TIMBER SUPPLY IMPACTS
OF THE CURRENT AND PLANNED SEED ORCHARD PROGRAM
IN THE GOLDEN TIMBER SUPPLY AREA

Prepared for:

Ivan Listar

Ministry of Forests

Nelson Forest Region

Prepared by:

Timberline Forest Inventory Consultants Limited

Victoria, B.C.

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EXECUTIVE SUMMARY

The goal of this analysis was to assess the potential timber supply impacts of incorporating genetically improved stock into the planting program for the Golden Timber Supply Area (TSA), employing the most current genetic gain information available from the Forest Genetics Council. A key element of this analysis was the requirement to geo-reference genetic gain estimates by seed planning unit (SPU) within the TSA. The analysis was designed to assess these impacts relative to the base case timber supply analysis developed for Timber Supply Review #2 (TSR2). Every effort was made to employ the same data and modeling assumptions as were used in the TSR2 analysis.

The TSR2 analysis, completed in 1998, presented a base case timber supply forecast in which the existing allowable annual cut (AAC) of 535,000 cubic meters would be maintained for two decades, followed by a downward transition in steps of 10%, then 7%, over the next two decades to a long-term annual harvest level of 446,000 cubic meters in the fourth decade. This project encountered numerous challenges in attempting to emulate the TSR2 analysis results, arising from the quality and format of the TSR2 data, and from insufficiently detailed documentation of the TSR2 analysis methodology. Consequently, the present analysis was only able to achieve a long-term annual harvest level of 433,350 cubic meters.

Stand level genetic gain estimates were introduced into the TSR2 benchmark data model using the following steps:

1. Combine overlapping SPUs into “strata” to identify species-specific genetic gains and seedling supply everywhere on the net landbase;
2. Subdivide TSR2 analysis units by SPU strata;
3. Develop stratum-specific regeneration strategies;
4. Estimate annual seedling requirements by species and SPU;
5. Establish genetic gain expectations by species;
6. Develop genetically improved TIPSY yield estimates; and
7. Re-evaluate minimum harvest ages and green up ages based on the new yield estimates.

The modified analysis unit structure and regeneration strategies were implemented without genetic gain in the “no gain” scenario, from which annual planting requirements were determined by species and SPU. As a consequence of the modified regeneration strategy, this scenario was unable to exactly reproduce the harvest forecast of the TSR2 benchmark analysis. Therefore, the harvest forecast from this scenario was used as the basis for comparison of the harvest forecasts involving genetic gain.

Based on annual orchard seedling supply and the estimated annual seedling demand within each SPU, scenarios were developed to represent three potential future genetic gain expectations. The “blended gain” scenario represented the planting of orchard and wild stand stock, reflecting existing orchard production and allocation to the Golden TSA. The “full gain” scenario explored an expanded genetic planting program by assuming that orchard stock would be planted everywhere except in areas where no seedling orchards presently exist. The "Pl high" scenario represented a further increase in genetic gain expectations by assuming that orchards would be developed within the high elevation Lodgepole pine SPUs, providing a source of genetically improved planting stock for those areas of the TSA in twenty years time.

The following two tables show the decadal net harvest levels for each scenario, and the relative increase over the "no gain" harvest level achieved in each of the three genetic gain scenarios, respectively.

Decade	Net Harvest (m^3/decade)			
	No Gain	Blended Gain	Full Gain	Pl High
1	5,350,000	5,350,000	5,350,000	5,350,000
2	5,283,000	5,350,000	5,350,000	5,350,000
3	4,815,000	5,350,000	5,350,000	5,350,000
4	4,203,000	4,815,000	4,815,000	4,815,000
5	4,203,000	4,353,000	4,353,000	4,353,000
6	4,203,000	4,353,000	4,353,000	4,353,000
7	4,203,000	4,353,000	4,353,000	4,353,000
8	4,203,000	4,353,000	4,353,000	4,353,000
9	4,203,000	4,353,000	4,353,000	4,353,000
10	4,203,000	4,353,000	4,353,000	4,353,000
11	4,203,000	4,353,000	4,353,000	4,353,000
12	4,203,000	4,638,000	4,613,000	4,761,000
13	4,203,000	4,638,000	4,613,000	4,761,000
14	4,203,000	4,638,000	4,613,000	4,761,000
15	4,203,000	4,638,000	4,613,000	4,761,000
16	4,203,000	4,638,000	4,613,000	4,761,000
17	4,203,000	4,638,000	4,613,000	4,761,000
18	4,203,000	4,638,000	4,613,000	4,761,000
19	4,203,000	4,638,000	4,613,000	4,761,000
20	4,203,000	4,638,000	4,613,000	4,761,000
21	4,203,000	4,638,000	4,613,000	4,761,000
22	4,203,000	4,638,000	4,613,000	4,761,000
23	4,203,000	4,638,000	4,613,000	4,761,000
24	4,203,000	4,638,000	4,613,000	4,761,000
25	4,203,000	4,638,000	4,613,000	4,761,000

Decade	% Increase over No Gain Scenario		
	Blended Gain	Full Gain	Pl High
1	0.0	0.0	0.0
2	1.3	1.3	1.3
3	11.1	11.1	11.1
4	14.6	14.6	14.6
5-11	3.6	3.6	3.6
12-25	10.3	9.8	13.3

While increased harvest levels were achieved throughout the planning horizon, unavoidable modeling anomalies were encountered that confounded the distinction expected between the “full gain” and “blended gain” scenarios, making the comparison of those two scenarios inconclusive. Specifically, the managed stand growth and yield model TIPSY predicted decreased volume at increased genetic gain for some large analysis units. Additionally, minor differences in the harvest schedule sequence produced by FSSIM were found to occur early in the planning horizon. The interaction of these two factors with a forest estate that is on the threshold of being constrained by green up requirements resulted in a reduction in the “full gain” long-term harvest level relative to the “no gain” scenario. While these modeling artifacts confounded the conclusions that might otherwise have been drawn from the analysis, they did serve to highlight the degree to which inherent characteristics of the forest estate and the limits on disturbance may impact the timber supply dynamics of the Golden TSA.

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1. INTRODUCTION

The expected impacts of incorporating genetically improved[1] stock into timber supply area (TSA) planting programs are often assessed as sensitivity analyses in the provincial Timber Supply Review (TSR) program. The second iteration of the provincial Timber Supply Review process (TSR2) was completed for the Golden TSA in January 2000 with the release of the Chief Forester's Rationale for Allowable Annual Cut Determination (MoF, 2000). The timber supply analysis for TSR2 was completed in August 1998 (MoF, 1998). However, no evaluation of the timber supply impacts associated with the use of genetically improved planting stock was undertaken.

The purpose of this analysis is to provide such an impact assessment, employing the most current genetic gain[2] information available from the Forest Genetics Council. The methodology employed in this analysis builds upon the experience gained in similar work undertaken for the Arrow TSA (Timberline, 2000).

[1] Genetically improved or select seed and vegetative material is the result of selecting parent trees in wild stands, testing their offspring in long-term field trials, and propagating the best parents for seed production in seed orchards.

[2] Genetic gain is the average percentage increase in a specific trait (e.g. stem volume or wood relative density) of trees grown from select seed (orchard-produced seed from selected parents), relative to trees grown from wild-stand seed. The genetic gain of a seedlot is expressed as its Genetic Worth (GW). The GW for stem volume is measured as the percentage gain in volume expected for a seedlot at or near a reference harvest age. Reference harvest ages are established in TIPSY as 80 years for interior spruce, and 60 years for all other species.

2. DATA COMPILATION

2.1 Data Sources

Three principal data sources were assembled for use in this analysis:

1. GIS spatial data prepared for the TSR2 timber supply analysis;
2. Forest cover inventory attribute database files prepared for the TSR2 timber supply analysis; and
3. Seed planning unit (SPU) spatial data.

The GIS spatial data files and inventory attribute database files from the TSR2 timber supply analysis were provided by Ministry of Forests (MoF) staff at the Nelson Forest Region. The SPU spatial data files were obtained from the GIS department at the Vancouver office of Timberline Forest Inventory Consultants Ltd. The SPU data are considered to be in draft form at the time of this analysis.

2.2 Data Preparation Methodology

2.2.1 TSR2 Spatial Data

The spatial data files for TSR2 were provided by the MoF in PAMAP™ format, the Ministry of Forests corporate GIS standard at the time of the TSR2 analysis. PAMAP uses a raster-based representation of geographic space, which is incompatible with the MoF's new vector-based ArcInfo™ standard format. A conversion of the TSR2 data from PAMAP raster format to ArcInfo™ vector format was therefore undertaken. The process of raster to vector conversion introduces some spatial distortion into the resulting vector GIS coverages, simply because of the difference between the two forms of spatial representation.

2.2.2 Seed Planning Units

The Forest Genetics Council has defined SPUs, which are mappable polygon features that geographically delineate the extent of biologically feasible seedling use for stock originating from specific seed orchards throughout the province. Each SPU identifies the area throughout which seedlings of a given species originating from orchards within a specific region of the province may be used in regeneration. Note also that each SPU lies within a prescribed elevation band. The SPUs listed in Table 2.1 represent all SPUs that fall within the Golden analysis area, and that could potentially contribute to the future regeneration planting requirements.

Table 2.1 Seed planning units

Coverage Name	Description	Elevation Band (m)
fdekal	East Kootenay Douglas fir seed planning zone, all elevations	0-1500
fdnehi	Nelson Douglas fir seed planning zone, high elevations	1000-1500
fdnelo	Nelson Douglas fir seed planning zone, low elevations	0-1000
fdqlal	Quesnel Douglas fir seed planning zone, all elevations	0-1500
plekhi	East Kootenay Lodgepole Pine seed planning zone, high elevations	1400-2000
pleklo	East Kootenay Lodgepole Pine seed planning zone, low elevations	0-1400
plnehi	Nelson Lodgepole Pine seed planning zone, high elevations	1400-2000
plnelo	Nelson Lodgepole Pine seed planning zone, low elevations	0-1400
plpghi	Prince George Lodgepole Pine seed planning zone, high elevations	1100-2000
plpglo	Prince George Lodgepole Pine seed planning zone, low elevations	0-1100
plpgnhi	Prince George/Nelson Lodgepole Pine seed planning zone overlap, high elevations	1400-2000
plpgnlo	Prince George/Nelson Lodgepole Pine seed planning zone overlap, low elevations	0-1100
plpgnov	Prince George/Nelson Lodgepole Pine seed planning zone overlap, mid elevations	1100-1400
pwkqal	East Kootenay/Quesnel White Pine seed planning zone overlap, all elevations	400-1400
sxekal	East Kootenay Spruce seed planning zone, all elevations	0-1700
sxnehi	Nelson Spruce seed planning zone, high elevations	1300-1700
sxnelo	Nelson Spruce seed planning zone, low elevations	0-1300
sxnekhi	Nelson/East Kootenay Spruce seed planning zone overlap, high elevations	1300-1700

The individual SPU coverages overlap each other in various combinations such that each unique combination of SPUs identifies a specific supply of seedlings of certain species originating from specific orchards, each with a particular genetic gain factor. Thus it is these unique combinations of overlapping SPUs that act as the common denominator for targeting genetic gain factors in the analysis of timber supply impacts. A GIS overlay was performed to identify the unique SPU combinations, which will be referred to collectively as "SPU strata" throughout the remainder of this report. The SPU strata identified through GIS analysis are summarized in Table 2.2.

Table 2.2 SPU strata definitions

SPU Stratum	Elevation (m)	Contributing Seed Planning Units	Net Landbase (ha)
1	all	none	489
2	1400-2000	Pl PGN high	724
3	1400-1700	Pl PGN high, Sx NE high	2,597
4	1100-2000	Pl PG high	883
5	1300-1700	Pl PG high, Sx NE high	2,147
6	1400-2000	Pl NE high,	21
7	1400-1700	Pl NE high, Sx NEK high	0
8	1400-1700	Pl NE high, Sx NE high	175
9	1400-2000	Pl EK high	9,187
10	1400-1700	Pl EK high, Sx EK all	14,554
11	400-1000	Fdi QLN low, Pl PGN low, Pw KQ all, Sx NE low	3,910
12	400-1000	Fdi QLN low, Pl NE low, Pw KQ all, Sx NE low	137
13	1100-1300	Fdi QLN high, Pl PGN overlap, Pw KQ all, Sx NE low	3,418
14	1300-1400	Fdi QLN high, Pl PGN overlap, Pw KQ all, Sx NE high	1,696
15	1000-1100	Fdi QLN high, Pl PGN low, Pw KQ all, Sx NE low	1,551
16	1400-1500	Fdi QLN high, Pl PGN high, Sx NE high	1,520
17	1000-1300	Fdi QLN high, Pl NE low, Pw KQ all, Sx NE low	55
18	1300-1400	Fdi QLN high Pl NE low, Pw KQ all, Sx NE high	42
19	1400-1500	Fdi QLN high, Pl NE high, Sx NE high	56
20	400-1100	Fdi QL all, Pl PG low, Pw KQ all, Sx NE low	11,864
21	1300-1500	Fdi QL all, Pl PG high, Sx NE high	1,668
22	1100-1300	Fdi QL all, Pl PG high, Pw KQ all, Sx NE low	4,774
23	1300-1400	Fdi QL all, Pl PG high, Pw KQ all, Sx NE high	2,012
24	400-1000	Fdi NE low, Pl NE low, Pw KQ all, Sx NE low	285
25	1000-1300	Fdi NE high, Pl NE low, Pw KQ all, Sx NE low	257
26	1300-1400	Fdi NE high, Pl NE low, Pw KQ all, Sx NE high	46
27	1400-1500	Fdi NE high, Pl NE high, Sx NE high	61
28	400-1400	Fdi EK all, Pl EK low, Pw KQ all, Sx EK all	92,721
29	1400-1500	Fdi EK all, Pl EK high, Sx EK all	9,910

2.2.3 Resultant File

The SPU strata and the converted TSR2 spatial data files were combined using GIS overlay techniques to produce a spatial resultant file.

The forest cover inventory attribute files for TSR2 were provided as a set of xBase format files. Each record in these files contains the polygon and mapsheet numbers of the forest inventory polygon to which the record refers. This information was used to join the spatial resultant database records to the appropriate forest inventory attributes, thus producing the final analysis database for this project.

3. BASE CASE ANALYSIS

The base case analysis was comprised of the following six steps:

1. Definition of the net timber harvesting landbase;
2. Characterization of current forest management practices;
3. Establishment of biodiversity objectives;
4. Development of stand-level growth and yield relationships;
5. Characterization of current harvesting and silvicultural practices, and
6. Modeling forest-level dynamics.

3.1 Net Landbase Definition

The Golden TSA is located in southeastern British Columbia within the Nelson Forest Region. The TSA encompasses roughly 906,000 hectares in the Rocky Mountain Trench and upper Columbia River Valley (MoF, 2000). The areas in provincial and federal parks that lie adjacent to, or are contained in, the TSA are included in the Golden landscape units for their contribution to biodiversity requirements. The combined area of the TSA and the adjacent park land is referred to as the Golden analysis area (GAA).

The procedures used to define the net harvesting landbase for this analysis follow those used in the TSR2 timber supply analysis as closely as possible. The resulting landbase classification is summarized in Table 3.1. The TSR2 results are also shown for comparison.

Table 3.1 Net landbase determination

Landbase Classification	Area (ha)	TSR2 Area (ha)
Gross Golden Analysis Area	1,182,484	1,160,461
Parks (Federal & Provincial)	276,014	267,109
Total TSA	906,471	893,352
Non-crown land	33,324	26,098
Non-productive	574,051	571,457
Productive crown landbase	299,096	295,797
Non-commercial	2,107	2,090
Inoperable	83,126	82,459
Environmentally sensitive areas	10,166	9,982
Deciduous stands	10,745	10,629
Low timber productivity	2,149	2,114
Problem forest types	1,270	1,255
Existing roads	6,870	5,315
Riparian	7,677	7,167
Stand-level biodiversity	8,224	8,171
NSR	14,922	15,073
Reduced landbase	151,840	151,543
NSR, included in net landbase	14,922	15,073
Current net harvesting landbase	166,762	166,615
Estimated reduction for future roads	6,854	8,522
Future net harvesting landbase	159,907	158,093

The item in Table 3.1 relating to the estimated reduction for future roads was included to maintain consistency with the corresponding table in the TSR2 Timber Supply Analysis Report (MoF, 1998). It is, however, somewhat misleading, and warrants further explanation. The methodology to account for the loss of productive forest land to the roads, trails and landings that will be constructed during future harvesting was developed for the TSR2 Timber Supply Analysis, and is documented in detail in the TSR2 Analysis Report (MoF, 1998). The allowance for future roads, trails and landings is made during the forest level analysis by reducing, at the time of harvest, the area of any stands whose age at the start of the simulation was greater than 30 years. The reduction factor derived for TSR2, and applied in the present analysis, was 7.34%. The 6,854 hectares listed in Table 3.1 is an *a priori* estimate of the productive area that will be removed from the timber harvesting landbase during the course of the forest level simulations. It was determined, prior to any forest level analysis, as 7.34% of the net harvesting landbase area in stands greater than 30 years, and is only intended to provide an estimate of what the net harvesting landbase area will be in the long term.

3.2 Biodiversity

Seral stage requirements for protecting biodiversity were established for the TSR2 timber supply analysis using a 45/45/10 weighting of the requirements for low, intermediate and high biodiversity emphasis options respectively, for each landscape unit. Furthermore, old growth retention for low biodiversity emphasis was phased in over three consecutive 70 year rotations. The derivation of biodiversity requirements is documented in the TSR2 timber supply analysis report (MoF, 1998). The resulting forest cover requirements are summarized in Table 3.2.

3.3 Current Forest Management Practices

Current forest management practices were modeled using the forest cover requirements defined in the TSR2 timber supply analysis. In the TSR2 analysis, disturbance limits were developed as height-based green up requirements and then translated into age-based requirements for each landscape unit. The resulting disturbance limits and retention requirements are listed in Table 3.3.

Table 3.2 Landscape level biodiversity retention percentages by biogeoclimatic zones

Time	NDT	Mature + Old					Old				
(yrs)		ESSF	ICH	MS	IDF	PP	ESSF	ICH	MS	IDF	PP
0 - 70	1	30.2	28.1				14.2	9.7			
	2	25.4	25.3				6.7	6.7			
	3	20.1	20.1	21.9			10.5	10.5	10.5		
	4		28.1		28.1	28.1		9.7		9.7	9.7
71-140	1	30.2	28.1				17	11.6			
	2	25.4	25.3				8	8			
	3	20.1	20.1	21.9			12.6	12.6	12.6		
	4		28.1		28.1	28.1		11.6		11.6	11.6
141+	1	30.2	28.1				19.9	13.6			
	2	25.4	25.3				9.4	9.4			
	3	20.1	20.1	21.9			14.7	14.7	14.7		
	4		28.1		28.1	28.1		13.6		13.6	13.6

Table 3.3 Forest Cover Requirements for each resource emphasis zone

Zone	Landscape Unit	Disturbance			Retention	
		Min Height (m)	Min Age (yrs)	Max Area (%)	Min Age (yrs)	Min Area (%)
Caribou (ESSF)	all				140	40
	1	2	26	25	250	10
	2	2	24	25	250	10
	3,4	2	23	25	250	10
	5,8	2	16	25	250	10
	11	2	15	25	250	10
	12	2	19	25	250	10
	29	2	21	25	250	10
Caribou (ICH)	all				140	40
	1	2	21	25	250	10
	2	2	19	25	250	10
	3,4,8,11,12	2	15	25	250	10
	5,29	2	16	25	250	10
Wildlife Mgt. Area	20,25	2	31	25	250	10
	23	2	26	25	250	10
Visual Quality Objectives, Partial Retention	14	6	29	15		
	15	6	42	15		
	16,17,19	6	22	15		
	20,25	6	23	15		
	21	6	25	15		
	22	6	31	15		
	23	6	24	15		
	24	6	33	15		
	26	6	27	15		
Watersheds						
1,2,6	20	6	25	25		
1	21	6	21	25		
2	21,26	6	31	25		
3	23	6	28	25		
4,5,7,8	25	6	22	25		
Ungulate Winter Range (UWR)	3,15	2	17	25	100	40
	4,6	2	15	25	100	40
	5,14,22,34,36	2	16	25	100	40
	7,8,9,17,23,27	2	13	25	100	40
	10,18	2	11	25	100	40
	11,12,16,28	2	14	25	100	40
	13,20,21,25,26,29	2	12	25	100	40
Integrated Resource Management (IRM)	1,6,7	2	18	25		
	2	2	19	25		
	3	2	22	25		
	4,8,20,26	2	15	25		
	5,11,19,22,28,32,33,34,35,36	2	16	25		
	9,10,13,15,17,18,21,24	2	17	25		
	12	2	20	25		
	14,16,23,27	2	14	25		
	25,29	2	13	25		

3.4 Growth and Yield Assumptions

3.4.1 TSR2 Analysis Unit Definition

The analysis unit definitions (TSR2 AUs) established for the TSR2 timber supply analysis were applied to develop the initial base case for this analysis. The analysis unit definitions and distribution of net harvesting landbase area among them are shown in Table 3.4.

Table 3.4 TSR2 Analysis Unit Definitions

Existing Analysis Unit #		Species	Inventory Type Group	Site Index	Net Area (ha)	
(age > 20)	(age ≤ 20)				(age > 20)	(age ≤ 20)
11	111	Fd, FdPl, FdL	1,5,7,8,33,34	≥ 22	4,149	430
12	112	Fd, FdPl, FdL	1,5,7,8,33,34	≥ 17, < 22	8,340	1,801
13	113	Fd, FdPl, FdL	1,5,7,8,33,34	> 0, < 17	4,391	640
14	114	FdC, FdH, FdS	2-4	≥ 21	2,897	386
15	115	FdC, FdH, FdS	2-4	≥ 17, < 21	5,673	1,341
16	116	FdC, FdH, FdS	2-4	> 0, < 17	5,707	566
21	121	H	12-17	≥ 14	2,768	930
22	122	H	12-17	≥ 11, < 14	5,740	300
23	123	H	12-17	> 0, < 11	2,572	0
24	124	C	9-11	≥ 19	1,719	2,403
25	125	C	9-11	≥ 14, < 19	5,987	386
26	126	C	9-11	> 0, < 14	4,535	752
31	131	S, B	18,20,21,24	≥ 19	3,969	3,872
32	132	S, B	18,20,21,24	≥ 15, < 19	7,196	4,274
33	133	S, B	18,20,21,24	≥ 10, < 15	8,420	1,335
34	134	S, B	18,20,21,24	> 0, < 10	11,551	60
41	141	SF,SH,SPl,BS	19,22,23,25,26	≥ 21	3,954	1,013
42	142	SF,SH,SPl,BS	19,22,23,25,26	≥ 17, < 21	4,602	1,307
43	143	SF,SH,SPl,BS	19,22,23,25,26	≥ 13, < 17	5,084	2,474
44	144	SF,SH,SPl,BS	19,22,23,25,26	> 0, < 13	4,808	1,344
51	151	Pw, Pa, Pl	27-31	≥ 21	5,555	757
52	152	Pw, Pa, Pl	27-31	≥ 19, < 21	7,270	4,182
53	153	Pw, Pa, Pl	27-31	≥ 16, < 19	4,380	6,353
54	154	Pw, Pa, Pl	27-31	> 0, < 16	5,920	2,670
81	181	Deciduous	35-42	≥ 16	0	0
82	182	Deciduous	35-42	≥ 12, < 16	0	0
83	183	Deciduous	35-42	> 0, < 12	0	0

3.4.2 Modeling Natural Stands

Volume yields for existing stands over 20 years of age were modeled using the MoF Variable Density Yield Prediction model (VDYP, batch version 6.6d). The resulting yield curves were modified by the application of a volume adjustment factor during the forest level analysis to remove any deciduous component. This deciduous reduction factor is also shown in Table 3.5.

Table 3.5 VDYP inputs for natural stand yield curves

Unit #	Net Area (ha)	Average SI50	Average CC	Species Composition								Deciduous
				sp1	%	sp2	%	sp3	%	sp4	%	Reduction
11	4,149	23.9	51	Fd	73	Pl	17	Pw	5	Se	5	1.00
12	8,340	19.2	48	Fd	73	Pl	19	Se	5	Pw	3	1.00
13	4,391	14.5	42	Fd	76	Pl	17	Se	4	At	3	1.00[3]
14	2,897	24.1	49	Fd	60	Se	29	Pl	6	Bl	5	1.00
15	5,673	18.9	45	Fd	59	Se	31	Pl	5	Cw	5	1.00
16	5,707	14.3	49	Fd	58	Se	27	Hw	7	Cw	8	1.00
21	2,768	17.3	36	Hw	58	Cw	25	Se	10	Bl	7	1.00
22	5,740	12.3	48	Hw	55	Cw	22	Se	16	Fd	7	1.00
23	2,572	10.2	48	Hw	61	Cw	25	Se	11	Fd	3	1.00
24	1,719	20.5	37	Cw	59	Hw	25	Se	11	Fd	5	1.00
25	5,987	16.4	51	Cw	61	Hw	26	Se	12	Fd	1	1.00
26	4,535	12.7	42	Cw	64	Hw	19	Se	13	Bl	4	1.00
31	3,969	22.8	41	Se	68	Bl	27	Fd	3	Pl	2	1.00
32	7,196	16.5	36	Se	58	Bl	34	Fd	4	Pl	4	1.00
33	8,420	12.3	39	Se	60	Bl	37	Fd	2	Hw	1	1.00
34	11,551	8.3	42	Se	61	Bl	38	Fd	0	Pa	1	1.00
41	3,954	23.5	47	Se	64	Fd	19	Cw	9	Pl	8	1.00
42	4,602	18.6	43	Se	61	Pl	21	Fd	15	Bl	3	1.00
43	5,084	15.5	44	Se	63	Fd	17	Cw	10	Pl	10	1.00
44	4,808	9.5	44	Se	63	Cw	15	Hw	12	Fd	10	1.00
51	5,555	23.3	53	Pl	78	Fd	12	Se	7	Pw	3	1.00
52	7,270	19.6	47	Pl	75	Fd	11	Se	11	At	3	0.97
53	4,380	17.1	44	Pl	76	Fd	11	Se	8	At	5	0.95
54	5,920	13.9	44	Pl	73	Se	16	Fd	9	At	2	0.98

3.4.3 Modeling Managed Stands

Existing and future managed stand yields were developed using the MoF Table Interpolation Program for Stand Yields (TIPSY), batch version 3.0. TIPSY incorporates regeneration assumptions and site index to derive a future stand yield curve for each analysis unit. The regeneration assumptions include:

- Species composition to be planted;
- Initial planting density;
- Regeneration method, and;
- Regeneration delay.

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[3] A deciduous reduction of 0.97 should have been applied to analysis unit 13, however the oversight was not noted until the analysis was completed.

For the TSR2 timber supply analysis, all analysis units were assumed to be regenerated by planting to an initial density of 1,200 stems per hectare, with a regeneration delay of 2 years. Regeneration delays were not reflected in the TIPSY yield curve generation procedure, but were incorporated into the forest level analysis.

The species composition inputs to TIPSY are shown in Table 3.6, along with the area-weighted average site index. The standard MoF operational adjustment factors of 15% and 5% (OAF1 and OAF2, respectively) were also provided as inputs to TIPSY.

Table 3.6 Regeneration assumptions for future managed stands

Existing Unit #		Future Unit #	SI50	Species Composition					
(age > 20)	(age ≤ 20)			SP1	%	SP2	%	SP3	%
11	111	111	23.9	Fd	40	Pl	40	Sw	20
12	112	112	19.2	Fd	40	Pl	40	Sw	20
13	113	113	14.5	Pl	80	Fd	20		
14	114	114	24.1	Fd	50	Sw	50		
15	115	115	18.9	Fd	50	Sw	50		
16	116	116	14.3	Fd	80	Pl	20		
21	121	121	17.3	Sw	60	Cw	20	HW	20
22	122	122	12.3	Sw	60	Cw	20	HW	20
23	123	123	10.2	Sw	70	Fd	20	Pl	10
24	124	124	20.5	Sw	60	Cw	20	HW	20
25	125	125	16.4	Sw	60	Cw	20	HW	20
26	126	126	12.7	Sw	70	Fd	20	Pl	10
31	131	131	22.8	Sw	70	Pl	20	BL	10
32	132	132	16.5	Sw	70	Pl	20	BL	10
33	133	133	12.3	Sw	80	Pl	20		0
34	134	134	8.3	Sw	70	Pl	20	BL	10
41	141	141	23.5	Sw	70	Fd	20	Pl	10
42	142	142	18.6	Pl	60	Fd	20	Sw	20
43	143	143	15.5	Pl	60	Fd	20	Sw	20
44	144	144	9.5	Sw	70	Fd	20	Pl	10
51	151	151	23.3	Pl	60	Fd	20	Sw	20
52	152	152	19.6	Pl	60	Fd	20	Sw	20
53	153	153	17.1	Pl	100				
54	154	154	13.9	Pl	60	Fd	20	Sw	20

The use of TIPSY version 3.0 is required in this analysis because it permits the incorporation of genetic gain expectations. This version of TIPSY also incorporates other significant modifications over the version employed in the TSR2 timber supply analysis, and tends to produce more conservative growth and yield estimates for stands aging beyond approximately 100 years of age. The following excerpt from the British Columbia Ministry of Forests Internet Site[4] describes the most significant (in the context of the present analysis) version 3.0 enhancement to TIPSY.

[4] http://www.for.gov.bc.ca/research/gymodels/tipsy/New/new.htm

> "New lodgepole pine site curves developed by Nigh 1999, replace the Goudie 1984 dry site curves. Merchantable volumes (12.5+) at stand heights of 12 to 30 m change by a noticeable amount in plantations and natural stands with the exception of low establishment densities (<1 000 trees/ha) where changes are relatively small. At the higher densities, the volume of natural stands tends to decline by 5 to 15 m3 (0 to 13%). Planted stands behave a little differently at these higher establishment densities. At heights of 12 to 20 m, volumes differ by about -15 to 15 m3 (-15 to 6%). At heights of 22 to 30m, volumes differ by about 15 to 30 m (3 to 6%). The maximum observed difference in the suite of test runs was 30 m3 (6%). Ninety percent were within 20 m3 (5%) and 50% were within 10m3 (4%)."

The new site index relationships for Lodgepole pine affect the yield predictions for every managed stand having a pine component. Further details of the TIPSY version history are available at the same internet location.

3.4.4 Minimum Harvest Ages

The minimum harvest ages used to develop the base case were derived for the TSR2 timber supply analysis which used criteria of 90% of culmination age, 25 cm minimum diameter, minimum volume per hectare and the professional judgment of MoF staff. They are shown in Table 3.7.

Table 3.7 Minimum Harvest Ages

Natural Stands		Managed Stands	
Unit #	Minimum Harvest Age	Unit #	Minimum Harvest Age
11	90	111	60
12	100	112	80
13	120	113	90
14	80	114	70
15	90	115	90
16	100	116	100
21	80	121	80
22	120	122	90
23	160	123	120
24	90	124	90
25	100	125	100
26	130	126	130
31	70	131	60
32	90	132	90
33	120	133	120
34	170	134	170
41	80	141	60
42	100	142	80
43	110	143	90
44	150	144	150
51	70	151	60
52	80	152	70
53	100	153	70
54	120	154	90

3.5 Harvesting and Silvicultural Systems

All harvesting in the analysis was assumed to be clear-cutting. The timber supply model was set to use the relative oldest first harvesting rule, in accordance with the procedures followed in the TSR2 timber supply analysis.

3.6 Forest Level Analysis

3.6.1 Results

The base case analysis was performed using the MoF timber supply model FSSIM (Forest Service Simulator), version 3.0. The decadal timber flow and attendant inventory characteristics projected for the 250 year time horizon are shown in Figure 3.1. The harvest flows are also shown in Table 3.8. The TSR2 base case timber flow is shown for comparison.

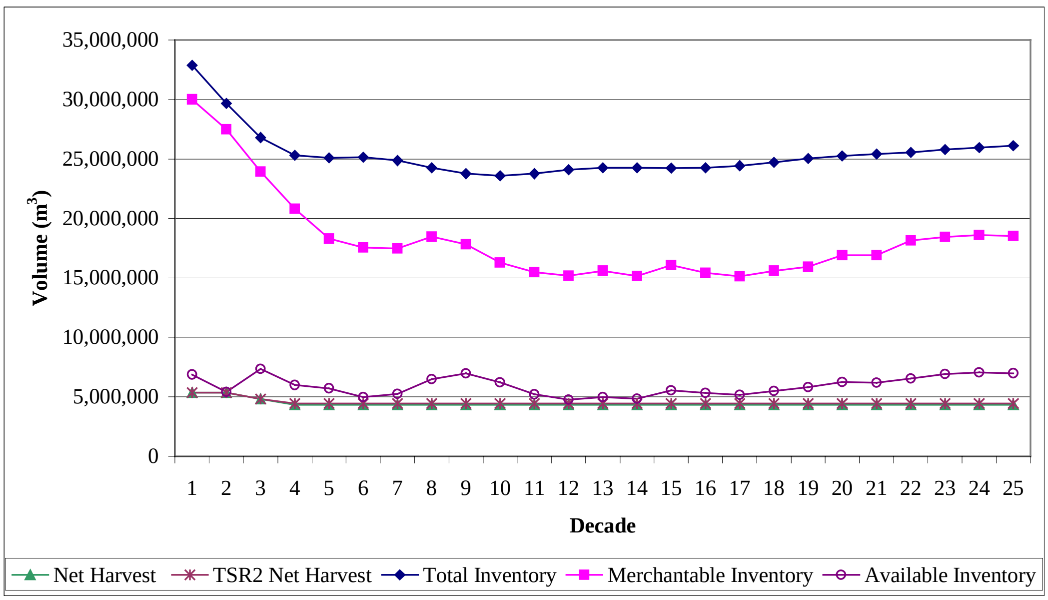

Figure 3.1 Harvest and growing stock profile – base case, TSR2 analysis units

In Figure 3.1, total inventory includes all of the softwood volume supported on the net harvesting landbase. Merchantable inventory is the proportion of the total inventory above minimum harvest age. Available inventory represents the maximum merchantable volume (net of non-recoverable losses) that could be harvested during the period without violating any of the forest cover constraints.

Table 3.8 Harvest levels – base case, TSR2 analysis units

Decade	Gross Harvest m³/decade	Non-recoverable Losses m³/decade	Net Harvest m³/decade	TSR2 Net Harvest m³/decade
1	5,597,000	247,000	5,350,000	5,350,000
2	5,597,000	247,000	5,350,000	5,350,000
3	5,062,000	247,000	4,815,000	4,815,000
4	4,580,500	247,000	4,333,500	4,460,000
5	4,580,500	247,000	4,333,500	4,460,000
6	4,580,500	247,000	4,333,500	4,460,000
7	4,580,500	247,000	4,333,500	4,460,000
8	4,580,500	247,000	4,333,500	4,460,000
9	4,580,500	247,000	4,333,500	4,460,000
10	4,580,500	247,000	4,333,500	4,460,000
11	4,580,500	247,000	4,333,500	4,460,000
12	4,580,500	247,000	4,333,500	4,460,000
13	4,580,500	247,000	4,333,500	4,460,000
14	4,580,500	247,000	4,333,500	4,460,000
15	4,580,500	247,000	4,333,500	4,460,000
16	4,580,500	247,000	4,333,500	4,460,000
17	4,580,500	247,000	4,333,500	4,460,000
18	4,580,500	247,000	4,333,500	4,460,000
19	4,580,500	247,000	4,333,500	4,460,000
20	4,580,500	247,000	4,333,500	4,460,000
21	4,580,500	247,000	4,333,500	4,460,000
22	4,580,500	247,000	4,333,500	4,460,000
23	4,580,500	247,000	4,333,500	4,460,000
24	4,580,500	247,000	4,333,500	4,460,000
25	4,580,500	247,000	4,333,500	4,460,000

3.6.2 Discussion

The present analysis was unable to achieve the same long-term harvest level as was determined for the TSR2 base case. This is attributed to the following two factors.

1. In the present analysis, managed stand yields were derived using BatchTIPSY version 3.0, which is known to predict lower volumes than the version (1.4) used in the TSR2 timber supply analysis, for stands over approximately 100 years of age. The version used here is required in order to introduce the yield gains expected from orchard seed stock later in the analysis.

2. Several problems were encountered in establishing a harvest flow to match the TSR2 base case. The most significant of these were associated with reproducing the distribution of area outside of the net harvesting landbase, but contributing to forest cover requirements, among the management groups defined in the TSR2 analysis. It was not possible to fully resolve these issues due to the absence of sufficiently detailed documentation of the methodology used for the TSR2 analysis.

The latter of these two factors provided some insight into the TSR2 timber supply analysis that warrant further elaboration.

Resource emphasis zones are represented in the forest level analysis as management groups, to which the forest cover requirements shown in Table 3.3 are applied. The area that contributes to satisfying these cover requirements is typically drawn from three separate components of the landbase area, as shown in Table 3.9. Note that, with the exception of the IRM zone, the management groups potentially overlap more than one component of the landbase.

Table 3.9 Landbase contributions by management group

Group	Inoperable Forest (ha)	Operable Excluded Forest (ha)	Net Harvesting Landbase (ha)
Biodiversity	217,752	66,597	166,762
Caribou	0	8,574	23,876
VQO-PR	0	7,238	21,456
Watershed	0	3,758	3,894
UWR	0	16,196	45,049
IRM	0	0	83,365

In trying to emulate the base case established in the TSR2 timber supply analysis, significant difficulties were experienced in matching the contribution of the inoperable and operable-but-excluded landbase components to each management group. It was ultimately discovered that the only way to approach the TSR2 analysis results was to include portions of the gross Golden Analysis Area (Table 3.1) that would not normally be considered as contributors to forest cover requirements. Table 3.10 shows that it was necessary to draw on non-productive, non-commercial and non-crown portions of the Golden analysis area in order to approximate the TSR2 base case results. The UWR and watershed management groups in particular are still underrepresented in the operable-but-excluded area category, when compared with the figures reported in the TSR2 analysis report (MoF, 1998).

Table 3.10 Distribution of non-THLB area by class type

Netdown Component	Inoperable Forest (ha)	Operable Excluded Forest (ha)
Productive[1]	0	47,101
Inoperable	83,126	0
Parks	119,481	14,751
Non-productive	13,942	738
Non-commercial	247	375
Non-crown[2]	957	3,632

[1]excludes non-commercial

[2]excludes ownership 40-N (private)

4. SEED ORCHARD PROGRAM

4.1 Current Supply of Genetic Planting Stock

Current orchard production and allocation figures for Douglas-fir, Lodgepole pine and Spruce are summarized in Table 4.1. Each SPU represents the potential supply of genetically improved seedlings of the given species available to meet the demand created through regeneration of that species within the geographic bounds of the SPU.

Table 4.1 Current seed planning unit production, allocation and genetic gain[5]

SPU	Genetic gain	Projected annual improved seed supply	Percent allocation to Golden	Golden's portion annual TI orchard supply
Fdi EK all	15	300,000	20	60,000
Fdi NE high	22	600,000	36	216,000
Fdi NE low	26	600,000	2	12,000
Fdi QL all	9	600,000	100	600,000
Fdi QLN high	16	1,200,000	100	1,200,000
Fdi QLN low	18	1,200,000	100	1,200,000
Pl EK high	0	0	3	0
Pl EK low	10	2,500,000	6	150,000
Pl NE high	0	0	3	0
Pl NE low	10	4,500,000	4	180,000
Pl PG high	0	0	0	0
Pl PG low	7	10,100,000	100	10,100,000
Pl PGN high	0	0	0	0
Pl PGN low	8	14,600,000	100	14,600,000
Pl PGN overlap	0	0	0	0
Sx EK all	25	1,800,000	20	360,000
Sx NE high	18	4,600,000	2	92,000
Sx NE low	12	4,600,000	13	598,000

4.2 No Gain Scenario

Columns 4 and 5 in Table 4.1 illustrate that, based on recent seedling request records, the Golden TSA does not have access to the full orchard production in all SPUs. Therefore, it may not be possible to satisfy all of Golden's regeneration needs for Lodgepole pine, Douglas-fir or Spruce with the orchard production that is currently allocated to the TSA. Consequently the full genetic gain as shown in Table 4.1 will not be realized in any SPU where such a shortfall in the genetically improved seedlings available to the TSA exists. Thus the "no gain" analysis scenario, described in the following sections, was developed to estimate the annual demand for seedlings of these species resulting from the modeled regeneration activity within each SPU. The "no gain" scenario also served to quantify any impact associated with the redefinition of analysis units.

[5] These data were provided by Tree Improvement Branch of the Ministry of Forests.

4.2.1 Genetic Gain Analysis Unit Definition

In order to ultimately model the genetic gains resulting from planting the orchard seedlings available in the various SPU strata, a new analysis unit was defined for each unique combination of SPU stratum and TSR2 AU found to occur in the net harvesting landbase. This procedure resulted in the definition of 420 natural stand analysis units and 448 managed stand analysis units. The difference in the number of natural and managed stand types is due to the fact that several of the managed stand analysis units have no thrifty or mature natural stand counterparts in the opening inventory. The new analysis units are referred to throughout this report as genetic gain analysis units (GAUs). Because of the large number of GAUs in the genetics data model, the remainder of this document describes the procedures by which the GAUs were parameterized, but does not provide tabular summaries of those parameters.

4.2.2 Regeneration Strategy

MoF staff provided guidance for developing a modified regeneration strategy in the form of elevation-specific regeneration preferences for each of the TSR2 AUs, as summarized in Table 4.2. Since no digital elevation model was available for inclusion in the resultant database created for this analysis, the SPU strata (as defined in Section 2.2.2) were used to infer the elevation band for each resultant polygon. Each stand polygon in the resultant file belongs to a single SPU stratum, and each SPU stratum represents a specific combination of SPUs which are themselves defined in part by elevation. Thus each SPU stratum occupies a specific elevation band, as recorded in Table 2.2.

By definition, each managed stand GAU represents a particular combination of TSR2 AU and SPU stratum. As a consequence of its membership in a particular SPU stratum, each GAU therefore lies within a specific range of elevation. Therefore each GAU was assigned the species composition from Table 4.2 corresponding to its TSR2 AU and elevation band. In cases where the elevation range of the GAU spanned two of the elevation bands identified in Table 4.2, the species compositions for the two bands were averaged. For example, GAU 5 is the spatial intersection of TSR2 analysis unit 11 and SPU stratum 25. SPU stratum 25 is in the 1000 to 1300 meter elevation band, which overlaps the low- and mid-elevation bands defined in the MoF regeneration preferences. The low- and mid-elevation species composition numbers were therefore averaged to arrive at a regenerated stand composition of 40% Pl, 30% Fd and 30% Sw. (By comparison, the natural stand composition for analysis unit 11 was Fd73, Pl17, Pw5, Se5 – see Table 3.5).

It should be noted that the regeneration species compositions in some of the analysis units include minor components of balsam, cedar and hemlock, and that the seed orchard program does not provide these species. Consequently, these species were modeled without genetic gain in all the scenarios developed for this analysis.

4.2.3 Natural Stand Yields

For every natural stand GAU in the genetics data model, area-weighted average crown closure, site index, and species composition values were calculated from the inventory attributes for each polygon. These averaged stand parameters were input to VDYP to generate a set of natural stand yield tables based on the new analysis unit structure.

Table 4.2 MoF regeneration preferences

TSR2 AU	Site Index	Species	TSR2 %	Low (0-1100 m) %	Mid (1100-1500 m) %	High (1500m +) %
11	24.0	F/Pl/S	40/40/20	40/40/20	20/40/40	0/40/60
12	19.1	F/Pl/S	40/40/20	40/40/20	20/40/40	0/40/60
13	14.5	Pl/F	80/20	80/20	80/20	100/0
14	24.6	F/S	50/50	50/50	30/70	0/100
15	18.9	F/S	50/50	50/50	30/70	0/100
16	14.3	F/Pl	80/20	80/20	50/50	0/100
21	20.5	C/S/H	20/60/20	40/50/10	40/50/10	0/100/0
22	16.4	C/S/H	20/60/20	40/50/10	30/60/10	0/100/0
23	12.7	S/F/Pl	70/20/10	60/20/20	60/10/30	90/0/10
24	16.6	C/S/H	20/60/20	40/50/10	30/60/10	0/100/0
25	12.3	C/S/H	20/60/20	40/50/10	30/60/10	0/100/0
26	10.0	S/F/Pl	70/20/10	70/20/10	70/20/10	90/0/10
31	22.8	Pl/S/B	20/70/10	20/70/10	30/60/10	10/80/10
32	16.6	Pl/S/B	20/70/10	20/70/10	40/50/10	10/80/10
33	12.4	Pl/S	20/80	80/20	70/30	10/90
34	8.3	Pl/S/B	20/70/10	80/10/10	80/10/10	10/80/10
41	23.5	S/F/Pl	70/20/10	70/20/10	70/20/10	90/0/10
42	18.6	S/F/Pl	20/20/60	40/10/50	40/10/50	90/0/10
43	15.4	S/F/Pl	20/20/60	20/20/60	20/20/60	90/0/10
44	9.6	S/F/Pl	70/20/10	10/20/70	10/20/70	90/0/10
51	23.3	S/F/Pl	20/20/60	20/30/50	20/30/50	70/0/30
52	19.6	S/F/Pl	20/20/60	20/30/50	20/30/50	70/0/30
53	17.1	Pl	100	100	100	100
54	13.9	S/F/Pl	20/20/60	10/10/80	10/10/80	50/0/50

4.2.4 Managed Stand Yields

The new regeneration species compositions and area-weighted site indices were provided as inputs to TIPSY to derive new yield curves for each managed stand GAU in the genetics data model. Note that the managed stand yield curves prepared for the planting requirements analysis did not incorporate any genetic gain estimates, hence the designation of this scenario as the "no gain" scenario.

4.2.5 Minimum Harvest Ages

As discussed in Section 3.4.4, the TSR2 analysis process applied several criteria in the development of minimum harvest ages (MHA). The formal criteria were: the age at which stands achieved: a minimum diameter of 25 cm dbh; a minimum yield of 150 m^3/ha for F, S and Pl stands and 200 m^3/ha for C and H stands; or 90% of the maximum mean annual increment (MAI). These criteria were augmented with professional judgment by MoF staff in the final determination of MHAs.

The application of professional judgment is not appropriate in the present analysis however, because the ultimate intent of this project is to determine the magnitude of increase in timber supply that might result from incorporating genetically improved stock into the planting programs within the TSA. The anticipated increase in timber flow is a direct result of the increased stand yields and reduced minimum harvest ages accruing from the more rapid growth of the genetically improved plantations. Therefore minimum harvest ages must be derived in a rigorous and repeatable manner so as to be directly related to the yield curves, in order to properly evaluate the timber supply gains. For this reason, the following methodology was adopted to define MHAs for each genetic gain analysis unit.

Three ages were determined from each yield curve: the age at which the stand first reaches a minimum diameter (25 cm dbh); the age at which the stand first achieves a minimum volume per hectare (150 m^3/ha for F, S and Pl stands and 200 m^3/ha for C and H stands); and the age at which the MAI first reaches 90% of the maximum MAI (determined to one decimal place). In a very few cases, some of the yield curves did not achieve either the minimum dbh or the minimum volume per hectare criterion so the minimum harvest age applied to that analysis unit in TSR2 was substituted for the missing age.

Several different strategies for choosing the appropriate MHA from the three choices for each GAU were explored by applying each strategy and then comparing the resulting harvest flow and growing stock dynamics to those of the base case analysis. It was found that the closest correspondence to base case results was achieved by choosing, from the three possible ages, the one closest to the base case MHA. Table 4.3 illustrates the results of applying this methodology by comparing the range of minimum harvest ages calculated for the various component GAUs to the MHAs of the TSR2 AUs. The columns labeled “Minimum” and “Maximum” show the range of MHA values that were assigned to all the various GAUs that were derived from each TSR2 AU, while the “Base Case” column shows the MHA applied in both the TSR2 timber supply analysis, and in the development of the base case illustrated in Figure 3.1.

Table 4.3 Minimum harvest ages for "no gain" scenario – comparison to base case

Natural Stand Minimum Harvest Ages				Managed Stand Minimum Harvest Ages			
TSR2 AU#	Minimum	Maximum	Base Case	TSR2 AU#	Minimum	Maximum	Base Case
11	55	80	90	111	30	60	60
12	75	105	100	112	70	80	80
13	100	125	120	113	70	90	90
14	55	80	80	114	40	70	70
15	70	80	90	115	70	80	90
16	90	105	100	116	80	110	100
21	65	80	80	121	70	90	80
22	90	120	120	122	80	90	90
23	120	165	160	123	110	150	120
24	65	95	90	124	60	80	90
25	75	95	100	125	80	100	100
26	100	160	130	126	110	140	130
31	55	70	70	131	50	70	60
32	80	85	90	132	80	90	90
33	80	115	120	133	90	120	120
34	140	215	170	134	140	220	170
41	60	70	80	141	40	70	60
42	70	90	100	142	70	80	80
43	80	105	110	143	80	100	90
44	100	150	150	144	110	170	150
51	50	85	70	151	50	60	60
52	60	95	80	152	60	70	70
53	85	105	100	153	60	60	70
54	100	135	120	154	90	110	90

4.2.6 Harvest Flow, "No gain" Scenario

A new harvest flow forecast was established for the "no gain" scenario, and is shown in Figure 4.1. The available growing stock is also shown, along with the harvest flow and available growing stock forecasts from the base case analysis. The volumes shown are decadal quantities, net of non-recoverable losses of 24,700 m^3/yr. Figure 4.2 provides a comparison of the total and merchantable growing stock profiles between the two data models.

It was not possible to fully achieve the base case harvest flow projection with the genetics data model. The long-term harvest level was reduced from the base case forecast. This reduction is deemed to be a necessary consequence of the modified regeneration strategy. The new harvest flow established for the "no gain" scenario will therefore serve as the benchmark against which the timber supply impacts of the various genetic gain scenarios explored in the following sections will be compared.

Figure 4.1 Harvest flow and available growing stock

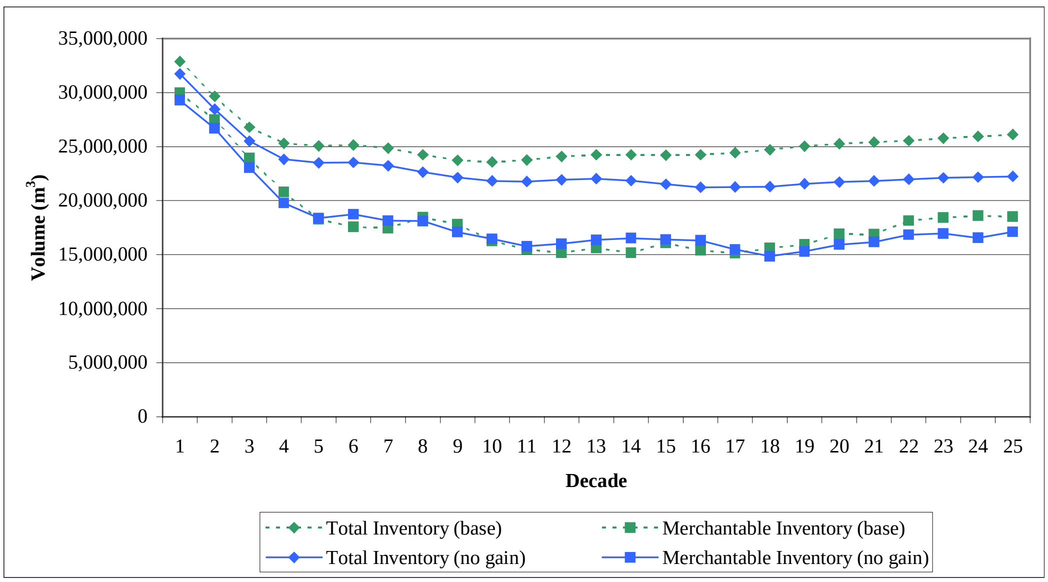

Figure 4.2 Total and merchantable growing stock

4.3 Estimated Demand for Genetic Planting Stock

Based on the "no gain" harvest flow forecast shown in Figure 4.1, the number of Douglas-fir, Lodgepole pine and Spruce seedlings planted during the first twenty years of the planning horizon were determined. The net area harvested in each GAU was first calculated as follows. The ratio of net volume harvested to gross volume harvested was determined, then used as a multiplier to reduce the gross area harvested in each GAU to account for non-recoverable losses. The area harvested in each GAU was further reduced by a factor of 7.34% to account for future roads, trails and landings[6]. The total

[6] The reduction factor for future roads was determined as part of the methodology for the TSR2 Timber Supply Analysis. The derivation is discussed in detail in the TSR2 Timber Supply

number of seedlings required to replant each analysis unit was then estimated by multiplying the net area harvested in each GAU with an assumed planting density of 1600 stems per hectare[7]. The total number of seedlings was allocated by species based on the stand regeneration composition for each GAU. Finally, the required number of seedlings of each species was summarized by SPU, since these units will determine the source and available supply of genetically improved stock.

The resulting average annual planting requirements for Douglas-fir, Lodgepole pine and Spruce are shown in Table 4.4. The estimated planting requirement shown for each SPU is the average annual demand for seedlings from that SPU that results from the modeled harvest and regeneration levels in the GAUs that are a part of that SPU. Note that these data do not reflect the regeneration of Cedar, Hemlock or Balsam that is also occurring in the TSA.

Table 4.4 Annual planting requirements for Douglas-fir, Lodgepole pine and Spruce

SPU	Estimated annual planting requirement (number of seedlings)
Fdi EK all	232,344
Fdi NE high	576
Fdi NE low	499
Fdi QL all	23,743
Fdi QLN high	15,220
Fdi QLN low	13,947
Pl EK high	154,013
Pl EK low	276,290
Pl NE high	424
Pl NE low	1,873
Pl PG high	28,758
Pl PG low	5,574
Pl PGN high	19,342
Pl PGN low	11,102
Pl PGN overlap	25,394
Sx EK all	629,615
Sx NE high	88,611
Sx NE low	236,200

Analysis Report (MoF, 1998). The reduction factor is applied during the forest level simulation, as previously described in Draft Report #1 – Base Case Analysis (Timberline, 2001). However, since the planting requirements shown in Table 4.4 were derived from the gross area harvested in the first two decades, the reduction factor was applied in the derivation to account (in an approximate way) for the portion of the harvested area that will not be replanted.

[7] Columbia Forest District staff advised that true planting densities are 1600 stems per hectare on average. However, as was done in the TSR2 analysis, all TIPSY curves for this analysis were constructed with an assumed planting density of 1200 stems per hectare based on the Nelson Forest Region free growing stocking standards.

4.4 Genetic Gain Scenarios

The planting requirements analysis results from Table 4.4 and the orchard seedling supply figures from Table 4.1 are combined in Table 4.5 to summarize the orchard seedling demand and supply balance for the Golden TSA. Column 7 in Table 4.5 represents the shortfall that must be met by planting wild stand seedlings (calculated as the difference between column 6 and column 5). The implication for those SPUs where a shortfall exists is that future managed stands which belong to a GAU that is defined by membership in such an SPU and which contain a component of the species being contributed by the SPU will not achieve the full genetic gain in yield of that species that would accrue in the absence of the shortfall.

Based on the seedling supply and demand dynamics expressed in Table 4.5, three scenarios were developed to explore the potential timber supply impacts of the Seed Orchard Program. Each scenario represents a different expectation of future genetic gain. The genetic gain analysis unit structure, regeneration species compositions, existing natural stand yields, and existing managed stand yields for each of the scenarios are implemented exactly as previously described for the "no gain" scenario (Sections 4.2.1, 4.2.2, 4.2.3,and 4.2.4 respectively).

It was the original intention of this analysis to also include two further scenarios, in which the existing allocation of genetically improved seedlings would be specifically directed toward the most constrained landscape units, or toward the least constrained landscape units, respectively. However these scenarios were found to be infeasible as a result of the modeling complications encountered during the analysis (described in Section 5.2.3 and APPENDIX I) and were therefore dropped from the analysis. Consequently, it was not possible to formulate any operational recommendations regarding the targeted use of a limited supply of genetically improved seedlings.

4.4.1 "Blended Gain" Scenario

This scenario was developed to assess the timber supply impacts of incorporating Golden's current allocation of genetically improved planting stock into the TSA regeneration program, as reflected by columns 5 and 7 in Table 4.5.

The genetic gain factors applied in the yield curve development process are shown in column 8 of Table 4.5. The values in the table reflect the blended use of orchard and wild stand seedlings, and were calculated by reducing the Forest Genetics Council's expected genetic gain in column 2 by the proportion of the annual seedling demand (column 6) that is fulfilled by Golden's allocation of the annual orchard seedling supply (column 5).

It is important to realize that the blended genetic gain values listed in Table 4.5 apply only to the particular species being provided by the orchards in that SPU (in fact this is true for all scenarios developed in this analysis). The manner by which these genetic gain factors are applied in the context of timber supply modeling is best described by way of a specific example. Consider stands belonging to a genetic gain analysis unit that was defined by the geographic overlap of TSR2 AU 12 (as defined in Table 3.4) and SPU Stratum 29 (as defined in Table 2.1). Once the model harvests these stands, they are regenerated according to the strategy described in Section 4.2.2. SPU stratum 29 lies between 1400 and 1500 meters in elevation, which is entirely within the mid-elevation band described in Table 4.2. Thus these stands are regenerated with a species

Table 4.5 Genetic gain scenarios

1	2	3	4	5	6	7	8	9	10
SPU	**Projected genetic gain**	**Projected annual TI seed supply**	**Percent allocation to Golden**	**Golden's portion annual TI orchard supply**	**Modeled annual seedling demand**	**Annual demand met by wild-stand seedlings**	**"Blended" genetic gain**	**"Full gain" genetic gain**	**"Pl High" genetic gain**
Fdi EK all	15	300,000	20	60,000	232,344	172,344	3.9	15	15
Fdi NE high	22	600,000	36	216,000	576	0	22.0	22	22
Fdi NE low	26	600,000	2	12,000	499	0	26.0	26	26
Fdi QL all	9	600,000	100	600,000	23,743	0	9.0	9	9
Fdi QLN high	16	1,200,000	100	1,200,000	15,220	0	16.0	16	16
Fdi QLN low	18	1,200,000	100	1,200,000	13,947	0	18.0	18	18
Pl EK high	0	0	3	0	154,013	154,013	0.0	0	10
Pl EK low	10	2,500,000	6	150,000	276,290	126,290	5.4	10	10
Pl NE high	0	0	3	0	424	424	0.0	0	10
Pl NE low	10	4,500,000	4	180,000	1,873	0	10.0	10	10
Pl PG high	0	0	0	0	28,758	28,758	0.0	0	10
Pl PG low	7	10,100,000	100	10,100,000	5,574	0	7.0	7	7
Pl PGN high	0	0	0	0	19,342	19,342	0.0	0	10
Pl PGN low	8	14,600,000	100	14,600,000	11,102	0	8.0	8	8
Pl PGN overlap	0	0	0	0	25,394	25,394	0.0	0	10
Sx EK all	25	1,800,000	20	360,000	629,615	269,615	14.3	25	25
Sx NE high	18	4,600,000	2	92,000	88,611	0	18.0	18	18
Sx NE low	12	4,600,000	13	598,000	236,200	0	12.0	12	12

composition of 20% Douglas-fir, 40% Lodgepole pine and 40% Spruce. SPU stratum 29 also represents the geographic overlap of the “Fdi EK all”, “Pl EK high”, and “Sx EK all” SPUs, and therefore these SPUs are the potential source for the genetically improved seedlings that can contribute to the regeneration of the stands in question. Table 4.5 shows that Golden’s portion of the current “Fdi EK all” orchard production is insufficient to provide the average annual number of Douglas-fir seedlings being planted by the model. Thus 74% (column 7 divided by column 6)of the annual planting requirements (in *all* GAUs that draw Douglas-fir seedlings from this SPU) must be met by wild stand seedlings and, conversely, 26% of the annual Douglas-fir seedling requirements can be met by the “Fdi EK all” orchard seedlings available to Golden. The expected genetic gain of 15% as predicted by the Forest Genetics Council is reduced to 3.9 by the blending of genetic and wild stand seedlings (and is further reduced for the analysis unit as a whole because Douglas-fir makes up only 20% of the regenerated stands in the GAU). The Lodgepole pine component of these stands must be made up entirely of wild stand seedlings, since there are no orchards in current production within the “PL EK high” SPU. Consequently the genetic gain factor applied to the Pl component of these stands for this scenario is 0. Finally, Golden’s share of annual orchard production from the “Sx EK all” SPU is also insufficient to meet the average annual demand for spruce seedlings from this SPU, thus the full expected genetic gain for the spruce component of these stands is reduced to 14.3 through the blended use of genetic and wild stand seedlings.

Use of the available genetically improved seedlings was assumed to begin in the first decade of the planning horizon, except in the case of GAUs whose supply of Lodgepole pine is to come from orchards in the “Pl EK low” SPU. Seedlings are not expected to be available from this orchard for another ten years. This delayed availability of orchard stock was modeled by regenerating any stands harvested in the “PL EK low” in the first decade to yield curves that incorporated no genetic gain for their Pl component, while stands from this SPU harvested after the first decade were regenerated to yield curves which incorporated the blended genetic gain value of 5.4 from Table 4.5.

4.4.2 “Full Gain” Scenario

This scenario was designed to explore the impact on harvest levels of assuming that all of Golden’s requirements for regeneration of Douglas-fir, Lodgepole pine and Spruce can be met from the existing orchards within the SPUs listed in Table 4.5. This scenario thus realizes the full genetic gain values predicted by the Forest Genetics Council, except for the Pl component of any stands that lie within the “Pl EK high”, “Pl NE high”, “Pl PG high”, “Pl PGN high” or “Pl PGN overlap” SPUs (since there are no existing orchards within these SPUs). The genetic gain values applied in this scenario are shown in column 9 of Table 4.5.

4.4.3 “Pl High” Scenario

This scenario was developed to explore the impact on projected harvest levels of developing future orchard production capacity within the “Pl EK high”, “Pl NE high”, “Pl PG high”, “Pl PGN high” and “Pl PGN overlap” SPUs. It was assumed that seedlings from newly developed orchards would become available for incorporation into Golden’s silviculture program at the start of the third simulation decade, following which seedling production would be sufficient to meet all of Golden’s Pl planting needs from these SPUs, thus realizing a genetic gain factor of 10. The genetic gain values applied in this scenario are shown in column 10 of Table 4.5.

4.4.4 Managed Stand Yields

The appropriate gain values listed in Table 4.5 were provided as inputs to TIPSY to produce a different set of future managed stand yield curves to which the GAUs were regenerated in each scenario. All other TIPSY inputs were unaltered from those used to develop the future managed stand yields for the “no gain” scenario (Section 4.2.4).

4.4.5 Minimum Harvest Ages

One of the anticipated benefits of using genetically improved planting stock is that stands will achieve the criterion for harvestability at a younger age. As previously described in Section 4.2.5, a specific criterion for assigning minimum harvest age was selected for each genetic gain analysis unit during the development of the “no gain” scenario. For each of the genetic gain scenarios developed for this analysis, the same criterion was applied to each GAU, but was evaluated on the new set of yield curves. Therefore, a new estimate of minimum harvest age was determined for all future managed stand yield curves, for each scenario. Minimum harvest ages for existing natural and managed stands were unchanged from those determined for the “no gain” scenario.

4.4.6 Green-up Heights

Another benefit to be expected from the incorporation of genetically improved trees into the future stands is a reduction in the age at which the green up height is reached. The disturbance constraints imposed on the various resource emphasis zones are initially expressed as a maximum proportion of area permitted to be under a certain height. However, the MoF timber supply model FSSIM requires that these constraints be expressed in terms of age, as was previously shown in Table 3.3. The large number of future managed stand types (see Section 4.2.1) made it impractical to re-evaluate the green up age individually for each GAU. The following methodology was employed instead.

Using the contribution of each genetic gain analysis unit to the net harvesting landbase as a weighting factor, an average height versus age relationship was calculated from the future managed stand yield curves for each scenario. The resulting relationships are illustrated in Figure 4.3, where the axes have been scaled to expose the detail within the range of green up height values. In the TSR2 analysis for the Golden TSA, a green up height of 6 meters was applied in the partial retention visual quality and domestic watershed zones, while 2 meters was applied elsewhere; these figures have also been assumed throughout the present analysis. The age at which each of these green up heights was achieved was interpolated from the average height-age relationships for each scenario. The results of the interpolations, summarized in the right-most column of Table 4.6, clearly justify a one-year reduction in green up ages for all three genetic gain scenarios from the values shown in Table 3.3.

An unavoidable consequence of the FSSIM implementation of disturbance constraints is that green up requirements for existing managed stands in the initial inventory are also reduced.

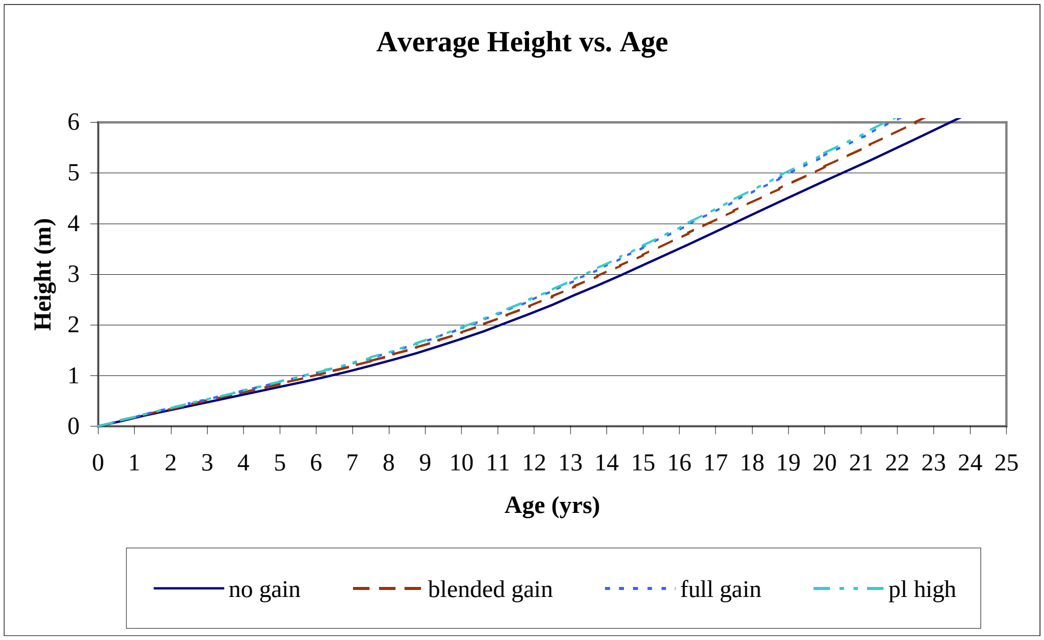

Figure 4.3 Area-weighted average height vs. age for each scenario

Table 4.6 Interpolated green up ages for each scenario

	Age (years)				
	No gain	Blended gain	Full gain	Pl High	Differential
Age at 2m:	11	10	10	10	-1
Age at 6m:	23	22	22	22	-1

5. GENETIC GAIN SCENARIO ANALYSIS

5.1 Harvest Forecasts

New harvest forecasts were established for each of the three genetic gain scenarios developed in the previous chapter, using the MoF timber supply model FSSIM (version 3.0). Figure 5.1 illustrates the decadal net harvest levels for the three genetic gain scenarios, and for the "no gain" scenario. A numerical summary of the same results is provided in Table 5.1.

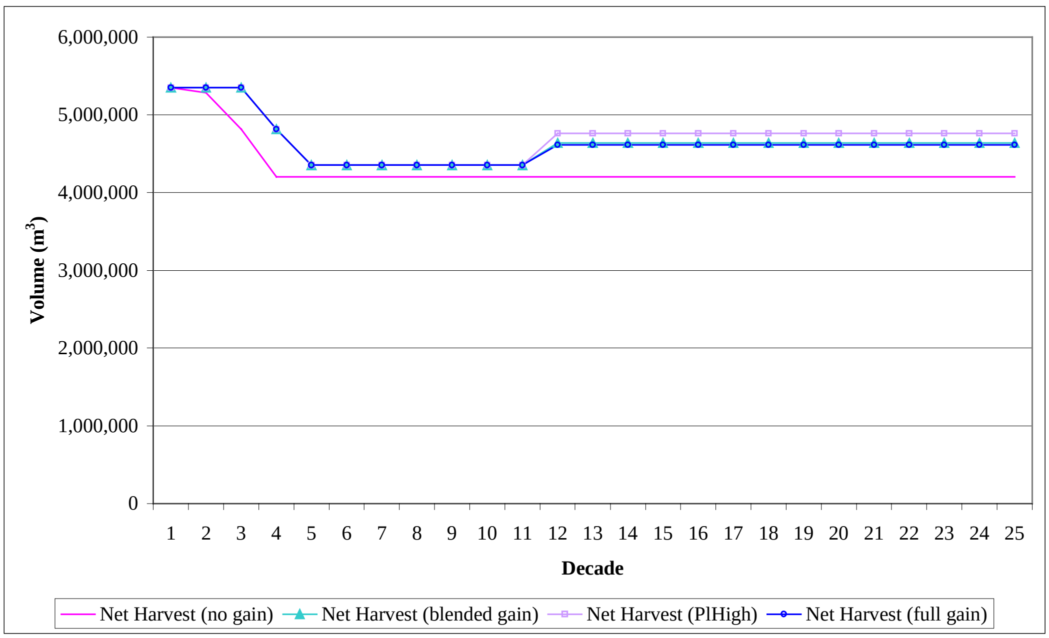

Figure 5.1 Net harvest levels, all scenarios

5.2 Discussion

Table 5.2 compares the three genetic gain harvest forecasts in terms of the increase in harvest level relative to the "no gain" scenario. All three forecasts demonstrate improvements over the "no gain" levels in all eras (short- , medium- , and long-term) of the planning horizon.

Table 5.1 Net harvest levels, all scenarios

Decade	Net Harvest (m^3/decade)			
	No Gain	Blended Gain	Full Gain	Pl High
1	5,350,000	5,350,000	5,350,000	5,350,000
2	5,283,000	5,350,000	5,350,000	5,350,000
3	4,815,000	5,350,000	5,350,000	5,350,000
4	4,203,000	4,815,000	4,815,000	4,815,000
5	4,203,000	4,353,000	4,353,000	4,353,000
6	4,203,000	4,353,000	4,353,000	4,353,000
7	4,203,000	4,353,000	4,353,000	4,353,000
8	4,203,000	4,353,000	4,353,000	4,353,000
9	4,203,000	4,353,000	4,353,000	4,353,000
10	4,203,000	4,353,000	4,353,000	4,353,000
11	4,203,000	4,353,000	4,353,000	4,353,000
12	4,203,000	4,638,000	4,613,000	4,761,000
13	4,203,000	4,638,000	4,613,000	4,761,000
14	4,203,000	4,638,000	4,613,000	4,761,000
15	4,203,000	4,638,000	4,613,000	4,761,000
16	4,203,000	4,638,000	4,613,000	4,761,000
17	4,203,000	4,638,000	4,613,000	4,761,000
18	4,203,000	4,638,000	4,613,000	4,761,000
19	4,203,000	4,638,000	4,613,000	4,761,000
20	4,203,000	4,638,000	4,613,000	4,761,000
21	4,203,000	4,638,000	4,613,000	4,761,000
22	4,203,000	4,638,000	4,613,000	4,761,000
23	4,203,000	4,638,000	4,613,000	4,761,000
24	4,203,000	4,638,000	4,613,000	4,761,000
25	4,203,000	4,638,000	4,613,000	4,761,000

Table 5.2 Increase in harvest levels relative to "no gain" scenario

Decade	% Increase over No Gain Scenario		
	Blended Gain	Full Gain	Pl High
1	0.0	0.0	0.0
2	1.3	1.3	1.3
3	11.1	11.1	11.1
4	14.6	14.6	14.6
5-11	3.6	3.6	3.6
12-25	10.3	9.8	13.3

5.2.1 Short-term era

The forecasts for the three genetic gain scenarios are identical over the short-term era. In contrast to the "no gain" scenario, it was possible to maintain the initial harvest level for three decades before beginning the transition to the mid-term level. This short-term effect is due to the reduction in green up ages (as previously described in Section 4.4.6), since the planting of genetic stock has no impact on harvest levels until the regenerated stands begin to reach harvestable age during the mid-term era. FSSIM green up ages are constant with respect to time, and are specified by resource emphasis zone, not by analysis unit. Consequently the age reduction that results from the improved growth of future managed stands benefits existing managed stands as well, since they also achieve green up at the reduced ages. As a result the landbase is less constrained by the green up requirements than it was in the "no gain" scenario. This can be seen in the available inventory volume curves of Figure 5.3, which were all determined at the "no gain" harvest levels. In decades two through four, the nearly identical curves for the three genetic gain scenarios are shifted upward, but parallel to, the "no gain" scenario curve.

5.2.2 Mid-term era

The harvest forecasts for the three genetic gain scenarios are also identical in the mid-term. A 3.6% increase was achieved over the "no gain" harvest levels in decades 5 through 11 (Table 5.2). Figure 5.2 illustrates the contribution of natural, existing managed, and future managed stands to the periodic volume and area flow for each scenario. Stands with a genetic stock component (future managed stands in the figure) start to make a marginal contribution to the harvest in decade 6, although most of the harvest at this point comes from the managed and natural stands that were present at the start of the simulation. It is conceivable that different harvest levels might have been established for each of the three scenarios as early as the 10^{th} decade based on the difference in genetic gains since genetically improved stands dominate the harvest by this point in the simulation. However, as elaborated in the following section, availability shortfalls that constrain the long-term harvest forecasts would have been further exacerbated by an attempt to raise mid-term levels. Thus it was decided to leave the timing of the transition from mid-term to long-term harvest levels unchanged from the previous analyses, and to concentrate instead on seeking the greatest possible improvement in long-term harvest levels.

5.2.3 Long-term era

The three genetic gain scenarios differ only in their respective long-term harvest levels (decades 12 through 25). The "blended gain" scenario achieves a 10.3% increase over the "no gain" harvest level in the same era (Table 5.2). The "Pl high" scenario achieves a 13.3% increase over the "no gain" long-term harvest level, and a 2.7% increase relative to the "blended gain" long-term level. The "full gain" scenario achieves a 9.8% increase over the long-term "no gain" harvest level, a smaller increase than was achieved in the "blended gain" scenario. Given that the "full gain" scenario represents the planting of a higher proportion of genetically improved seedlings than the "blended gain" scenario, this result is entirely counterintuitive.

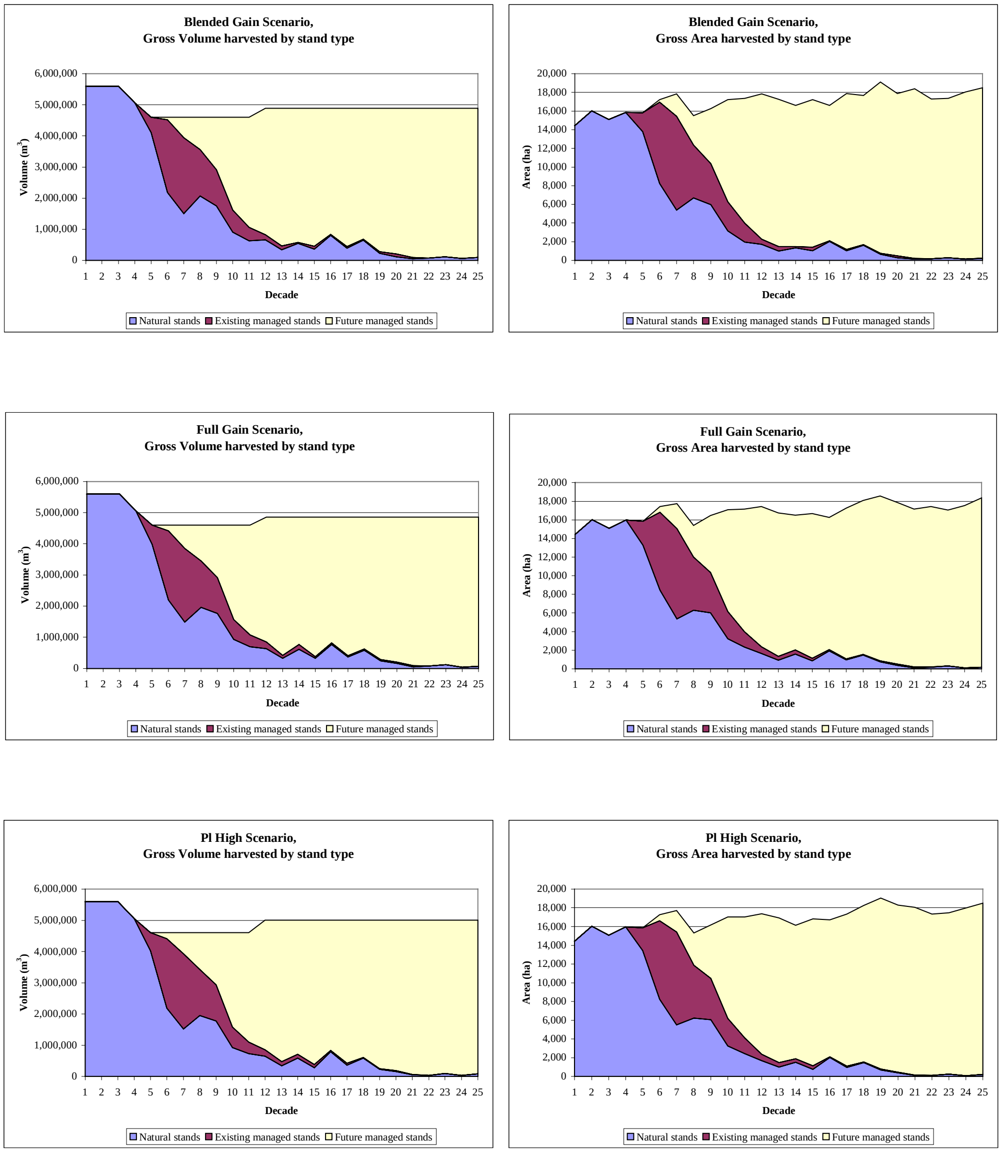

Figure 5.2 Harvest contributions of natural, existing and future managed stands

Several hypotheses were explored, as reported in detail in the appendix to this report, leading to the following explanation for the long-term behaviour of the three genetic gain scenarios. The long term harvest level observed in the "full gain" scenario is suppressed with respect to the "blended gain" scenario as a result of the interaction between a tightly constrained landbase and two separate modeling anomalies, one acting in the short term and the other acting in the long term.

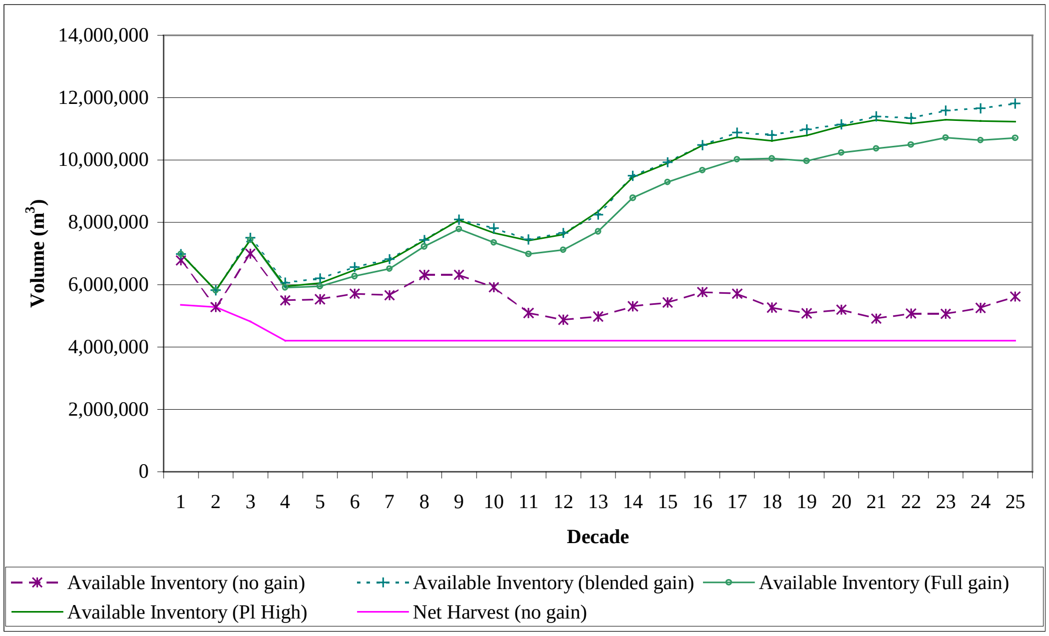

Figure 5.3 Available inventory, no gain harvest levels

FSSIM belongs to the family of timber supply analysis models known as sequential inventory projection models. This means that it is a simulation model that advances chronologically through the planning horizon. In each simulation time period it chooses a sequence of harvest units to achieve a specified volume target without violating any of the forest cover constraints. The model does not consider the future consequences of the harvest schedule developed in any given period. Consequently the scheduling decisions made in one period may in fact limit the harvest scheduling flexibility in future periods, as was found to be the case in the short-term era of the present analysis. Subtle differences in the sequence of scheduled harvest units emerged between the two scenarios (beginning in the second decade of the planning horizon), with the result that more area was harvested in the "full gain" scenario in order to achieve the same harvest targets. At the same time, the condition of the forest estate was such that several constraint zones within the timber harvesting landbase (THLB) were already on the verge of the disturbance limits imposed in the integrated resource management (IRM) zone. Consequently a small increase in harvested area increased the area excluded from the harvest queue as a result of binding disturbance constraints. This was observed to occur from the fourth decade onward in the "full gain" scenario.

The increase in THLB area bound by disturbance constraints remained relatively constant until the onset of the long term era, at which point second-growth stands began to dominate the flow of harvested volume. From this point onward the second modeling anomaly, related to some TIPSY idiosyncrasies, began to act. TIPSY's internal database only contains information for each species up to a certain height[8], (30m for Pl, 50m for Fd and 40m for Sw). TIPSY will report data up to age 350, but simply repeats the last

[8] TIPSY internal yield curves plot volume vs. height for a given species and stocking. These are translated to volume vs. age yield curves through site curves, which set the rate at which a given stand grows along the internal yield curve.

valid interpolated value once it goes beyond the limits of the database. The 'last valid interpolated value' determines the maximum volume reported for a given yield curve. This volume will be that which corresponds to the age step that returns the largest height not exceeding the range of the database[9]. Also, if any one species in a mixed stand surpasses its maximum height, volume growth is halted for all species at the last valid interpolated age. The issue is more significant on highly productive stands because these stands have larger height growth increments which increases the potential for the 'last interpolated value' to be significantly lower than the maximum, and because highly productive stands have higher volume increments which increases the likelihood of the 'last interpolated value' being different from the maximum. The consequence of relevance to this analysis was that TIPSY predicted *less* volume for stands with higher genetic gains over significant areas and at stand ages as young as 81 years. Compounding the binding constraints that originated in the short-term, a further increase in the area harvested to achieve a given harvest target forced a further increase in the THLB area locked out due to binding disturbance constraints in the IRM zone.

It should be noted that the same dynamics discussed above with reference to the "full gain" scenario are present in the "Pl high" scenario, although the constraints on long-term timber supply were in this case offset by the incremental timber volume made available within the PL high SPUs.

5.3 Conclusions

5.3.1 Timber supply impact of the seed orchard program

Analysis of the three genetic gain scenarios developed in Section 4.4 of this report demonstrated that harvest levels in both the mid- and long-term could be increased through the incorporation of genetically improved planting stock into the Golden TSA's silviculture programs. Based on existing seed orchard production levels, current allocation of genetic stock to Golden, and model estimates of Golden's annual planting requirements over the next twenty years, a 3.6% increase in mid-term harvest levels, and a 10.3% increase in long-term harvest levels could be achieved. Furthermore, the "Pl high" scenario analysis identified a potential long-term increase of a further 2.7% if the Forest Genetics Council were to develop Lodgepole pine orchards in the high elevation seed planning units.

It was not possible to draw conclusions about the timber supply impacts of increasing Golden's allocation of the existing seed orchard production due to the combined impact of several factors on the results of the "full gain" scenario analysis. A tightly constrained forest estate interacted with idiosyncrasies of both FSSIM and TIPSY in both the short- and long-term eras such that more area was required for a given harvest level in the "full gain" scenario. This resulted in an increase in the THLB area locked out by disturbance limits in the IRM zone and an inability of the "full gain" scenario to maintain the "blended gain" scenario harvest levels.

[9] The following hypothetical scenario illustrates the issue. A Pl stand growing at the rate of 2m per decade could grow from 28.1m to 30.1m in one decade. This would result in the last valid interpolated height being 28.1m and the maximum volume would be extrapolated accordingly. If the same stand had grown 1.9m in that decade, the last interpolated height would be 30m and the maximum volume would be higher.

5.3.2 Recommendations for Future Timber Supply Analyses

The following recommendations are presented with regard to incorporating genetic gain estimates into future timber supply analyses.

In order to effectively recreate past timber supply analyses to provide a benchmark and basis for further analysis, it is imperative to have access to the original spatial data in an appropriate format (i.e. vector). A significant amount of spatial noise was introduced to the data model at the very start of the present analysis simply as a result of having to convert a spatial resultant database from raster to vector format in order to introduce the data required to geo-reference the genetic gain expectations.

The application of professional judgment in establishing model parameters should be avoided in instances where systematic adjustment to those parameters is required for subsequent analyses. In the case of the present analysis, professional judgment was applied in the definition of minimum harvest ages for TSR2. This then required the adoption of a complicated protocol for approximating the TSR2 minimum harvest ages based on values calculated from the yield curves in a reproducible manner.

It is also important to use consistent elevation breaks in geo-referencing the genetic gain estimates and regeneration assumptions. In the present analysis the regeneration assumptions were developed to a different set of elevation bands than the genetic gain estimates. In order to resolve the differences an unnecessarily complex blending of the stated regeneration assumptions was required.

Within a timber supply analysis context, genetic gain estimates and regeneration assumptions are most easily geo-referenced through the use of seed planning zones (SPZs) and explicit elevation bands defined to suit the specifics of the analysis. The experience of this project has shown that the methodology followed in the Arrow TSA genetic gain analysis (Timberline, 2000) produced a more tractable and flexible data model for analysis. The seed planning units (SPUs) used in the Golden TSA analysis were developed from the more general seed planning zones (SPZs) in order to introduce some elevational resolution to the geo-referencing of genetic gain factors and seedling allocation statistics. However it was found that, for timber supply analysis purposes, the SPUs were too rigidly defined thus reducing the opportunities for generalizing the stratification of genetic gains, seedling allocation, and regeneration assumptions by elevation. Unlike the Arrow TSA analysis, the present project encountered the situation of partially overlapping SPUs.

The methodology of defining SPU strata was developed in response to this situation, and a similar approach would be appropriate in any future analysis involving partially overlapping SPZs.

6. REFERENCES

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APPENDIX I LONG-TERM ERA ANALYSIS

As previously discussed in Section 5.2.3 of the report, several hypotheses were explored to arrive at an understanding of the long-term behaviour of the three genetic gain scenarios. This appendix discusses the hypothesis testing in detail.

First, the methodology by which future managed stand yield curves were derived was reviewed for both the "blended gain" and "full gain" scenarios. It was confirmed that all TIPSY inputs, including genetic gain values, were correct for all analysis units in each scenario. This is corroborated by the total inventory volume curves shown for the three genetic gain scenarios in Figure I.1. The three curves are essentially identical up to decade eight, and then diverge from decade nine onwards as the genetically improved future managed stands become the dominant source of harvested volume (as shown in Figure 5.2). Throughout these latter decades, the three curves show that the "Pl high" scenario produces the most total inventory volume, followed by the "full gain" scenario and then the "blended gain" scenario. This is the expected order, given the relative contributions to each scenario of seed orchard planting stock.

The assignment of minimum harvest ages (MHAs) was also verified as part of the review of future stand yield methodology. It was confirmed for all GAUs in each scenario that MHAs were calculated according to the appropriate rule (as described in 4.4.5), and were either equal to or less than the corresponding MHAs for scenarios of lesser genetic gain. This conclusion is validated by the merchantable inventory volume curves shown in Figure I.1. The "Pl high" scenario produces the most merchantable inventory volume, followed by the "full gain" and "blended gain" scenarios, respectively.

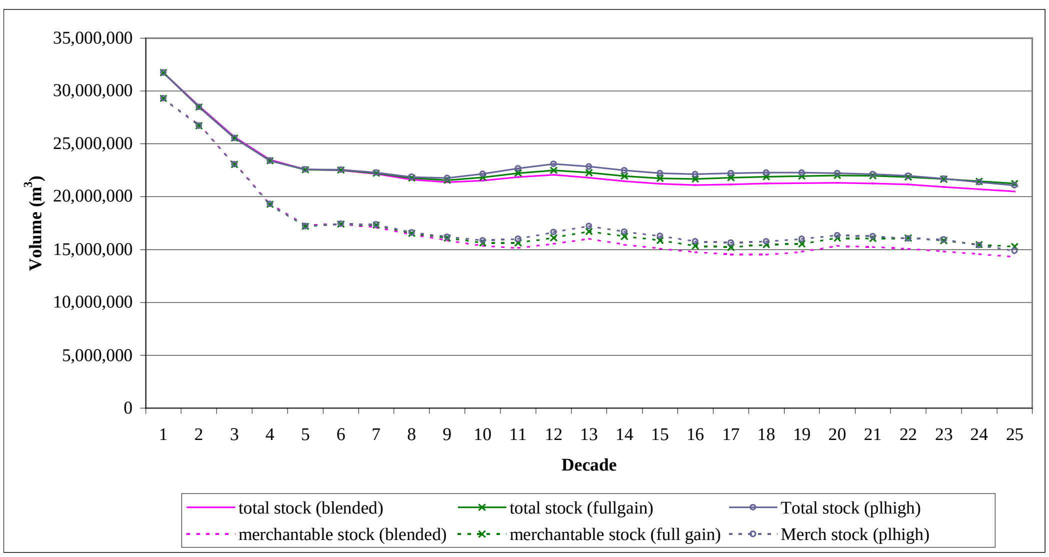

Figure I.1 Total and merchantable inventory, all scenarios

As a further result of the review of future managed stand yields, however, it was found that TIPSY exhibits some unfortunate idiosyncrasies[10]. Specifically, it was observed that given two sets of input stand descriptions that differ only in the genetic gain factors applied to the component species, TIPSY will in some cases generate a yield table that predicts *less* volume at a given age for the stand with higher genetic gains. Such results were observed in a significant number of genetic gain analysis units of significant area and at surprisingly young stand ages. In total, 29 GAUs representing 69,935 hectares (44%) of the future net harvesting landbase were found to produce anywhere between 1 and 31 m^3/ha less starting at stand ages ranging from 80 to 290 years, in spite of greater genetic gain factors. For example, GAU 308, defined by the combination of TSR2 AU 41 and SPU stratum 28, contains 70% Spruce, 20% Douglas-fir and 10% Lodgepole pine and occupies 2,890 hectares (2%) of the future net harvesting landbase. For this GAU, TIPSY predicts 17 m^3 *less* volume per hectare from age 80 onward for the "full gain" scenario than for the "blended gain" scenario. In many cases the decreased volume yields occur at ages young enough to impact the harvest schedule by forcing the harvest of more area to achieve a given harvest level. This effect, although slight, can be seen to occur in some decades in Figure 5.2 (decades 18, 20 and 22 for example).

The next steps taken in exploring the results noted in Table 5.2 were dictated by reviewing the available inventory volume curves shown in Figure 5.3. In contrast to Figure I.1, this figure shows that the "full gain" scenario produces significantly lower volume available for harvesting in the long term than the other two genetic gain scenarios. This suggested that the depressed long-term harvest level was also related to the forest cover constraints.

To explore this hypothesis further, the available inventory volume for all three scenarios was also determined using the "blended gain" harvest levels, as shown in Figure I.2. This figure provides further clues toward understanding the dynamics of the "full gain" scenario relative to the other scenarios. First, the fact that the "pl high" scenario provides significantly more available volume in the long term than the "full gain" scenario, while exhibiting only marginal increases in total and merchantable growing stock in the long term reinforces the hypothesis that binding forest cover constraints are responsible for the unexpectedly low available volume produced by the "full gain" scenario. Second, the fact that the three available inventory volume curves begin to diverge in decade 4, prior to any significant contribution to the harvest from future managed stands, indicates that short-term factors are contributing to the suppression of long-term harvest levels in the "full gain" scenario. Finally, the factors that are constraining the harvest level throughout the planning horizon appear to be an inherent condition of the forest estate. This is indicated by the fact that the shape of the available volume curves for both the "blended gain" and "full gain" scenarios in Figure I.2 is very similar to the shape of the "no gain" availability curve in Figure 5.3. The three curves are constraining, or very nearly so, over the same parts of the planning horizon (2, 4-5, 11-12, 19-25). While the gains incorporated into the three genetic gain scenarios were able to relieve the minima in available volume at the "no gain" harvest levels, the same constraint points returned once the harvest level was increased.

In order to understand the early divergence of the available volume curves, a comparison of the specific disturbance constraint zones limiting harvest in each decade was

[10] These idiosyncrasies were known to the Ministry of Forests prior to this analysis.

undertaken for both the "blended gain" and "full gain" scenarios. It was found that the binding disturbance constraint zones are identical between the two scenarios for the first three decades, but begin to differ starting in the fourth decade. Specifically, from the fourth decade onward more area is bound by the integrated resource management (IRM) zone disturbance constraints in the "full gain" scenario than in the "blended gain" scenario.

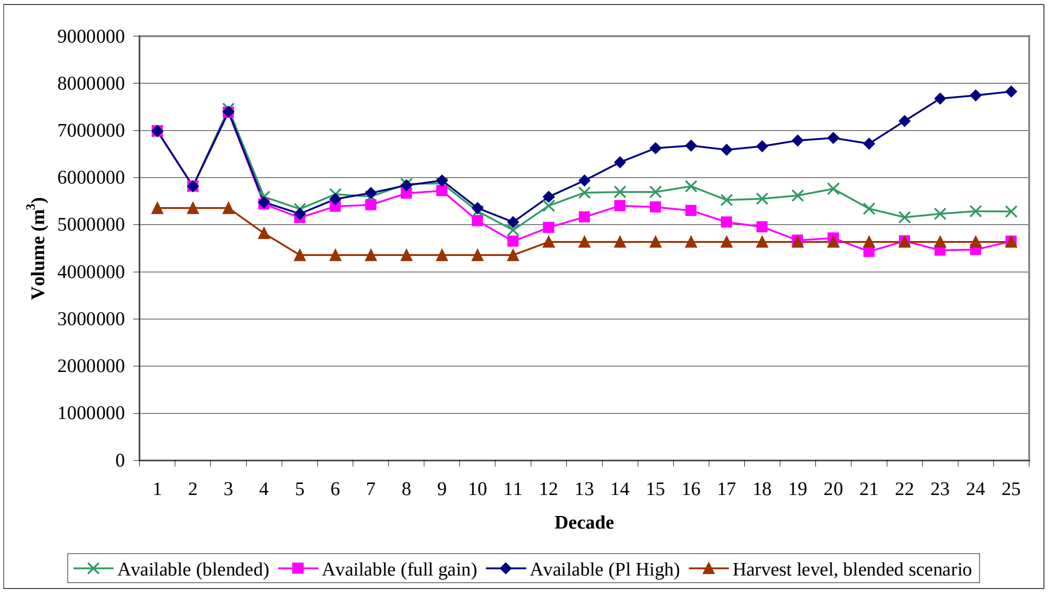

Figure I.2 Available inventory, blended gain harvest levels

A sensitivity analysis was completed on the "full gain" scenario to confirm that disturbance constraints are the limiting factor. With all other model inputs unaltered, green up ages were reduced to 1 year in all relevant resource emphasis zones, and the available inventory volumes were determined (at the "no gain" harvest levels) for both the "blended" and "full gain" scenarios. The results, shown in Figure I.3, confirm that with non-binding green up constraints the "full gain" scenario does provide more available volume than the "blended gain" scenario, as should be the case given the greater genetic gains.

Further comparative analysis of the "full gain" and "blended gain" simulations was performed to identify the cause of the difference in area bound by IRM zone disturbance limits. Because the same natural stand yield curves are used in all genetic gain scenarios, they should exhibit identical schedules until at least the fifth decade, when managed stands begin contributing to the harvest. However, it was found that the harvest schedules actually begin to diverge in decade 2. In the short term, the two scenarios are identical in all respects except that the "blended gain" scenario explicitly modeled the delayed availability of orchard program seedlings from the Pl EK Low SPU (see Section 4.4.1), whereas this delay was not incorporated in the "full gain" scenario so as to simplify the analysis. The delay is implemented in FSSIM by introducing a transfer of area at the start of the second decade, for all remaining natural stands that lie within the "Pl EK low" SPU, to new analysis units. The only differences in the analysis units before and after the transfer are the future managed stand yield curve and the analysis unit number. Thus the transfer should have no effect on the short-term schedule. Therefore the only feasible explanation for the difference in harvest schedules is that

FSSIM has selected candidates from the harvest queue in a different order in each of the two scenarios. While the "relative oldest first" rule for harvest candidate selection has been applied throughout this analysis, the change in analysis unit number resulting from the area transfer produced a different ordering of the queue where stands are tied according to the "relative oldest first" rule. Consequently a different harvest schedule emerges in the two scenarios such that more area is harvested in the "full gain" scenario to achieve the same volume target. The difference in area is very slight (on the order of a few hectares) but is sufficient to cause a greater proportion of the net harvesting landbase to become constrained by disturbance limits in the IRM zone at the start of the fourth decade.

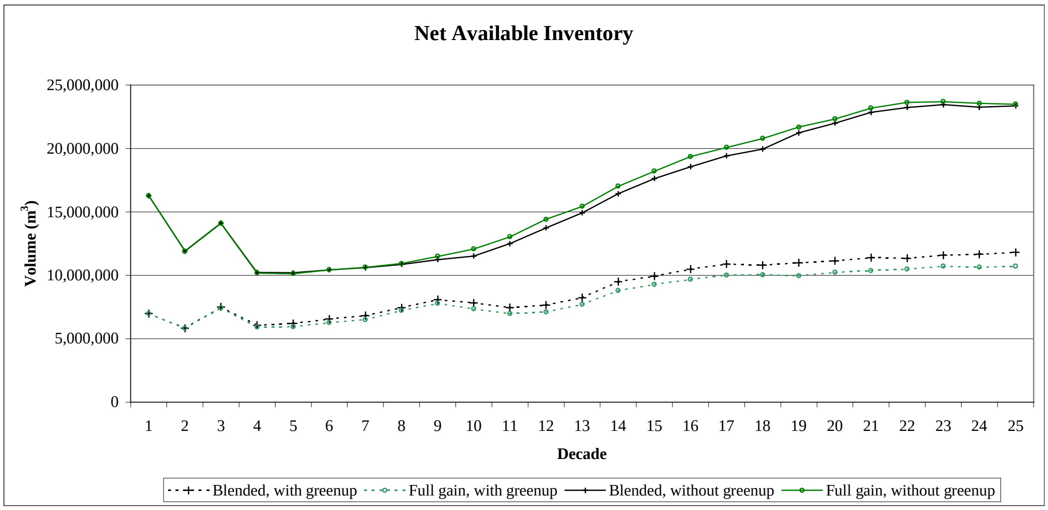

Figure I.3 Available inventory, with and without greenup constraints

Figure I.2 illustrates that the difference in constraint behaviour between the "blended gain" and "full gain" scenarios stays essentially the same (i.e. the two lines are parallel) from decade 4 until decade 11, when the future managed stands first constitute more than 50% of the total harvest. The gap between the two availability curves begins to close at the start of the long-term era as a result of the greater genetic gains represented in the "full gain" scenario, until the TIPSY volume anomaly discussed above causes a similar effect in that more slightly more area must be cut to achieve a given harvest level, and thus the disturbance constraints again limit the long-term harvest level in the "full gain" scenario. By comparison, the "Pl high" scenario is able to overcome the suppression of long-term harvest levels because of the increased volume contributed by analysis units within the Lodgepole pine high elevation SPUs.