaper.com
Island Timberlands Ltd.	www.islandtimberlands.com
J.D. Irving Ltd.	www.jdirving.com
Louisiana-Pacific Canada Ltd.	www.lpcorp.com
Meadwestvaco Corporation	www.meadwestvaco.com
Rayonier Inc.	www.rayonier.com
Seven Islands Land Company	www.sevenislands.com
Western Forest Products Inc.	www.westernforest.com
Weyerhaeuser Saskatchewan Ltd.	www.weyerhaeuser.com

Consultants

Cortex Consultants Inc.	www.cortex.org
Forest Ecosystem Solutions Ltd.	www.forestecosystem.ca
FORSight Resources LLC	www.FORSightResources.com
James W. Sewell Company	www.jws.com
Mason, Bruce and Girard, Inc.	www.masonbruce.com

Software Providers

D.R. Systems Inc.	www.drsystemsinc.com
FORCE/Robak Associates Ltd.	www.fra.nb.ca
Gowlland Technologies Ltd.	www.gowlland.ca
National Council for Air and Stream Improvement, Inc.	www.ncasi.org
Remsoft	www.remsoft.com

Universities

Georgia	www.uga.edu
Maine	www.umaine.edu
New Brunswick	www.unb.ca

Other

American Forestry and Paper Association	www.afandpa.org
Canadian Forest Service	www.nrcan.gc.ca/cfs
Maine Forest Service	www.maineforestservice.org

Forest Estate Modelling Examples

OPTIMISATION

Cortex Consultants Inc.

Cortex Consultants are based in Victoria, British Columbia and comprise of eight analysts, including Doug Williams, co-founder of the company. Cortex has evolved from timber planning to spatial planning.

Cortex's principal tool for optimisation is Woodstock, coupled with the Mosek linear programming optimiser. Cortex are typically building large matrix problem files, about 1.3Gb. They use a 64-bit computer with 6Gb of RAM to solve these problems in about 1½ hours.

Cortex's approach is to model forest growth first, with no wood production activity, to understand features like oldgrowth potential. After this, constraints on activity are added.

Innovations in the use of Woodstock, based on Doug Williams' Operations Research background, include manually setting up a variable time step in their models (eg, 30 periods as 10 1-year periods, followed by 20 10-year periods), building two sets of yield tables and transitioning between them at period 10. The recently developed compress time option in Woodstock allows a simpler achievement of the same thing from the users perspective.

Similarly, Cortex use their own formulation of goal programming for their big models, which they claim is more efficient than Woodstock's generic _GOAL functionality. Typically this involves an objective function that maximises the weighted short- and long-term harvest level without compromising non-wood values like oldgrowth and landscape.

An approach used for clients and stakeholders who prefer simulation models, is to use Woodstock to initially simulate 250 year old sereal forest area, for example, to

identify requirements. Then use this result to set constraints when harvesting in the optimisation model, which then requires less weightings in the objective function.

Timber supply analysis for clients around British Columbia is undertaken, including harvest plans and silvicultural regimes. Woodstock is used for strategic modelling, but there is typically a disconnect with operational planning, which uses different coverages and product specifications. Stanley, Remsoft's spatial harvest planning tool is used for some clients in conjunction with Woodstock, thus remaining in the vector world of GIS coverages and shapefiles. However another tool, SELES (refer to Heuristics, Gowlland Technologies Ltd.) is also used by Cortex, because it surpasses Stanley's functionality. SELES is rastor-based, and suits spatially-explicit stochastic ecosystem modelling. SELES can do everything that Remsoft's Spatial Planning System can do, and more, like building roads, but there is no optimisation functionality.

SELES is a flexible, programming language that is used by Cortex grouping many models, including Woodstock, under the SELES umbrella. A favoured approach is to start with a SELES rastor and build an area section for Woodstock using Cortex's own program, then produce a harvest schedule with Woodstock, and finally take the result back to SELES.

To conclude, two examples of Cortex's recent work follow:

1. Queen Charlotte Islands Landuse Plan 2004-2005

   This project involved assessment of timber supply and ecosystem impacts, including riparian management, roading network and wildlife habitat.

   A spatially-explicit modelling approach was taken, whereby the landbase was represented with Woodstock and solved as a linear program. Then the harvest schedule result was fed into SELES for further analysis, including habitat evaluation.

2. Spotted Owl Recovery 2003-2005

   This multi-stakeholder project included federal and provincial/state governments, and the forest industry. Modelling was undertaken in SELES at a strategic level only. Results generated covered timber supply, spotted owl population and protected habitat. The challenge now is to operationalise these results. Some project-specific programming to post-process results, integrating forest management areas with owl habitat now, and in the future, has been undertaken.

FORCE/Robak Associates Ltd.

Force/Robak Associates Ltd. is based in Fredericton, New Brunswick and is staffed by five people. They have been developing forest management software for a number of years.

Their current offering is OperMAX. It sits on top of a Microsoft Access database (or Oracle database), using tables and/or a shapefile as input. Spreadsheets can be used as input too. Simply put, OperMAX suggests a harvest plan in terms of where (harvest unit), when (year of harvest) and how (harvest system), and reports area and log products cut. FORCE/Robak use either the CWHIZ or CPLEX linear programming optimisation solver with OperMAX.

FORCE/Robak's approach is to work with potential clients to demonstrate the effectiveness of OperMAX. This is done by comparing a company's previous years actual operations and results with OperMAX's alternative approach. In a fully constrained OperMAX model actuals are simulated for comparison, with an optimised run. J.D. Irving have used OperMAX (see Optimisation, J.D. Irving Ltd.), but favour WOODMAN for their supply chain planning.

Stora Enso, based at Port Hawkesbury in Nova Scotia are currently evaluating OperMAX. Forestry Tasmania have hosted a presentation from FORCE/Robak on OperMAX, but does not have the integrated forest and forest product operations to warrant the use of OperMAX. In all cases the quality and timeliness of the input data to OperMAX is critical to the outcome.

FORSight Resources LLC

FORSight Resources LLC is a consultancy firm with offices in Charleston, South Carolina; Vancouver, Washington; and Bangor, Maine. Its area of expertise involves technical aspects of forest management – biometrics, GIS, and forest estate modelling, mainly to support acquisitions and divestitures. Much time is spent checking client's data, and including the spatial element, which is often important for forest management planning. A 'universal translator' is being built currently to automate the quality assurance process for yield table generation.

FORSight use, or have used, a wide variety of modelling software. The USFS's Forplan/Spectrum models are well known and robust, but inflexible. Remsoft's Spatial Planning System (RSPS) is the main tool used, mainly for flexibility in building models and output generation. RSPS includes Woodstock, Spatial Woodstock, Stanley and Allocation Optimiser.

Habplan (refer to Heuristics, National Council for Air and Stream Improvement, Inc.), a simulated annealing heuristic, has advantages in some circumstances. In FORSight's experience Habplan is good for solving spatially constrained problems, focussed on non-wood values. However it is not an optimiser (ie, there is no measure of solution ranking) and is complex to understand and run.

Patchworks (refer to Heuristics, Louisiana-Pacific Canada Ltd.) is another simulated annealing heuristic. In FORSight's experience its biggest limitation is that it does not look beyond the current rotation.

Another tool is the 'spatial feasibility test', like an automated colouring pencil, often used to post-process a spatial harvest plan to assess wildlife habitat suitability. Results are often integrated with the forest estate model to improve wildlife habitat outcomes.

Examples of the use of Woodstock models include two USFS National Forests. For Big Horn National Forest, a number of non-wood values were assessed, initially using goal programming with arbitrary weights, and finally creating a model that maximised

net present value, while meeting all non-wood constraints. For Black Hills National Forest each strata had a fire risk score, and a harvest plan was developed that minimised this fire risk score.

Most clients run Woodstock, and hand the result, in terms of area and volume cut and silviculture applied, to field foresters to implement. A minority of clients understand the potential implications of spatial constraints required to meet Forest Practices Codes and/or the Sustainable Forestry Initiative (SFI) and other certification of sustainable forest management. Often what is required is to lock out adjacent areas to recent harvest in strategic Woodstock models to add more operational reality, prior to further tactical planning based on this strategic woodflow.
Woodstock models built by FORSight typically have 10-14 themes, comprising five biological and administrative themes each and are usually solved by Mosek in about 20 minutes, although they have built and solved a 2.2 Gb matrix on a 64-bit computer in a number of hours.

FORSight Resources favour the optimisation approach to forest estate modelling. They typically start with an unconstrained run to identify optimal economic stand rotations, and then add constraints, potentially as a goal program initially to understand the problem. Yields are often delivered comprising of standing volume inventory, flags describing stand characteristics, and harvest removal (ie, traditional log product yield tables).

With the use of Stanley, which FORSight Resources describe as a monte-carlo integer programming heuristic, they can identify a percentage of the optimal solution that can be achieved while taking account of spatial constraints. Uncertainty and risk is often dealt with by replanning when events happen, because the potential futures are infinite. This realist approach often differs from the theorists.

Hancock Timber Resource Group

Hancock Timber Resource Group is a global TIMO (Timber Investment Management Organisation). Hancock's has acquired forest throughout the United States, Australia and New Zealand as investments for pension funds, trusts and private wealth.

Hancock Forest Management Group manages the forests, charging the investors a fee for services, including forest planning.

As an economic investment the main focus is on items that have a monetary value, and the financial return on that investment. There is relatively less focus on non-wood values, but long term stewardship is important. Formal habitat plans exist. Two examples are spotted owl recovery, over large areas, which are incorporated into strategic modelling, and threatened woodpecker species, over small areas, which are just excluded from woodflow planning. In addition, landscape analysis is usually conducted after strategic modelling.

RSPS is Hancock's core modelling tool. Prior to this spreadsheets only were used for valuations. Now woodflow from Woodstock is fed into a Microsoft Access Timber Investment Model database.

Hancock's use many Woodstock templates for acquisitions and 'what if' forest management analysis. Woodstock models are typically about ten themes and 100,000 hectares, modelling 80 one-year periods and reporting the first 50 years. These models, using Mosek as the linear programming optimiser, build, solve and report in about half an hour.

In the US South rolling five-year tactical plans are updated annually. Stanley is used to develop an initial tactical plan, incorporating the SFI's three-year five foot height green-up and 200 foot adjacency rules, with a maximum opening size of 200 acres. This tactical plan is then viewed using ArcGIS/ArcMap by field foresters in an in-house tool called 'TacPlanner', programmed by Orbis GIS, Inc. The shapefile, and yield report, from Woodstock are incorporated in a geo-database, along with cut period, action and age, and allows field foresters to make manual adjustments to the plan. This result is then run back through Woodstock (and Stanley) to show the impact. These tactical planning tools are currently being developed further.

J.D. Irving Ltd.

J.D. Irving Ltd. is a large private company, headquartered in Saint John, New Brunswick, with operations in Maine, New Brunswick and Nova Scotia, covering industries such as transportation, oil, fish, shipbuilding and forestry. The company owns 13 sawmills, a pulp mill, a paper mill, a tissue mill and a corrugated cardboard mill.

J.D. Irving is the licensee of two forest crown licences in New Brunswick totalling one million hectares. They also own their own freehold forest land in Maine, New Brunswick and Nova Scotia, totalling a similar area. One set of forest policy and rules are applied across their entire forest management estate regarding adjacency, buffers and deer wintering area (DWA).

J.D. Irving's Woodland Information System appeared to be state-of-the-art. It includes real time Global Positioning Systems (GPS) for silvicultural and harvest operations. Company supervisory staff use Pocket PCs running ArcPad GIS to record operational details in the field, described as a 'connected workforce'. Harvesting machinery are currently having Toughbooks added to the cab, providing the operators with realtime GPS location to aid communication and progress within operational forest areas.

Toughbook in harvesting machinery cab

Strategic planning uses RSPS. A typical model includes seven themes:

TH1 Licence
TH2 Cover type
TH3 Strata name (10 digit)
TH4 Ecological land classification
TH5 Site classification
TH6 Forest zone eg, DWA, buffer, old forest
TH7 Vegetation community

The objective function usually involves maximising discounted softwood volume. Yield tables are generated for total merchantable volume only, split by broad species groups, and piecesize, from which stocking can be derived. Log product volume breakdown is done outside the model.

A number of different pieces of software have been tired for tactical planning. OperMAX is good, but not integrated with anything else. Halco Software Systems' product, WOODMAN, has been favoured recently for matching supply and demand for forest products. Remsoft's Allocation Optimiser has been used too, although it is considered a lightweight equivalent to WOODMAN. WOODMAN is used for operational planning too, plus J.D. Irving's own operational planning tool, using their connected workforce approach, integrating with its corporate Woodland Information System.

New Brunswick Department of Natural Resources

New Brunswick's Department of Natural Resources (DNR-NB) administers ten crown licences covering the province's public forest. A five-yearly renewal of these licences involves the six current licensees in the province building a forest estate model (one model per licence) to demonstrate the state of the forest and their forest management plans for the future.

All licensees in the province, plus DNR-NB are using RSPS, which assists consistency of approach, and facilitates review by DNR-NB and ease of comparison.

The Woodstock models include all forest area, whether or not they are used for wood production, including protected natural areas (PNA), deer wintering areas (DWA), mature forest areas and biodiversity areas.

Models are typically 16 five-year periods, totally an 80-year planning horizon, as an aspatial strategic plan. The first five periods (ie, 25 years) are considered in some detail, as a spatial tactical plan, whereby areas are identified for harvest within a five-year period. Finally operational plans are developed annually.

Typically there is no log product segregation, just total volume by species group. Often the objective function is to maximise total softwood volume cut. A non-declining yield of softwood is calculated with hardwood treated as an arising. In the 25-year spatial tactical plan this non-declining yield of softwood forms the basis of an agreed annual allowable cut (AAC). This is set by the government after reviewing licensees' modelling.

Creation of yield tables is a collaborative effort throughout New Brunswick, with an independent Yield Table Unit funded jointly, with results used by all participants.

A common Woodstock model construct that is used to model non-wood values, like DWA and mature forest areas, is to include each individual area's status as a yield table 'flag' with the value of zero or one. Zero is taken to mean an area does not meet a particular requirement, and a one means it does. An example will best illustrate, where area is suitable as DWA from period five onwards:

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*Y  ? ? ?
DWA 1 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1  ;deer wintering area flag
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The modelling framework seems well developed in New Brunswick. The challenge faced by a new taskforce in the province is to confirm that modelled strategic and tactical outcomes are operational feasible in terms of wood production and residual non-wood forest values.

Staff from DNR-NB, UNB and the Yield Table Unit in maple regeneration after variable retention harvest

Seven Islands Land Company

Seven Islands Land Company has owned land in Maine since 1840. The private owners' objectives for their 300,000 hectares of freehold forestland today include making money, sustainability and aesthetics.

The Forest Practices Act, enforced by the Maine Forest Service, aims to preserve water quality, limit clearcutting and ensure regeneration. The forest is mostly mixed hardwood and softwood, and managed with partial harvesting, usually two entries, 20 years apart, once the stand is merchantable.

Seven Islands builds 20 five-year period forest estate models, and has been using Woodstock since 2002 when it replaced FORMaine, a derivative of Forplan from the USFS. This modelling is updated every five years, which is currently in progress, using for the first time Spatial Woodstock and the USFS's FVS (Forest Vegetation Simulator) – a tree-level growth model – to create yield tables. Yield tables are built

for five species groups, log products that distinguish softwood sawlog, pulp and hardwood non-pulp, basal area and stocking. The objective function is to maximise total volume, given a forest structure constraint. CWHIZ is used as the linear programming optimiser, solving in a couple of minutes.
Typical themes in Seven Islands forest estate model are:

TH1 Habitat class
TH2 Size (maturity)
TH3 Density (crown closure)
TH4 Status (existing / ready for shelterwood / first thinning / second thinning / pre-commercial thinning)
TH5 Protection zone
TH6 District (unit)
TH7 Site Class (one of three)
TH8 Yard ID (deer wintering area)

Weyerhaeuser Saskatchewan Ltd.

Weyerhaeuser has operated in Saskatchewan since 1999 when it acquired cutting rights to public forestland, defined as a Forest Management Area (FMA), and then doubled its activity when purchasing MacMillan Bloedel Ltd. The total area of the two FMAs is 4.9 million hectares - more than all the forest area in Tasmania!

Weyerhaeuser Saskatchewan are based in Prince Albert in the centre of the province and operate sawmills and pulp and paper mills (although at the time of visiting the pulp and paper mills were up for sale or potential closure).

The forest is managed without clearcutting, by maintaining patches of forest and single trees across the harvested landscape. The harvest operations are heavily mechanised. Trees reach only 30 metres in height before harvest, and produce few logs with a small end diameter greater than 30 centimetres.

Harvest operation in Birch Lake area

RSPS is used for forest estate modelling to demonstrate long-term woodflow, and for tactical planning. Weyerhaeuser intend to extend their use by purchasing Allocation Optimiser.

SIMULATION

British Columbia Ministry of Forests and Range

The British Columbia Ministry of Forests and Range is organised into three regions – northern interior, southern interior and coastal – and there are 20 districts province-wide. The provincial timber harvesting landbase is some 25 million hectares, which are covered by either Timber Supply Areas (TSAs) - 75% of the total forest cut - or Tree Farm Licences (TFLs). The TSAs are a volume-based tenure, where Ministry of Forests and Range are responsible for doing the woodflow modelling, then setting an AAC for the licensee. The TFLs are an area-based tenure, the licensee is responsible for doing the woodflow modelling, and presenting a plan, again from which an AAC is set. Typically this analysis is required every five to ten years, with a 200-250-year planning horizon, including a 20-year spatial plan.

The first timber supply review in recent times was undertaken in the early 1990s using a British Colombia version of the FORMAN simulator from the University of New Brunswick. Prior to this linear programming optimisation had been used.

The second timber supply review (1996-2002) used a more complex pseudo-spatial simulation model called FSSIM (Forest Service Simulator), including more overlapping non-wood constraints like visuals (requiring long rotations), wildlife habitat, biodiversity and community watersheds, as a result of the introduction of a Forest Practices Code in 1995.

The third timber supply review is currently underway. This time a new model, FSSAM (Forest Service Spatial Analysis Model) is being used. It is a vector model, using the IDL Language from Barrodale Computing Services Ltd. Its inputs include preblocked harvest units, any fixed harvest schedule and an explicit roading network (ie, specific polygon constraints). The specification for the new simulator included the ability to grow ten million stands annually for 200 years in ten minutes. It has been configured to use multi-CPUs, pick a point from within the solution space, simulate, then pick the next best spot, simulate again, and so on to get a pseudo-optimum.

Another approach being pursued concurrently uses SELES (see Heuristics, Gowlland Technologies Ltd.) - a rastor-based heuristic. A potential third approach, using Woodstock, is not happening.

This multi-model approach seems to sum up forest estate modelling in British Columbia. Mostly simulators are used, but there are applications of spatially-explicit simulated annealing heuristics and optimisation using Woodstock. Consultants often do analysis for TFL license holders, using their favoured modelling tools.

Forest Ecosystem Solutions Ltd.

Forest Ecosystem Solutions is a fairly young consultancy firm, based in Vancouver, British Columbia. They have developed their own forest estate modelling tool, FSOS (Forest Simulation Optimisation System). FSOS comprises of 3 components – GIS

coverages; Microsoft Access database; and a modelling algorithm. FSOS can be run either as a simulator with targets or a pseudo-optimiser heuristic with weighted targets.

Canfor is a major client in British Columbia, and for their TFLs FSOS is run as a simulator for 200 years in five-year period increments. Bowater is a client in Ontario, but there is competition from Patchworks (see Heuristics, Louisiana-Pacific Canada Ltd.) in that part of Canada. Forest Ecosystem Solutions have provided the Ontario Forest Service with a copy of FSOS to try, but they are unsure of entering the software sales/support area, preferring their current consultancy role.

Washington State Department of Natural Resources

Washington State Department of Natural Resources (DNR) is a corporatised public forest management agency, much like Forestry Tasmania, but with one significant difference. DNR manages 2.1 million acres of multi-use forest to generate revenue for 12 public institution trusts, like schools, each having its own specific forest area.

DNR operates to the Forest Practices Act, and a number of other pieces of legislation, relating to forest protection (eg, fire, health, wildlife habitat, aquatic ecosystems). Forest management is often decided through the courts.

A 75-year multi-species Habitat Conservation Plan has been developed in the past. The three most important species considered are northern spotted owl, marbled murrelet and salmon. In 1996, a simplistic approach using ageclass as a surrogate for stand structure was used. The need for improved metrics was identified, and the result was DNR's own system identifying three stand structures – ecosystem initiation; competitive exclusion; and structurally complex. No clearcut harvest occurs, rather dispersed retention harvests occur, leaving at least 20 trees per hectare, and they are referred to as regeneration harvests (or 'regens').

A current project on marbled murrelet, a small bird that lays its eggs on large branch platforms, illustrates complexity and modelling challenges. Unknowns include:

1. Land classification required, but what?
2. What silviculture to create required habitat?
3. How to do harvest to minimise predation of eggs

A habitat quality and contiguity matrix has been created to assist modelling, with the goal of maintaining the species as part of DNR's Habitat Conservation Plan.

A large project to calculate the sustainable harvest from the 1.4 million acres of DNR forest in the western part of the State, which accounts for 90% of DNR's revenue, was started in 2000. A simulation modelling approach was taken, using Options, a spatial deterministic simulator from D.R. Systems Inc. in Nanaimo, British Columbia. Options has a certain structural requirement for its input data, but is limited only by its users' imagination. Its underlying database is a result of GIS overlays, then species groups, site classes, treatments and regimes are defined. Finally harvesting rules and ecological and management constraints are added.

In using Options at DNR the user acted like a heuristic, running the simulator many times, to improve the result. In this way more recently, using the same forest description, Woodstock was run as an optimisation and got basically the same result as the Options simulation.

Six alternatives were assessed in the sustainable harvest project:

1. Business as usual
2. 1996 view
3. Business as usual, but remove constraints and remove even flow
4. Conservation, avoiding 150-year+ stands, no riparians, longer rotations
5. Industrial forest management, by value
6. Preferred alternative - mix of five alternatives above, with thinning (50% removal) in habitat areas

The later was agreed in 2004, but subsequently challenged in court, and now requires review of its environmental impact statement.

Further work on the Habitat Conservation Plan in 2005 involves using the six alternatives (as before) in Options, with nine habitats defined, and run as a scenario-based analysis. In 2006 the intention is to use Woodstock, with habitat yield tables (delivered using DLLs (Dynamic Link Libraries)), evaluating alternatives and seeking a win:win solution.

The USFS's SVS (Stand Visualisation System) software has been used to visualise stand structure options, based on forest inventory tree lists.

DNR's current Woodstock model incorporates eight themes, but will probably increase to manage transitions:

TH1	Administration
TH2	Deferral
TH3	Owl habitat
TH4	Land class
TH5	Site class
TH6	Species type
TH7	Natural or plantation
TH8	Yield status

This new optimisation modelling is being presented as 'value scheduling' to those more familiar with a simulation approach. Results from all this forest estate modelling can be shared organisation-wide using an ARCIMS site on the Intranet as a GIS viewing tool. Other innovations include a new heuristic forest estate modelling approach being programmed for DNR through D.R. Systems Inc. In addition, DNR recently commissioned a US$32,000 64-bit computer with 4 x 2 MHz processors and 16GB RAM.

DNR impress as an innovative public forest land manager, willing to try many approaches to meet its forest estate modelling challenges of wood and non-wood values, strategic, tactical and operational planning.

Western Forest Products Inc.

Western Forest Products hold three TFLs in the British Columbia coast region, mostly on Vancouver Island. 500,000 hectares of the gross 800,000 hectares is used to produce 2.3 million cubic metres per year of wood to supply company sawmills and a pulp mill.

Western Forest Products uses the simulator Complan for its forest estate modelling. Complan, currently owned by Timberline Forest Inventory Consultants, was written by staff at Olympic Resource Management in the 1990s. Complan has a spatial element, so enables use of model output to suggest where harvesting should occur, usually within five-year periods.

Western Forest Products run a heavily constrained forest estate model, so see little advantage in running an optimisation model. Instead they concentrate on the quality of data input, notably forest inventory.

United States Forest Service

The USFS is naturally a very large organisation, spread across the nation. It has a number of research stations based in different regions within the United States, and manages federal forests, predominantly in the west, and mostly for non-wood values in recent years.

The USFS produces a large number of modelling software tools, with major activity centred at Fort Collins in Colorado, which was not part of this study tour itinerary. However there was an opportunity while in Portland, Oregon to visit the Pacific Northwest Region office briefly.

The USFS is currently moving away from linear programming optimisation forest estate models, like its well-known and previously widely-used tools, Forplan and Spectrum, to new simulation models. One such model is maintained in the Pacific Northwest. It is called Vegetation Dynamics Development Tool (VDDT), and is described as a State Transition Model. VDDT can be downloaded from

www.essa.com. There is a spatial version of VDDT, called TELSA, but it becomes more complicated.

VDDT operates by simulating a number of pixels each representing an initial state. Utah and Idaho are using VDDT for ten-yearly plan revisions. And a large project, known as the Pacific Northwest Landscape Analysis, involving all land ownership in Washington and Oregon, is currently underway, using VDDT.

HEURISTICS

Gowlland Technologies Ltd.

Gowlland Technologies is a single person operation, based in Victoria, British Columbia. Andrew Fall has developed a rastor-based forest estate modelling tool called SELES (Spatially Explicit Landscape Event Simulator).

SELES is free to download from www.gowlland.ca. Andrew's philosophy is to make the software freely available, and provide a consultancy service, including training, in the use of SELES. His expectation is that SELES users – there are very few currently – will share their experience.

SELES has its own programming language, and is totally blank, like Woodstock, when a user starts. This indicates a lot of flexibility and power, but an initial challenge to get started. The user provides a number of rastor coverages of interest to model, plus future states, and SELES simulates change through time spatially.

Louisiana-Pacific Canada Ltd.

Louisiana-Pacific operate in Manitoba. In conjunction with the Manitoba Conservation Forestry Branch Louisiana-Pacific have used RSPS for modelling woodflow on their public forest licence area. However Louisiana-Pacific were finding this modelling framework restrictive as they added more non-wood values from their consultative stakeholder planning process to their forest estate modelling.

Louisiana-Pacific chose Patchworks, a heuristic model from Spatial Planning Systems (www.spatial.ca) in Deep River, Ontario (not part of this study tour itinerary), as an additional tool. Patchworks enables a large number of spatial constraints to be assessed concurrently to derive a harvest schedule.

Mason, Bruce & Girard, Inc.

Mason, Bruce and Girard are a forestry consultancy firm based in Portland, Oregon. They have a range of clients, from public organisations like the Oregon State Department of Forestry, to small private clients (eg, 20-year harvest plan in 5-year periods for 5000 hectares).

Mason, Bruce and Girard previously used the Spectrum linear programming software as their preferred forest estate modelling tool, mainly because clients knew it and were comfortable with it. Mason, Bruce and Girard are now looking to use RSPS.

In addition they have their own simulated annealing heuristic model, programmed in-house. Modules are programmed in C as required for specific client problems. Standard examples include maximum harvest opening size, adjacency green-up and adjacency to reserves. The model will handle millions of polygons, many time periods and decision variables for silviculture and harvest. This heuristic represents strategic and tactical planning rolled into one. The model works from the bottom up, applying a schedule to polygons, evaluating, then trying the next iteration looking for a better solution. There is no graphical user interface to the model – it comprises of text file inputs and outputs. Outputs are post-processed with GIS and spreadsheet tools.

The decision usually for Mason, Bruce and Girard is when to use linear programming, and when to use heuristics. Generally the former is used for simple problems, and the later for spatial multi-dimensional complexity.

National Council for Air and Stream Improvement, Inc.

The National Council for Air and Stream Improvement (NCASI) focuses predominantly on environmental issues associated with industrial mills. Another focus is wildlife habitat. At the University of Massachusetts in Lowell a small team has built a spatial harvest scheduling heuristic call Habplan. Habplan is about six years old, and continues to be developed. A limited version is available for download at http://ncasi.uml.edu/projects/habplan, as the unlimited version is only available to NCASI members.

The Habgen module generates inputs for Habplan, based on simple stand parameter input. Habread is a more recently developed module that enables a traditional linear programming MPS matrix problem file to be read into Habplan.

Habplan includes a spatial component, driven by a shapefile. Habplan is written in JAVA, can be run under any operating system, and is limited only by computing power. Habplan has an objective function, made up of all components of interest. Habplan iterates, trying for a better result, and producing alternative harvest schedules as it proceeds. For example, Habplan could be requested to minimise clearfelling near watercourses, based on the shapefile input. A ten-author paper is in preparation describing the use of Habplan and habitat models, like population viability analysis, to assess habitat effects of harvest schedules.

During the study tour a number of organisations were visited that have some experience using Habplan. Users ranged from those who have tried Habplan and discarded it, to those who include Habplan in their modelling 'toolkit', used in certain circumstances, and to those still experimenting with Habplan's application within their organisation.

University of Georgia

Staff at the School of Forest Resources at the University of Georgia have a wealth of experience in forest estate modelling in industry and at the university. Over the years they have collectively used industry in-house linear programming formulations (based

initially on Jerry Clutter's MaxMillion linear program) and experimented with various heuristics.

Woodstock has been used, at the stand level, combining both strategic and tactical planning. The linear programming result is post-processed to identify spatial adjacency problems, and shadow prices used to reschedule stands, enabling the cost of adjacency rules to be identified. Habplan has been used to achieve a similar result, but there is no optimal solution to compare the cost of adjacency rules.

A simple Heuristic Algorithm Teaching Tool (HATT) is available from http://warnell.forestry.uga.edu/Warnell/Bettinger/planning/index.htm. HATT is used by small forest owners and an advanced planning class. HATT is coded in Visual Basic, and includes six types of heuristic:

1. Genetic algorithm
2. Monte-carlo
3. Raindrop method
4. Simulated annealing
5. Tabu search
6. Threshold accepting

A Tactical Planning Harvest Schedular has been developed for International Paper, written initially in VB, but currently being rewritten in C# to speed up run times. Each GIS polygon, representing a stand, is modelled and scheduled independently over a 20-year planning horizon. Many possible regimes are assessed, while controlling the maximum opening size and adjacency, and delivering 20 log products within a specified range each year, while maximising the net present value objective. This is considered too complex for optimisation so it has been developed as a heuristic.

The University of Georgia has also used D.R. Systems' Options simulator to undertake wood supply projects for the Georgia Forestry Commission. USFS FIA inventory data, supplemented with Landsat satellite imagery, has been used in Options to undertake wood basket sustainability modelling for mill location studies.

Conclusions

Australian forestland managers are generally on par with most forestland managers visited, in terms of their use of forest estate modelling, and in particular traditional wood supply analysis. However, Australian forestry organisations are relatively weak at incorporating non-wood values into traditional wood supply analysis. Examples regularly seen during the study tour incorporated the entire forest landbase in the forest estate model, and included fauna species habitat and forest vegetation community values.

Remsoft's Spatial Planning System (RSPS) is the tool many Australian forestry organisations know and use, and it is also used extensively in North America. RSPS is considered an industry standard, both in North America and Australia. Australian forestry organisations should continue to develop the use of this tool for their forest estate modelling.

There are other tools available for forest estate modelling, particularly for incorporating non-wood values into wood supply analysis. Of these, some like Habplan and SELES are immediately available for use. Others have been developed in-house, and if they are available, it is only as a consultancy.

All alternative tools require an investment of time to utilise (and in some cases money). It is important to remember that all tools have their advantages and disadvantages, which are often not discovered until the tools are implemented.

Appendix 1: Itinerary

September 22nd - November 4th 2005

Day		Night	
22nd	Hobart to Tokyo, via Sydney	1	In transit
23rd	Tokyo	2	Tokyo
Sat 24th	"	3	"
25th	Tokyo to Fredericton, via Minneapolis and Toronto	4	Fredericton
Mon 26th	Visit University of New Brunswick, FORCE/Robak & Remsoft (contacts: Thom Erdle, Ragnor Oborn, Andrea Feunekes)	5	"
27th	Visit DNR-NB (contact: Tom Ng)	6	"
28th	"	7	"
29th	Attend Remsoft Annual User Group Meeting (contact: Andrea Feunekes)	8	Saint John
30th	Visit J.D. Irving (contact: Dave Young)	9	"
Sat 1st	Saint John to Bangor by bus	10	Bangor
2nd	Bangor	11	"
Mon 3rd	Visit Seven Islands, University of Maine & James W. Sewell (contacts: John Kolenik, Jeremy Wilson, Ernest Bowling)	12	"
4th	Visit Maine Forest Service (contact: Ken Laustsen)	13	Portland, ME
5th	Attend 7th Annual Forest Inventory and Analysis Symposium to visit NCASI (contact: Paul Van Deusen)	14	"
6th	Portland to Boston by train, then to Washington DC	15	Washington DC
7th	Visit AF&PA (contact: John Heissenbuttel)	16	"
Sat 8th	Washington DC	17	"
9th	Washington DC to Atlanta, get rental car, drive to Tallahasse	18	Tallahasse
Mon 10th	Visit Division of Forestry & Suwannee River Water Mgmt. District (contacts: Steve Jennings, Charlie Houder)	19	Fernandina Beach
11th	Visit Rayonier & International Paper (contacts: Scott Katzer, Jim Rakestraw)	20	Charleston
12th	Visit FORSight Resources & MeadWestvaco (contacts: Bruce Carroll, John Thermes)	21	Charlotte
13th	Visit Hancock Timber Resource Group (contact: Brent Keefer)	22	Athens

14th	Visit University of Georgia (contact: Bob Izlar)	23	"
Sat 15th	Drop off rental car, then Atlanta to Saskatoon	24	Saskatoon
16th	Saskatoon	25	"
Mon 17th	Attend workshop on Reporting Wood Supply (contact: Brendan Hemens)	26	"
18th	"	27	Prince Albert
19th	Visit Weyerhaeuser (contact: Mike Leblanc)	28	"
20th	Attend meeting of Inter-Provincial Resource Analysts (contact: Brendan Hemens)	29	"
21st	"	30	"
Sat 22nd	Prince Albert to Saskatoon, then to Seattle, get rental car	31	Seattle
23rd	Drive to Portland	32	Portland, OR
Mon 24th	Visit FORSight Resources, M,B&G & USFS (contacts: Karl Walters, Roger Lord, Jim Merzenich)	33	Olympia
25th	Visit DNR (contact: Weikko Jaross)	34	Hoquiam
26th	Visit Rayonier (contact: David Kenney)	35	Port Angeles
27th	Car ferry to Victoria, then visit MoF & Gowlland Technologies (contacts: Tim Bogle, Andrew Fall)	36	Victoria
28th	Visit Cortex & CFS (contacts: Doug Williams, Graham Stinson)	37	"
Sat 29th	Vancouver Island	38	"
30th	"	39	Campbell River
Mon 31st	Visit Canfor & D.R. Systems (contacts: Patrick Bryant, Don Reimer)	40	Nanaimo
1st	Visit Cascadia FP & Island Timberlands (contact: Peter Kofoed)	41	"
2nd	Car ferry to Vancouver, then visit Forest Ecosystem Solutions, Western Forest Products & Weyerhaeuser (contacts: Colin Mahony, David Byng, Randy Webb)	42	Seattle
3rd	Drop off rental car, then Seattle to Tokyo	43	In transit
4th	Tokyo to Brisbane	44	"
Sat 5th	Brisbane to Hobart		