IMPACT OF THE CURRENT AND PLANNED SEED ORCHARD PROGRAM ON TIMBER FLOW IN THE ARROW TSA

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EXECUTIVE SUMMARY

The purpose of this analysis was to assess the expected impacts of incorporating genetically improved stock into the planting program for the Arrow 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 planning zone and elevation bands within the TSA. The analysis was designed to assess these impacts relative to the base case timber supply analysis developed as part of the Arrow Innovative Forest Practices Agreement (IFPA). The assumptions employed in the IFPA analysis closely mirrored those employed in the recently completed Timber Supply Review (TSR) Analysis of the Arrow TSA. Several differences have subsequently been noted, and their effect has been assessed.

The IFPA base case analysis determined that a harvest of 615,000 cubic metres/year could be maintained for one decade, after which the harvest must be reduced in two decadal steps to a mid-term level of 451,000 cubic metres. A long-term level of 557,000 cubic metres was projected in the IFPA analysis.

Incorporating stand-level genetic gain estimates into the analysis involved the following steps:

1. Incorporate seed planning zone/elevation bands into Arrow GIS;
2. Stratify analysis units by seed planning zone/elevation band;
3. Develop zone specific silviculture strategies;
4. Establish planting requirements by zone, elevation band and species;
5. Establish genetic gain expectations by species;
6. Develop genetically improved TIPSY yield estimates and;
7. Develop FSSIM forecasts (base vs. genetic).

The results of the analysis demonstrated significant forest-level timber supply gains attributable to the stand-level genetic gain estimates. Specifically, increases in the order of 46% can be expected as early as the fourth decade. These were based on planting genetically improved stock in all applicable seed planning zones within the TSA. The forest-level timber supply increases are attributable to one or more of the following stand-level factors:

1. Average 1 year reductions in greenup;
2. Average 4 year reduction in minimum harvest age; and
3. Long-term yield gains in the order of 10%.

Several key issues were identified in the course of the analysis:

1. Considerable additional data preparation is associated with geo-referencing the genetic gain expectations. This includes incorporation of seed planning zones into the GIS data base, and development of a much greater range and complexity of stand yield forecasts (analysis units) in the timber supply analysis. This taxes both computer processing capacity and the functionality of the FSSIM timber supply model used in the analysis. However, ultimately all the problems could be managed within the functionality of the model.

2. The resolution of assumptions employed in the analysis must be consistent. For example, it was necessary to modify regeneration strategies employed in the base case, in order to make them specific to the elevational differences associated with the genetic gain information.

3. An initial step-up to full genetic gains is associated with the current program. However, in the case of the Arrow TSA, the analysis was not sensitive to this factor.

4. The sensitivity analyses included in this study demonstrated proportional reductions in timber supply gains associated with reductions in the size of the program. Conversely, a modest (1%) incremental gain in long-term supply could be achieved if genetically improved seed could be employed at higher elevations. This linear effect implies that timber supply gains are more attributable to the stand yield improvements associated with genetic gain, than with reductions in minimum harvest age and greenup age. The latter tend to effect timber supply in a less linear fashion.

5. The gains identified in this analysis were consistent with those identified in the TSR analysis.

6. In other TSAs, the more detailed, geographically specific approach employed in this study may or may not yield results which differ significantly from those derived from more generalized analyses. However, there is an inherent reduction in uncertainty associated with more explicit accounting of factors surrounding the seed orchard program. These factors include:

    - Variation in genetic gain associated with elevational differences;
    - Allowance for future increases in orchard production;
    - Reconciliation of seed supply/demand budgets;
    - Consideration of all stand-level factors impacted by genetic gain expectations; and

    Explicit incorporation of these factors greatly reduces uncertainty around expected benefits, and therefore improves the basis for strategic program planning.

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1. BACKGROUND

The expected impacts of incorporating genetically improved stock into TSA planting programs are assessed as sensitivity analyses in the provincial Timber Supply Review (TSR) program. The purpose of this analysis was to expand upon this approach, 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 planning zone and elevation bands within the TSA.

An Innovative Forest Practices Agreement (IFPA) has been established between the Arrow Forest Licensee Group and the Ministry of Forests (MoF). The agreement area lies within the bounds of the Arrow Timber Supply Area (TSA). Preparation of the Forestry Plan for this IFPA included a timber supply analysis base case and applicable sensitivity analyses. This base case analysis was completed in March of 1999, and employed all of the inputs associated with the second Timber Supply Review (TSR2) process. Results of this analysis have been reported under separate cover (ARROW IFPA BASE CASE ANALYSIS Final Report, Timberline Forest Inventory Consultants Ltd. March 30, 1999).

Subsequent to this analysis, Timberline was contracted to conduct an analysis of the impact of the current and planned seed orchard program on wood flow in the Arrow TSA. The methodology employed the following steps:

1. Incorporate seed planning zone/elevation bands into Arrow GIS;
2. Stratify analysis units by seed planning zone/band;
3. Develop zone specific silviculture strategies;
4. Establish planting requirements by zone;
5. Establish genetic gain expectations by species;
6. Develop genetically improved TIPSY yield estimates;
7. Develop FSSIM forecasts (base vs. genetic); and
8. Conduct sensitivity analyses.

The analyses were performed using the results of the IFPA base case analysis as a benchmark against which the forest level effects of the seed orchard program were measured.

Since the initiation of this project, the TSR2 report for the Arrow TSA has been released. The TSR2 report includes a sensitivity test for genetic gain that utilizes a methodology which differs in some respects from that used in this study. A comparison of the results is contained in Section 4 of this report.

2. BASE CASE ANALYSIS

The base case analysis entails 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 the dynamics of forest-level development.

2.1 Net Landbase Definition

The net landbase incorporated the landbase netdown steps summarized in Table 1.

Table 1. Timber harvesting landbase determination – Base Case

Land Classification	Total landbase		Timber License Area
	Area (ha)	Volume (m)	(ha)
Total Area	**740775**	**81505037**	
Not administered by Forest Service	129892	11535588	
New parks	5368	456006.4	
Total TSA	**605515**	**69513443**	
Non-productive & Non-forest	204099	0	
Non-commercial (NCBr)	5861	0	
Productive Forest	**395555**	**69513443**	**2108**
Inoperable (Inaccessible)	114921	18365566	32
Operable	**280634**	**51147877**	**2075**
ESA – outside watersheds	32239	5569900	78
ESA – inside watersheds	11490	2638542	0
Low productivity	1790	109647	0
Deciduous	8319	0	231
Problem forest types	3065	1121203	122
Riparian (RRZ, RMZ)	8076	1692752	54
Existing roads	3879	468352	0
Landings	1339	1519	24
Stick nests	32	4948	0
Dewdney trail	118	16113	0
Wildlife tree patches	7360	1383372	55
NSR	5735	0	119
Timber licenses	1392	285200	
Total Reductions	84835	13291548	683
Reduced landbase	**195798**	**37856329**	**1392**
Plus NSR	5735		
Current Timber Harvesting Landbase	**201533**		
Plus timber licenses	1392		
Less future roads	11858		
Future Timber Harvesting Landbase	**191067**		

2.2 Current Forest Management Practices

Current forest management practices were modeled using forest cover requirements. For the Arrow TSA TSR2 analysis, most of these have been defined in the Kootenay-Boundary Land Use Plan (KBLUP) Implementation Strategy. Table 2 provides a summary of these objectives.

Table 2. Resource emphasis zone forest cover requirements

Zone	Green-up Requirements			Older age requirements		Landbase
	Min. ht (m)	Min. age(1)	Max %	Min. age	Min. %	
IRM	2	14	25	40	70	Timber harvesting landbase
Caribou-ESSF	2	14	25	140	37	Operable < 80% slope
Caribou-ICH	2	14	25	140	40	Operable < 80% slope
Ungulate winter range	2	14	25	100	40	Operable
VQO-retention	7	28	5			Crown forest
VQO-partial retention	7	28	15			Crown forest
VQO-modification	6	26	25			Crown forest
Class 1 domestic watershed	9(2)	34	15			Crown forest
Class 2 domestic watershed	9(2)	34	20			Crown forest
Class 3 domestic watershed	9(2)	34	25			Crown forest
Community watershed	9(2)	34	20			Crown forest
Regionally significant streams	9(2)	34	25			Crown forest

(1) Determined based on weighted average site index curves
(2) In the final TSR2 analysis, height requirements for watersheds were reduced from 9 to 6 metres.

2.3 Biodiversity

Biodiversity seral stage requirements were established at the Biogeoclimatic (BEC) variant level within each landscape unit. All of the Crown forest was considered in determining the status of these requirements. Minimum target percentages are summarized in Tables 3 and 4.

Table 3. BEC/NDT seral stage requirements (minimum percent)

Emphasis	NDT(2)	Mature + Old			Old		
		ESSF	ICH	IDF	ESSF	ICH	IDF
Low(1)	1	19	17		6 / 13 / 19(1)	4 / 9 / 13(1)	
	2	14	15		3 / 6 / 9(1)	3 / 6 / 9(1)	
	3		14			4 / 9 / 13(1)	
	4		17	17		4 / 9 / 13(1)	4 / 9 / 13(1)
Intermediate	1	36	34		19	13	
	2	28	31		9	9	
	3		23			14	
	4		34	34		13	13
High	1	54	51		28	19	
	2	42	46		13	13	
	3		34			21	
	4		51	51		19	19

(1) Full biodiversity requirements in low will be met in stages over three 70-year rotations
(2) Natural Disturbance Type

Table 4. BEC/NDT seral stage requirements (minimum age)

NDT	Mature + Old			Old		
	ESSF	ICH	IDF	ESSF	ICH	IDF
1,5	120	100		250	250	
2	120	100		250	250	
3	120	100		140	140	
4		100	100		250	250

2.4 Growth and Yield Assumptions

2.4.1 Analysis unit definition

The following criteria were used to define the analysis unit aggregations summarized in Table 5:

- species mix (inventory type group (ITG));
- site productivity (site index (SI) range);
- age (immature, mature, old growth); and
- silviculture regime.

Table 5. Analysis unit definitions

< age 141		> age 140		Description	Species	ITG	SI range	Regime
Unit #	Age	Unit #	Age					
11 12 21	21-140	211 212 221	> 140	FL_g FL_m FL_p	fir/larch	1-8,32-34	> 23 17-23 < 17	natural
31 32 41	11-140	231 232 241	> 140	CH_g CH_m CH_p	cedar/hemlock	9-17	> 18 13-18 < 13	natural
55 63	11-140	255 263	> 140	B_gm B_p	balsam	18-20	> 12 ≤ 12	natural
51 53 61	11-140 11-140 11-140	251 253 261	> 140	S_g S_m S_p	spruce	21-26	>19 12-19 < 12	natural
71 73 81	11-140 11-140 11-140	271 273 281	> 140	P_g P_m P_p	pine	27-31	> 19 12-19 < 12	Natural+
118 138 158 178	< 21 < 11 < 11 < 11	n.a. n.a. n.a. n.a.		FL_im CH_im SB_im P_im	fir/larch cedar/hemlock spruce/balsam pine	1-8,32-34 9-17 18-26 27-31	all all all all	managed

2.4.2 Modeling existing stands

Existing stands were modeled using the MoF Variable Density yield Prediction (VDYP) model. Inputs are defined in Table 6.

Table 6. VDYP analysis unit inputs

Unit #	Description	Net Area	Average SI50	Average CC	Species Composition							
					sp1	%1	sp2	%2	sp3	%3	sp4	%4
11	FL_g	11083	25.7	55.5	Lw	46	FD	40	PL	8	At	6
12	FL_m	47722	19.9	53.6	FD	45	Lw	38	PL	12	PW	5
21	FL_p	12413	15.4	50.0	FD	49	Lw	33	PL	14	Hw	4
31	CH_g	6801	19.8	47.8	Hw	52	CW	29	FD	13	PW	6
32	CH_m	5127	16.0	43.4	Hw	56	CW	27	FD	11	PW	6
41	CH_p	3384	11.2	31.0	Hw	65	CW	23	Se	6	FD	6
55	B_gm	16872	16.4	33.5	Bl	64	Se	26	PL	6	Hw	4
63	B_p	2310	10.0	20.0	Bl	69	Se	25	PL	4	Hw	2
51	S_g	2626	22.6	44.2	Se	62	Bl	28	Lw	7	Hw	3
53	S_m	6139	16.4	33.6	Se	59	Bl	27	PL	10	Hw	4
61	S_p	355	9.0	17.6	Se	52	Bl	36	CW	6	Hw	6
71	P_g	9067	21.6	52.7	PL	70	Lw	16	FD	10	PW	4
73	P_m	22083	17.1	45.9	PL	79	Lw	10	FD	7	Bl	4
81	P_p	809	11.0	24.0	PL	72	Bl	13	Lw	8	Se	7
211	FLxg	14	23.8	60.0	Lw	36	FD	29	PL	27	Hw	8
212	FLxm	1639	19.3	55.8	FD	57	Lw	21	Hw	14	PW	8
221	FLxp	3961	14.8	50.7	FD	56	Lw	31	Hw	7	CW	6
231	CHxg	225	19.6	53.0	Hw	48	CW	26	FD	15	Bl	11
232	CHxm	6189	14.5	55.4	Hw	60	CW	29	Se	6	Bl	5
241	CHxp	3846	11.1	55.9	Hw	69	CW	22	Bl	6	Se	3
255	Bxgm	2013	13.9	46.5	Bl	61	Se	36	Hw	2	CW	1
263	Bxp	6359	10.7	44.8	Bl	63	Se	35	Hw	1	PA	1
251	Sxg	434	21.9	49.5	Se	66	Bl	23	Hw	6	FD	5
253	Sxm	3848	14.5	46.3	Se	66	Bl	29	Hw	3	PL	2
261	Sxp	3366	8.8	46.3	Se	59	Bl	37	Hw	2	PL	2
271	Pxg	79	21.9	43.8	PL	45	Lw	28	CW	19	PW	8
273	Pxm	338	14.8	56.2	PL	56	Se	20	PW	12	FD	12
281	Pxp	216	11.8	44.7	PL	56	Se	24	Bl	16	Lw	4

2.4.3 Modeling managed stands

Existing and future managed stand yields were developed using MoF BatchTIPSY (Version 2.1). TIPSY incorporates the following inputs to derive a yield curve for each analysis unit:

- Species mix;
- Initial density - based on current stocking objectives (1200 stems/ha);
- Regeneration method (planting);
- Weighted average site index;
- Operational adjustment factors (OAF1 = 15%, OAF2 = 5%);
- Regeneration delay - 0 (delays are incorporated in forest level analysis);

Inputs to BatchTIPSY are presented in Table 7.

Table 7. TIPSY analysis unit inputs

Existing Unit #	Description	Future Unit #	Average SI50	Species 1 Name	%	Species 2 name	%	Species 3 name	%
11	FL_g	311	25.7	F	50	Pl	30	C	20
12	FL_m	312	19.9	F	50	Pl	30	C	20
21	FL_p	321	15.4	F	50	Pl	35	C	15
31	CH_g	331	19.8	F	60	S	40		
32	CH_m	332	16.0	F	60	S	40		
41	CH_p	341	11.2	F	60	S	40		
55	B_gm	355	16.4	S	60	Pl	25	F	15
63	B_p	363	10.0	S	60	Pl	25	F	15
51	S_g	351	22.6	S	60	Pl	25	F	15
53	S_m	353	16.4	S	60	Pl	25	F	15
61	S_p	361	9.0	S	60	Pl	25	F	15
71	P_g	371	21.6	Pl	50	F	30	S	20
73	P_m	373	17.1	Pl	50	F	30	S	20
81	P_p	381	11.0	Pl	50	F	30	S	20
118	FL_im	118	17.9	F	50	Pl	30	C	20
138	CH_im	138	19.0	F	60	S	40		
158	SB_im	158	15.7	S	60	Pl	25	F	15
178	P_im	178	17.1	Pl	50	F	30	S	20
211	FLxg	511	23.8	F	50	Pl	30	C	20
212	FLxm	512	19.3	F	50	Pl	30	C	20
221	FLxp	521	14.8	F	50	Pl	35	C	15
231	CHxg	531	19.6	F	60	S	40		
232	CHxm	532	14.5	F	60	S	40		
241	CHxp	541	11.1	F	60	S	40		
255	Bxgm	555	13.9	S	60	Pl	25	F	15
263	Bxp	563	10.7	S	60	Pl	25	F	15
251	Sxg	551	21.9	S	60	Pl	25	F	15
253	Sxm	553	14.5	S	60	Pl	25	F	15
261	Sxp	561	8.8	S	60	Pl	25	F	15
271	Pxg	571	21.9	Pl	50	F	30	S	20
273	Pxm	573	14.8	Pl	50	F	30	S	20
281	Pxp	581	11.8	Pl	50	F	30	S	20

2.4.4 Minimum harvest ages

Minimum harvest ages were based on achieving a minimum volume of 150 m^3/ha, and minimum DBH of 25 cm. These ages were also compared against those determined at MAI culmination points. Harvest and culmination ages are presented in Table 8.

Note: In the TSR2 analysis, harvest ages for managed stands were based on a minimum 25 cm DBH for the largest 250 trees, while in this analysis the average was based on all trees. As a result, the TSR2 analysis employed younger minimum harvest ages for managed stands.

Table 8. Minimum harvest ages

Natural Types				Managed Types			
Unit #	Description	Harvest Age	Culmination Age	Unit #	Description	Harvest Age	Culmination Age
				118	FL_im	100	100
				138	CH_im	90	90
				158	SB_im	100	110
				178	P_im	110	90
11	FL_g	60	100	311	FPg	60	70
12	FL_m	80	120	312	FPm	80	90
21	FL_p	100	120	321	FPp	130	100
31	CH_g	60	80	331	FSg	90	90
32	CH_m	70	90	332	FSm	120	110
41	CH_p	110	120	341	FSp	250	170
55	B_gm	60	90	355	SPg	100	70
63	B_p	80	100	363	SPm	170	90
51	S_g	60	80	351	SPp	70	90
53	S_m	80	170	353	SPgm	100	170
61	S_p	150	160	361	SPp	190	160
71	P_g	100	70	371	PFg	70	70
73	P_m	110	80	373	PFm	100	90
81	P_p	150	120	381	PFp	250	120
211	FLxg	70	110	511	FPg	60	80
212	FLxm	70	100	512	FPm	90	110
221	FLxp	110	110	521	FPp	140	100
231	CHxg	60	80	531	FSg	90	90
232	CHxm	80	100	532	FSm	150	120
241	CHxp	110	130	541	FSp	260	180
255	Bxgm	90	80	555	SPg	120	80
263	Bxp	140	110	563	SPm	160	110
251	Sxg	60	90	551	SPp	70	120
253	Sxm	90	170	553	SPgm	110	160
261	Sxp	150	140	561	SPp	200	140
271	Pxg	90	60	571	PFg	70	70
273	Pxm	140	90	573	PFm	140	100
281	Pxp	170	110	581	PFp	210	120

2.5 Harvesting and Silvicultural Systems

All harvesting in the analysis was assumed to be clearcutting. The timber supply model was set to harvest the oldest stands first.

2.6 Timber Supply Analysis

The base case analysis was prepared using FSSIM Version 3.0. It employed the landbase definition developed from the netdown protocol, as well as the resource emphasis, biodiversity zones and yield curves documented earlier.

The timber flow and attendant inventory characteristics projected for the 250 year time horizon are depicted in Figure 1 and Table 9. Total inventory includes all of the softwood volume supported on the net harvestable landbase. Merchantable inventory is the proportion of the total inventory above minimum harvest age. Available inventory represents the maximum merchantable volume which could be harvested during the period without violating any of the forest cover constraints.

The difference between the available and actual harvest volumes represents the surplus which could be harvested during the period without violating any of the management requirements. It therefore reflects the degree of flexibility in actually locating the harvest operationally. **The availability curve does not represent a timber flow option**. A change in any input assumption may affect both timber flow and timber availability, either positively or negatively depending upon the nature of the change.

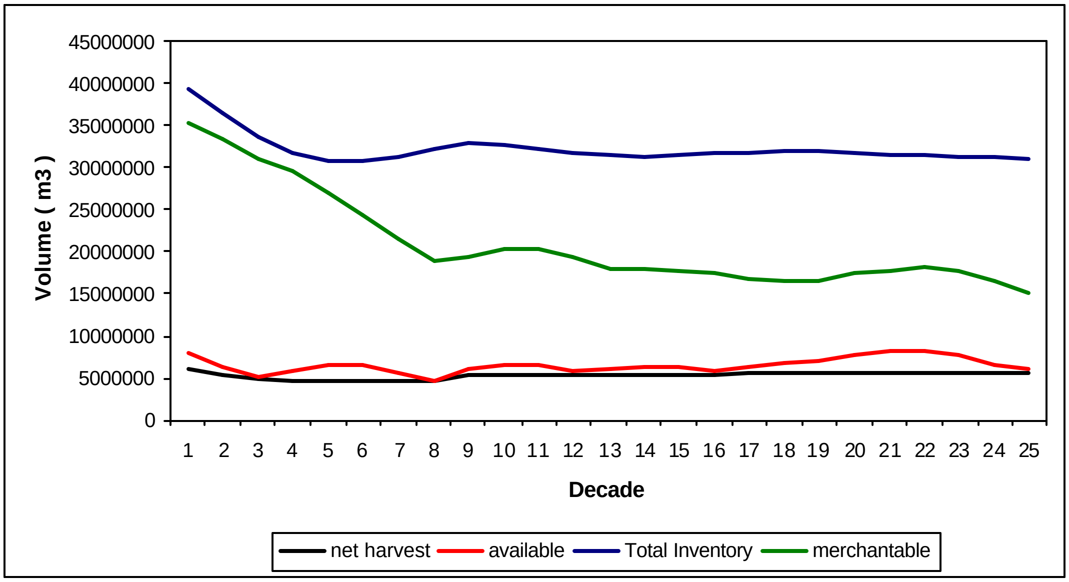

Figure 1. Harvest and growing stock profile – base case

Table 9. Harvest levels – base case

Decade	Gross Depletion(1) (m^3)	Non-recovered losses (m^3)	Net Harvest (m^3)
1	643800	288000	615000
2	582300	288000	553500
3	527000	288000	498200
4	480000	288000	451200
5	480000	288000	451200
6	480000	288000	451200
7	480000	288000	451200
8	480000	288000	451200
9	570000	288000	541200
10-16	570000	230000	547000
17-25	580000	230000	557000

(1) Gross depletion represents volume removals from both harvesting and non-recoverable losses.

Overall timber availability under the base case assumptions is significantly constrained at 4 points over the time horizon of the analysis. The surplus averages only 25% of the harvest over the entire time horizon. It drops to 6% in decades 3, 8 and 12, and 9% in decade 16, which therefore represent the limiting points in time controlling harvest flow. When non-recoverable losses are taken into consideration, the surplus available for harvesting drops by another 5%. Therefore, there is literally no surplus available during the critical decades. For this reason, it is highly unlikely that the base case harvest level is in fact operationally attainable.

If the seed orchard program is to have a positive impact on timber supply in this scenario, it must increase the availability of timber. In particular, if short-term gains are to be realized, availability in decades 3 and 8 must be improved.

Figure 2 shows the harvest distribution by maturity. Harvest in decades 1-8 is almost exclusively drawn from the thrifty (age < 141) and mature (age > 140) existing natural stand types. Shifts between thrifty and mature proportions are largely driven by the status of mature+old and old growth landscape level biodiversity constraints. Significant harvest in existing natural and future regenerated stand types commences in decade 9, as these types reach minimum harvest age.

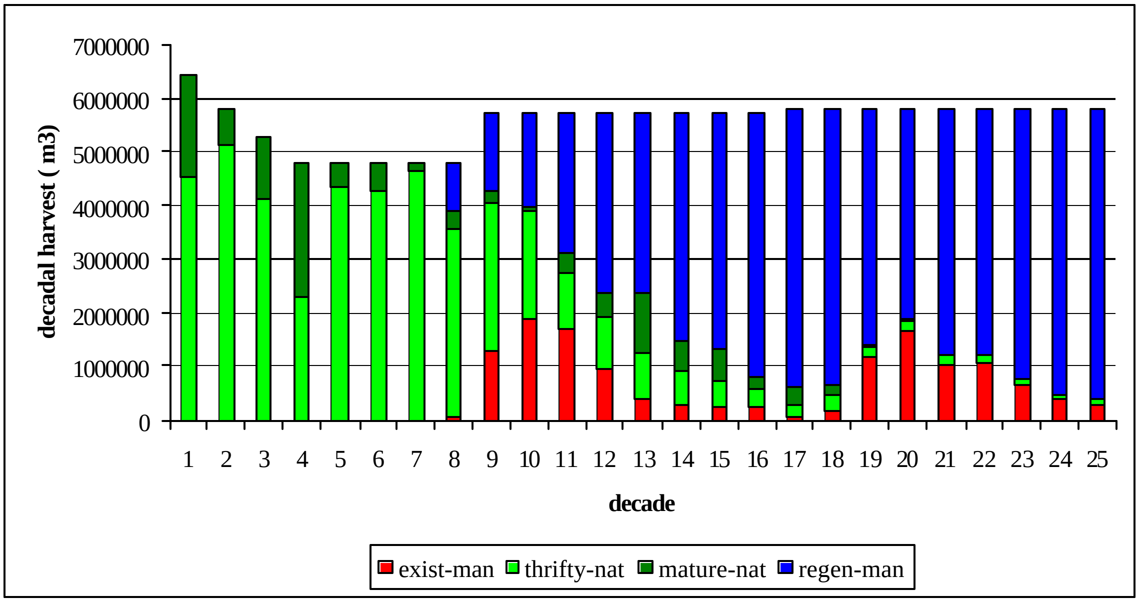

Figure 2. Harvest by maturity – base case

The fact that managed stand volumes become available for harvest in decades 8-9, at the same time that growing stock inventory minimizes, is critical to any factors that increase the growth rate of these managed stands. Reductions in greenup age and/or minimum harvest age may therefore result in improvements in wood flow earlier than decade 8.

3. SEED ORCHARD PROGRAM

This section outlines the six tasks employed to modify the FSSIM data model to incorporate allowances for yield gains associated with the seed orchard program. The tasks were:

1. Definition of planning zones;
2. Establishment of genetic gain expectations;
3. Modification of analysis units;
4. Verification of planting requirements; and
5. Modification of plantation yield curves.

3.1 Planning Zones

Seed planning zones have been established in the Nelson Region for spruce, Douglas fir; lodgepole pine and larch. In each case, the genetic volume gain expectations vary according to elevation. In order to georeference these gain expectations, 100 metre elevation bands were generated across the TSA, using 1:250 000 TRIM digital elevation data. These bands were used to define six separate elevation zones (A-F). These are summarized in Table 10. Low vs. high distinctions are made in cases where genetic gain differs by elevation.

Table 10. Planning Zones

Planted species	Zone A < 1000	Zone B 1000-1300	Zone C 1300-1400	Zone D 1400-1500	Zone E 1500-1700	Zone F > 1700
Spruce	Low	Low	High	High	High	None
Douglas fir	Low	High	High	High	None	None
Larch	Low	Low	Low	None	None	None
Lodgepole pine	Low	Low	Low	None	None	None
Cedar	None	None	None	None	None	None

3.2 Genetic Gain

Genetic gain estimates were obtained for each planted species from the species plans of the Forest Genetics Council for each planted species. These factors were based on current genetic gain expectations by elevation band within each seed planning zone, and take into account seed production expectations within each zone. The factors are summarized in Table 11. To reflect expanding seed orchard programs, for each species and elevation band genetic gain estimates are presented for years 1-5, 6-10 and 11+.

Table 11. Genetic Gain % – years 1-5/years 6-10/years 11+ (*weighted by total production)*

Planted species	Zone A	Zone B	Zone C	Zone D	Zone E	Zone F
	< 1000 m	1000-1300 m	1300-1400 m	1400-1500 m	1500-1700 m	> 1700
Spruce	*6/11/12*	*6/11/12*	*716/18*	*7/16/18*	*7/16/18*	None
Douglas fir	*16*[(1)]*/26/26*	*0/22/22*	*0/22/22*	*0/22/22*	None	None
Lodgepole pine	*7/10/10*	*7/10/10*	*7/10/10*	None	None	None
Larch	*7/7/7*	*7/7/7*	*7/7/7*	None	None	None
Cedar	None	None	None	None	None	None

(1) Available for years 3-5 only

After year 10, further changes in genetic gain are relatively minor. To simplify modeling, the gain figures for years 6-10 and 11+ were combined. In addition, in TIPSY, larch is modeled as Douglas fir. Therefore, the Douglas fir and larch genetic gain expectations were blended based on the expected ratio of larch/Douglas fir in the planting program.

Table 12. Genetic Gain –years 1-5/years 6+ (*simplified for modeling purposes)*

Planted species	**Zone A**	**Zone B**	**Zone C**	**Zone D**	**Zone E**	**Zone F**
	< 1000 m	1000-1300 m	1300-1400 m	1400-1500 m	1500-1700 m	> 1700
Spruce	*6/12*	*6/12*	*7/18*	*7/18*	*7/18*	None
Pure Douglas fir	*16/26*	*0/22*	*0/22*	*0/22*	None	None
Pure Larch	*7/7*	*7/7*	*7/7*	None	None	None
Fir/Larch	*11/15*	*3/16*	*4/13*	None	None	None
Lodgepole pine	*7/10*	*7/10*	*7/10*	None	None	None
Cedar	None	None	None	None	None	None
% larch	***60***	***40***	***60***	None	None	None

3.3 Analysis Unit Definitions

In order to incorporate the genetic gain expectations into the plantation yield curves, it was necessary to develop separate yield curves for each analysis unit/elevation zone combination. To accomplish this, the original 64 analysis units (32 existing and 32 future) were further broken down by elevation zone to yield a total of 408 analysis units. It should be noted that genetic gain estimates are only applied to the future plantation yield curves. However, modeling of the regeneration strategy requires a one-to-one correspondence between existing and future yield curves. The analysis unit numbering scheme is presented in Table 13. The TSR2 regeneration strategy (planted species mix assigned to each analysis unit) is also included in this table.

Table 13. Analysis unit inputs

TSR Unit		New Unit (Existing) (no genetic improvement)						New Unit (Future) (genetic improvement if applicable)						TSR2 Regeneration Strategy					
														Sp 1		Sp 2		Sp 3	
		A	B	C	D	E	F	A	B	C	D	E	F		%		%		%
11	FL_g	1	101	201	301	401	501	601	701	801	901	1001	1101	F	50	Pl	30	C	20
12	FL_m	2	102	202	302	402	502	602	702	802	902	1002	1102	F	50	Pl	30	C	20
21	FL_p	3	103	203	303	403	503	603	703	803	903	1003	1103	F	60	Pl	35	C	15
31	CH_g	4	104	204	304	404	504	604	704	804	904	1004	1104	F	60	S	40		
32	CH_m	5	105	205	305	405	505	605	705	805	905	1005	1105	F	60	S	40		
41	CH_p	6	106	206	306	406	506	606	706	806	906	1006	1106	F	60	S	40		
55	B_gm	7	107	207	307	407	507	607	707	807	907	1007	1107	S	60	Pl	25	F	15
63	B_p	8	108	208	308	408	508	608	708	808	908	1008	1108	S	60	Pl	25	F	15
51	S_g	9	109	209	309	409	509	609	709	809	909	1009	1109	S	60	Pl	25	F	15
53	S_m	10	110	210	310	410	510	610	710	810	910	1010	1110	S	60	Pl	25	F	15
61	S_p	11	111	211	311	411	511	611	711	811	911	1011	1111	S	60	Pl	25	F	15
71	P_g	12	112	212	312	412	512	612	712	812	912	1012	1112	Pl	50	F	30	S	20
73	P_m	13	113	213	313	413	513	613	713	813	913	1013	1113	Pl	50	F	30	S	20
81	P_p	14	114	214	314	414	514	614	714	814	914	1014	1114	Pl	50	F	30	S	20
211	FLxg	16	116	216	316	416	516	616	716	816	916	1016	1116	F	50	Pl	30	C	20
212	FLxm	17	117	217	317	417	517	617	717	817	917	1017	1117	F	50	Pl	30	C	20
221	FLxp	18	118	218	318	418	518	618	718	818	918	1018	1118	F	60	Pl	35	C	15
231	CHxg	19	119	219	319	419	519	619	719	819	919	1019	1119	F	60	S	40		
232	CHxm	20	120	220	320	420	520	620	720	820	920	1020	1120	F	60	S	40		
241	CHxp	21	121	221	321	421	521	621	721	821	921	1021	1121	F	60	S	40		
255	Bxgm	22	122	222	322	422	522	622	722	822	922	1022	1122	S	60	Pl	25	F	15
263	Bxp	23	123	223	323	423	523	623	723	823	923	1023	1123	S	60	Pl	25	F	15
251	Sxg	24	124	224	324	424	524	624	724	824	924	1024	1124	S	60	Pl	25	F	15
253	Sxm	25	125	225	325	425	525	625	725	825	925	1025	1125	S	60	Pl	25	F	15
261	Sxp	26	126	226	326	426	526	626	726	826	926	1026	1126	S	60	Pl	25	F	15
271	Pxg	27	127	227	327	427	527	627	727	827	927	1027	1127	Pl	50	F	30	S	20
273	Pxm	28	128	228	328	428	528	628	728	828	928	1028	1128	Pl	50	F	30	S	20
281	Pxp	29	129	229	329	429	529	629	729	829	929	1029	1129	Pl	50	F	30	S	20
118	FL_im	31	131	231	331	431	531	631	731	831	931	1031	1131	F	50	Pl	30	C	20
138	CH_im	32	132	232	332	432	532	632	732	832	932	1032	1132	F	60	S	40		
158	SB_im	33	133	233	333	433	533	633	733	833	933	1033	1133	S	60	Pl	25	F	15
178	P_im	34	134	234	334	434	534	634	734	834	934	1034	1134	Pl	50	F	30	S	20

3.4 Determination of Base Case Planting Requirements

Once the FSSIM data model was modified to reflect the new analysis unit definitions, the base case analysis was rerun to:

- Verify that similar results were attainable under the new analysis unit structure, and
- Determine that planting requirements over the next 10 years are realistic.

For each analysis unit, the area harvested was determined based on the FSSIM results. The planting requirements were based on an assumed planting density of 1200 trees/hectare. Planting requirements by species were determined by applying the planted species percentages to the total planting requirement for each analysis unit. These species requirements were then summarized across all analysis units. The results are presented in Tables 14 and 15.

Table 14. Base case planting requirements (number of seedlings) – years 1-5

Planted Species	Zone A < 1000	Zone B 1000-1300	Zone C 1300-1400	Zone D 1400-1500	Zone E 1500-1700	Zone F > 1700	Total
Spruce	516284	872256	318271	285713	479808	635625	3107957
D. fir	1700003	2355374	677559	423985	287885	183421	5628227
L. pine	868318	996919	328231	235772	262375	278472	2970087
Cedar	223123	297758	71383	34750	12912	62	639988
Total	3307728	4522307	1395444	980220	1042980	1097580	12346259

Table 15. Base case planting requirements (number of seedlings) – years 6-10

Planted Species	Zone A < 1000	Zone B 1000-1300	Zone C 1300-1400	Zone D 1400-1500	Zone E 1500-1700	Zone F > 1700	Total
Spruce	331376	444799	228742	415343	835483	929498	3185241
D. fir	1725983	1758254	501058	431890	542286	329632	5289103
L. pine	994702	1152481	317410	365297	587918	511079	3928887
Cedar	450571	407810	104791	63202	60490	7543	1094407
Total	3502632	3763344	1152001	1275732	2026177	1777752	13497638

From these initial results, it was determined that the planting requirements by species were not realistic, particularly in the upper elevations. The base case regeneration strategies reflect overall TSA-wide expectations, but do not take into account the elevational variation of planted species, necessitated by silvics. Therefore, the results are skewed in the low and high elevation zones. To address this problem, regeneration strategies were revised by MoF Arrow District and Nelson Region staff to account for these differences, and to better reflect operational practices. The revised species percentages are summarized in Table 16.

Table 16. Analysis unit inputs – revised silviculture strategies

TSR Unit			Silviculture Strategy								
			Low elevations (A,B)			Mid elevations (C,D)			High Elevations (E,F)		
			Sp 1 %	Sp 2 %	Sp 3 %	Sp 1 %	Sp 2 %	Sp 3 %	Sp 1 %	Sp 2 %	Sp 3 %
Old #	Name	New #									
11	FL_g	1	F 50	P 40	C 10	F 50	P 30	C 20	P 70	F 20	C 10
12	FL_m	2	F 50	P 40	C 10	F 50	P 30	C 20	P 70	F 20	C 10
21	FL_p	3	F 50	P 40	C 10	F 50	P 30	C 20	P 70	F 20	C 10
31	CH_g	4	F 60	S 40		F 60	S 409		S 95	F 5	
32	CH_m	5	F 60	S 40		F 60	S 409		S 95	F 5	
41	CH_p	6	F 70	S 30		F 70	S 30		S 95	F 5	
55	B_gm	7	S 60	P 25	F 15	S 60	P 25	F 15	S 50	P 50	
63	B_p	8	S 60	P 25	F 15	S 60	P 25	F 15	S 50	P 50	
51	S_g	9	F 45	S 30	P 25	S 60	P 25	F 15	S 60	P 35	F 5
53	S_m	10	F 45	S 30	P 25	S 60	P 25	F 15	S 60	P 35	F 5
61	S_p	11	F 45	P 35	S 20	S 55	P 30	F 15	P 60	S 40	
71	P_g	12	P 50	F 30	S 20	P 50	F 30	S 20	P 50	S 45	F 5
73	P_m	13	P 50	F 30	S 20	P 50	F 30	S 20	P 50	S 45	F 5
81	P_p	14	P 50	F 30	S 20	P 50	F 30	S 20	P 70	S 30	
211	FLxg	16	F 50	P 40	C 10	F 50	P 30	C 20	P 70	F 20	C 10
212	FLxm	17	F 50	P 40	C 10	F 50	P 30	C 20	P 70	F 20	C 10
221	FLxp	18	F 50	P 40	C 10	F 50	P 30	C 20	P 70	F 20	C 10
231	CHxg	19	F 60	S 40		F 60	S 409		S 95	F 5	
232	CHxm	20	F 60	S 40		F 60	S 409		S 95	F 5	
241	CHxp	21	F 70	S 30		F 70	S 30		S 95	F 5	
255	Bxgm	22	S 60	P 25	F 15	S 60	P 25	F 15	S 50	P 50	
263	Bxp	23	S 60	P 25	F 15	S 60	P 25	F 15	S 50	P 50	
251	Sxg	24	F 45	S 30	P 25	S 60	P 25	F 15	S 60	P 35	F 5
253	Sxm	25	F 45	S 30	P 25	S 60	P 25	F 15	S 60	P 35	F 5
261	Sxp	26	F 45	P 35	S 20	S 55	P 30	F 15	P 60	S 40	
271	Pxg	27	P 50	F 30	S 20	P 50	F 30	S 20	P 50	S 45	F 5
273	Pxm	28	P 50	F 30	S 20	P 50	F 30	S 20	P 50	S 45	F 5
281	Pxp	29	P 50	F 30	S 20	P 50	F 30	S 20	P 70	S 30	
118	FL_im	31	F 50	P 40	C 10	F 50	P 30	C 20	P 70	F 20	C 10
138	CH_im	32	F 60	S 40		F 60	S 409		S 95	F 5	
158	SB_im	33	F 45	S 30	P 25	S 60	P 25	F 15	S 60	P 35	F 5
178	P_im	34	P 50	F 30	S 20	P 50	F 30	S 20	P 50	S 45	F 5

Using these species percentages, new TIPSY yield curves were developed, and the base case re-run to generate new planting requirements. These are summarized in Tables 17 and 18. These results were reviewed by MoF staff, and deemed to reflect more reasonable expectations for the region, particularly in the elevational extremes.

Table 17. Base case planting requirements (number of seedlings) – years 1-5 - revised

Planted	Zone A < 1000	Zone B 1000-1300	Zone C 1300-1400	Zone D 1400-1500	Zone E 1500-1700	Zone F > 1700	Total
Spruce	281778	617578	232189	234027	512827	562592	2440991
D. fir	1721312	2402663	688256	433810	56476	9071	5311588
L. pine	1051466	1216570	306328	224363	456806	525362	3780895
Cedar	253160	285522	168672	88032	16883	556	812825
Total	3307716	4522333	1395445	980232	1042992	1097581	12346299

Table 18. Base case planting requirements (number of seedlings) – years 6-10 - revised

Planted	Zone A < 1000	Zone B 1000-1300	Zone C 1300-1400	Zone D 1400-1500	Zone E 1500-1700	Zone F > 1700	Total
Spruce	245844	342421	199004	388592	930063	902033	3007957
D. fir	1736892	1778465	513967	436633	117026	41361	4624344
L. pine	1244864	1383797	311992	358356	945078	830574	5074661
Cedar	275032	258672	127025	92138	34009	3772	790648
Total	3502632	3763355	1151988	1275719	2026176	1777740	13497610

4. RESULTS

4.1 Stand Level Results

Using species plan data, genetic gain estimates for each species/elevation zone were incorporated into the TIPSY yield curves using the functionality developed for Version 2.1 of the TIPSY model. These factors affect not only stand yield expectations, but also estimates of age to greenup, and minimum harvest age. These impacts are summarized in Tables 19-21. The tables depict the stand level gains in height (ages 10-50), volume (age 60-150), and minimum harvest age. The height and volume gains are expressed in percentage increases relative to the no genetic gain base case. Minimum harvest ages are expressed in terms of reductions in years. The gains are presented by elevation zone and time of planting. Time of planting is expressed as years after the start of the simulation (year 0 = existing plantations with no gain).

Table 19. Percentage height gains by zone (A-F) and time of planting

Zone	Time of Planting	Reference Age					Average
		10	20	30	40	50	
A	0	0	0	0	0	0	0
A	1-5	8	7	6	5	5	6
A	6+	12	10	9	8	7	9
B	0	0	0	0	0	0	0
B	1-5	6	4	4	3	3	4
B	6+	13	11	9	8	7	10
C	0	0	0	0	0	0	0
C	1-5	4	3	3	3	2	3
C	6+	11	9	8	7	7	9
D	0	0	0	0	0	0	0
D	1-5	1	1	1	1	1	1
D	6+	6	6	6	5	5	5
E	0	0	0	0	0	0	0
E	1-5	1	1	1	1	1	1
E	6+	3	3	3	3	3	3
F	0	0	0	0	0	0	0
F	1-5	0	0	0	0	0	0
F	6+	0	0	0	0	0	0
	Average	5	4	4	3	3	4

Table 20(a). Percent volume gains by zone (A-F) and time of planting

Zone	Time of Planting	Reference Age					Average
		60	70	80	90	100	
A	0	0	0	0	0	0	0
A	1-5	12	19	13	9	8	12
A	6+	19	30	18	15	11	19
B	0	0	0	0	0	0	0
B	1-5	9	11	8	6	5	8
B	6+	24	28	23	16	13	21
C	0	0	0	0	0	0	0
C	1-5	9	8	7	5	4	7
C	6+	28	26	21	16	12	20
D	0	0	0	0	0	0	0
D	1-5	2	2	3	2	2	2
D	6+	16	18	15	13	10	14
E	0	0	0	0	0	0	0
E	1-5	3	5	4	4	3	4
E	6+	10	11	11	10	8	10
F	0	0	0	0	0	0	0
F	1-5	0	0	0	0	0	0
F	6+	0	0	0	0	0	0
	Average	10	12	10	8	6	9

Table 20(b). Percent volume gains by zone (A-F) and time of planting

Zone	Time of Planting	Reference Age					Average
		110	120	130	140	150	
A	0	0	0	0	0	0	0
A	1-5	6	5	4	3	3	4
A	6+	8	7	5	4	3	6
B	0	0	0	0	0	0	0
B	1-5	5	3	3	2	2	3
B	6+	11	9	7	6	5	8
C	0	0	0	0	0	0	0
C	1-5	3	3	2	2	1	2
C	6+	10	8	7	6	5	7
D	0	0	0	0	0	0	0
D	1-5	2	1	1	1	1	1
D	6+	8	7	6	5	5	6
E	0	0	0	0	0	0	0
E	1-5	3	2	2	2	1	2
E	6+	6	5	4	4	4	5
F	0	0	0	0	0	0	0
F	1-5	0	0	0	0	0	0
F	6+	0	0	0	0	0	0
	Average	5	4	3	3	2	3

Table 21. Minimum harvest age reductions by zone (A-F) and time of planting

Zone	Time of Planting	Reduction (years)
A	0	0
A	1-5	-5
A	6+	-8
B	0	0
B	1-5	-3
B	6+	-8
C	0	0
C	1-5	-3
C	6+	-8
D	0	0
D	1-5	-1
D	6+	-6
E	0	0
E	1-5	-2
E	6+	-5
F	0	0
F	1-5	0
F	6+	0
	Average	-4

The TIPSY algorithm incorporates the genetic gain percentages in an age dependant fashion. For example, a genetic gain of 10% translates into a 10% volume increase at rotation. The gain is expected to decrease after this point.

At the TSA level, these gains will translate into:

- Average 1 year reductions in greenup;
- Average 4 year reduction in minimum harvest age; and
- Long-term yield gains in the order of 10%.

These do not appear to be large changes. However, the averages are deceiving in that stand yield gains can be as high as 28%, and these are associated with the largest reductions in minimum harvest age (-10 years) and the fastest greenup rates. So the best gains will be achieved at mid elevations. With respect to greenup improvements, a resolution problem exists, in that greenup ages are not applied at the analysis unit level, but at a more general constraint zone level. As these constraint zones are not tied to elevation, it was not possible to capture the variation in greenup age across elevations. A gain of 1 year was therefore applied in all cases. Yield gains and reductions in minimum harvest ages are more easily handled, as they are tied to individual analysis units, which are tied to the elevation zones A-F.

4.2 Forest Level Results

The following are the results of the base case analysis. Three scenarios are compared. The first is the IFPA base case. The second is the new base case incorporating the previously discussed changes to the analysis unit definitions and regeneration assumptions. The third scenario represents the application of the genetic gain estimates. Figure 3 depicts the impact on timber availability. At any point in time, the difference between availability and harvest level represents the surplus which could be harvested during that decade without violating any constraints. There are small changes in availability associated with the altered base case data model. Both the redefinition of analysis units, as well as the modified regeneration assumptions contribute to these changes. Genetic gain results in predictable increases in availability. The initial gains are associated with reductions in greenup rates (1 year). The more significant increases in availability start to show up in the sixth decade, and are associated with increases in yield and decreases in minimum harvest ages.

Figure 4 and Table 22 represent the net timber harvest under the three scenarios.

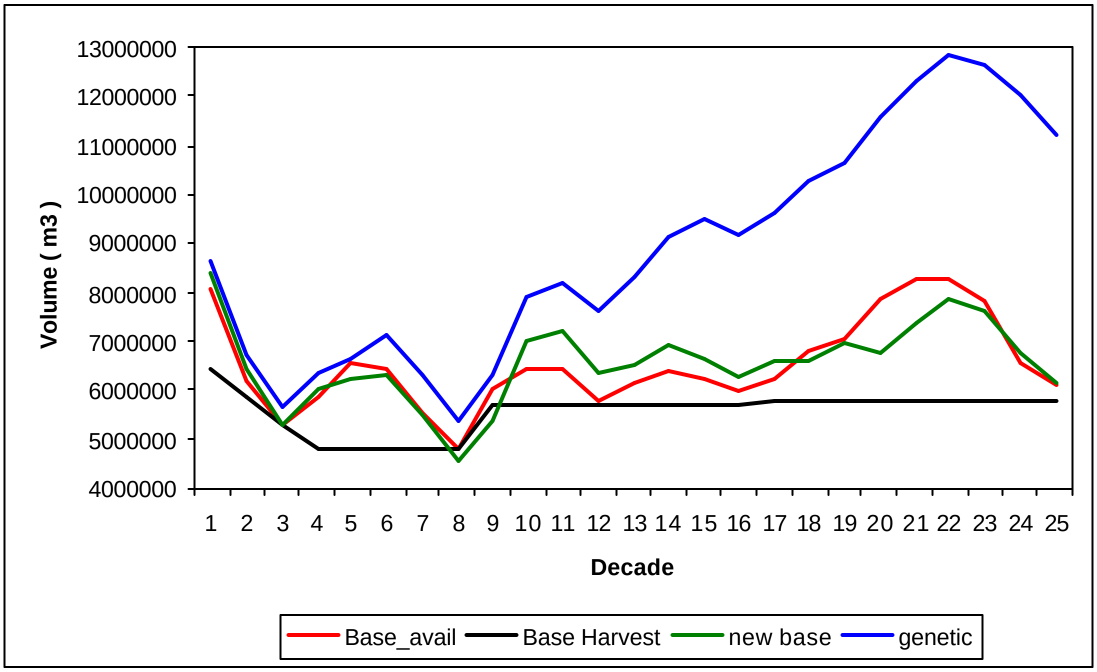

Figure 3. Impacts of new regeneration strategy and genetics on timber availability

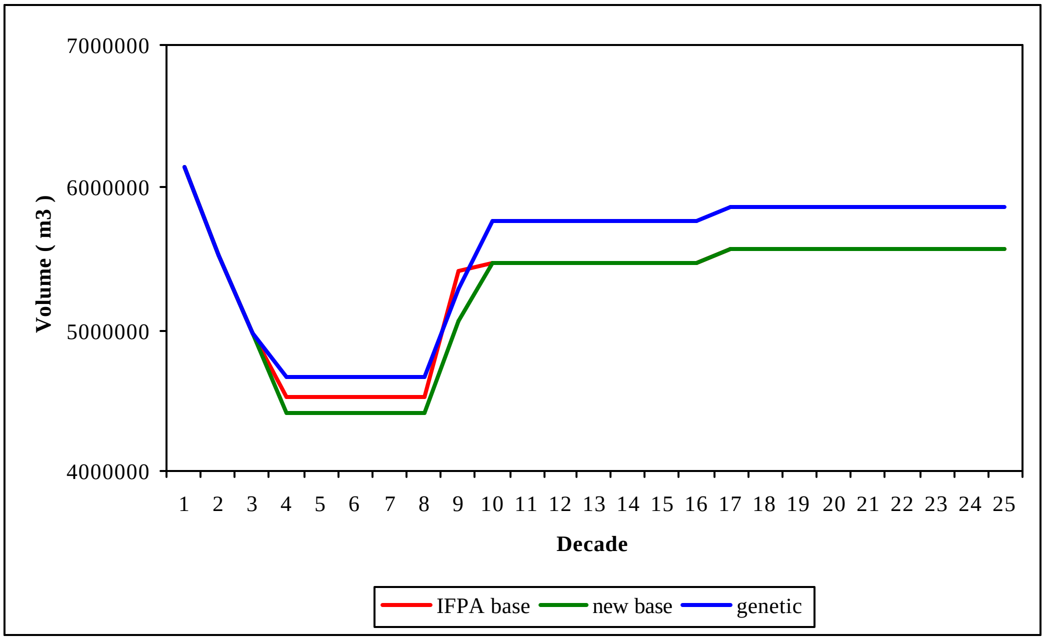

Figure 4. Timber harvest scenarios

Table 22. Annual net timber harvest scenarios (cubic metres/year)

Decade	IFPA Base Case	New Base Case	Genetic	Gain (%)
1	615000	615000	615000	0
2	553500	553500	553500	0
3	498200	498200	498200	0
4-8	451200	441200	466200	5.7%
9	541200	506200	529200	4.5%
10-16	547000	547000	577000	5.5%
17-25	557000	557000	587000	5.4%

While the stand level genetic gain estimates shown earlier in Table 17 indicate a stepwise increase over the first 5 years, modeling this initial step had no impact on the timber supply forecast (as compared to implementing the full genetic gain value from the onset). Given the decadal resolution of the analysis, and the complexities associated with modeling this step-up, all of the analyses were completed using the full genetic gain factors over the entire time horizon.

The genetic improvement scenario assumes that sufficient orchard seed is available to meet all the planting requirements throughout the 250 year planning horizon. To evaluate the feasibility of this assumption, planting requirements were reassessed under the genetic scenario. Figures 5 and 6 show the patterns which emerge during the first rotation (years 1-80). Based on expected supply from the orchards during these periods, it is deemed reasonable to expect that these requirements can be met from the existing program.

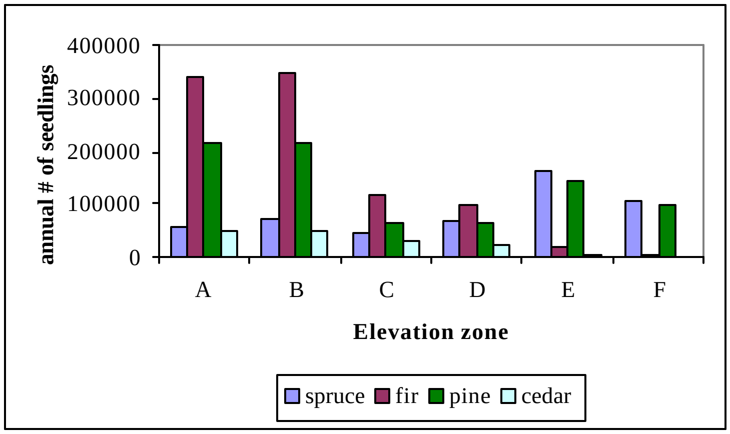

Figure 5. Planting requirements – years 1-30

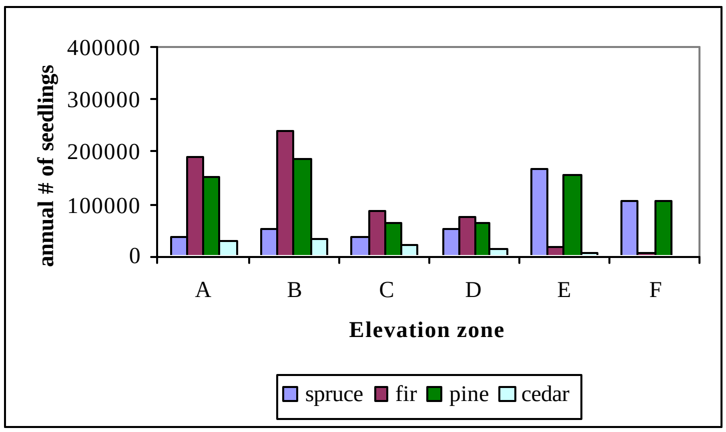

Figure 6. Planting requirements – years 31-80

4.3 Sensitivity Analysis

Five scenarios were compared to the genetic gain and base case scenarios. Scenarios 1-4 represent the targeted application of genetically improved stock. In each scenario, only 50% of the area planted with genetically improved stock in the base genetic run received improved stock, with the balance planted with unimproved stock. The hypothesis was that by targeting specific landscape units, more effective use could be made of a smaller quantity of genetically improved stock. In each scenario, a different approach was taken to selecting the target landscape units.

Scenario 1. Target the most constrained landscape units.
The percentage of the base case harvest within each landscape unit was determined for the three most constrained periods (3,8 and 12). This was compared to the percentage of the total harvestable area represented by each landscape unit. On average, one would expect the landscape unit to contribute to the harvest in proportion to its area. If it were heavily constrained, its proportional contribution would be less than its proportional area, and *vice versa*. In each of the three constrained decades, a constraint ratio was determined for each landscape unit:

constraint ratio = area (%) / harvested area (%).

A ratio > 1 indicates higher than "average" constraints. Table 23 lists the landscape units which were targeted:

Table 23. Targeted landscape units – Scenario 1

LU #	LU Name	Area (ha)	Constraint ratio		
			Period 3	Period 8	Period 12
2	ROSSLAND	3183	0.8	3.0	1.2
4	PEND OREILLE	5533	1.6	3.0	3.2
5	STAGLEAP	5975	4.6	2.3	2.7
8	BLUEBERRY	8619	5.6	3.9	2.5
9	DOG/JOHNSON	7032	16.0	4.9	7.4
19	EAGLE	20561	23.4	44.5	46.4
22	CARIBOU	10294	36.0	53.0	8.9
23	HILLS	5755	3.4	18.1	5.4
31	FISH	1033	7.9	1.5	12.6
	Total	67985			

For each landscape unit, the area represents the net harvestable area within zones A-D, where the majority of the genetically improved seedlings are planted. 67,985 ha represents about 50% of the total area in Zones A-D.

Scenario 2. Target the least constrained landscape units.
In sensitivity scenario 2, the targets were reversed. The target LUs are listed in Table 24.

Table 24. Targeted landscape units – Scenario 2

LU #	LU Name	Area (ha)	Constraint ratio		
			Period 3	Period 8	Period 12
1	SHEEP	7506	0.3	1.4	0.9
3	BEAR	8748	1.6	0.8	1.5
6	ERIE	5786	0.9	1.3	0.9
7	GLADE	4345	0.5	0.2	0.3
11	CAYUSE	1770	1.6	1.7	1.0
12	LADYBIRD	7770	0.4	0.6	0.4
13	PEDRO	4805	1.4	0.8	1.4
14	PERRY	2054	0.4	0.8	0.3
15	LEMON	6304	1.6	0.5	1.0
20	BARNES-WHATSHAN	1222	0.2	0.1	0.2
21	GLAD/KOCH/WODEN	1342	1.9	2.2	2.2
24	IDAHO	5226	1.3	0.9	0.7
25	WILSON	7949	1.2	0.6	1.5
26	VIPOND	1060	0.1	0.1	0.1
27	FOSTHALL	197	0.1	0.2	0.1
28	KUSKANAX	7975	2.5	1.1	1.5
29	HALFWAY	877	0.1	0.1	0.1
30	TROUT	573	0.1	0.1	0.2
	Total	75509			

Scenario 3. Target the landscape units with the highest proportion of area in VQOs.
In sensitivity scenario 3, target landscape units were selected based on the percentage of the area in zones A-D which falls within VQO forest cover zones. The targeted landscape units are listed in Table 25.

Table 25. Targeted landscape units – Scenario 3

LU #	LU Name	Area (ha)	% VQO
14	PERRY	2054	94.0
23	HILLS	5755	90.0
7	GLADE	4345	83.0
24	IDAHO	5226	81.0
31	FISH	1033	80.0
12	LADYBIRD	7770	79.0
21	GLAD/KOCH/WODEN	1342	62.0
8	BLUEBERRY	8619	58.0
13	PEDRO	4805	57.0
3	BEAR	8748	47.0
28	KUSKANAX	7975	44.0
15	LEMON	6304	42.0
6	ERIE	5786	41.0
	Total	69762	

Again, the 69,762 ha represents about 50% of the total area in Zones A-D.

Scenario 4. Target the landscape units with the highest proportional increase in harvest
In sensitivity scenario 4, target landscape units were selected based on the highest percentage increase in harvest under the full genetics program. For example, in the Stagleap landscape unit, the genetic improvement scenario resulted in a 29% increase in harvest. Targeted landscape units are summarized in Table 26.

Table 26. Targeted landscape units – Scenario 4.

LU #	LU Name	Area (ha)	% Increase in Harvest
5	STAGLEAP	5975	29
24	IDAHO	5226	25
14	PERRY	2054	23
30	TROUT	573	19
11	CAYUSE	1770	17
19	EAGLE	20561	16
1	SHEEP	7506	16
28	KUSKANAX	7975	8
23	HILLS	5755	8
2	ROSSLAND	3183	7
20	BARNES-WHATSHAN	1222	7
7	GLADE	4345	6
13	PEDRO	4805	6
	Total	70950	

The annual net timber harvest scenarios associated with scenarios 1-4 are listed in Table 27.

Table 27. Annual harvest (cubic metres/year) – Scenarios 1-4

Decade	Base case	Full Genetics Program		Scenario 1		Scenario 2		Scenario 3		Scenario 4	
		Harvest (m^3/yr)	%	Harvest (m^3/yr)	%	Harvest (m^3/yr)	%	Harvest (m^3/yr)	%	Harvest (m^3/yr)	%
1	615000	615000	0	615000	0	615000	0	615000	0	615000	0
2	553500	553500	0	553500	0	553500	0	553500	0	553500	0
3	498200	498200	0	498200	0	498200	0	498200	0	498200	0
4-8	441200	466200	5.7	453100	2.7	455900	3.3	454400	3.0	453200	2.7
9	506200	529200	4.5	529200	4.5	529600	4.5	529600	4.5	529600	4.5
10-16	547000	577000	5.5	569300	4.1	569400	4.1	571100	4.4	568000	3.8
17-25	557000	587000	5.4	571300	2.6	573500	3.0	570600	2.4	573800	3.0
9-25			5.4		3.3		3.5		3.4		3.4

During decades 4-8, 50% of the full genetic program provides marginally more than 50% of the timber gain. Given the resolution of the modeling process, this marginal difference would not be significant. Moreover, all four scenarios produced reasonably similar results.

The explanation for this result lies in the way in which the changes affect timber availability. Increased timber availability can be realized by two mechanisms:

- Reduction in downward pressure associated with non-timber value constraints, and/or;
- Increased volume/hectare in stands available for harvest.

As discussed earlier, genetic improvement potentially provides for both mechanisms. The intent of Scenarios 1-4 was to capitalize on reductions in constraint status by targeting specific landscape units.

The fact that the improvements were only proportional to the size of the genetically improved planting program means that the improvements in greenup and minimum harvest age were not sufficient to reduce constraint pressure. The improvements in timber supply were the result of the higher volumes/hectare associated with genetically improved seed.

Scenario 5. Expand genetic program.
In this scenario, the genetic improvement program was expanded to include pine and larch in Zones D and E. Zone C genetic gain values for these species were applied to these zones. The results are presented in Table 28. The expansion of the program results in a further 1% gain in long-term supply.

Table 28. Annual harvest (cubic metres/year) – Scenario 5

Decade	Base Case	Full Genetic Program		Scenario 5	
		Harvest (m^3/yr)	%	Harvest (m^3/yr)	%
1	615000	615000	0	615000	0
2	553500	553500	0	553500	0
3	498200	498200	0	498200	0
4-8	441200	466200	5.7	466200	5.7
9	506200	529200	4.5	529200	4.5
10-16	547000	577000	5.5	582000	6.4
17-25	557000	587000	5.4	594000	6.6
9-25			5.4		6.4

4.4. Comparison With TSR2

In the Arrow TSR2, a sensitivity analysis was included to demonstrate the impact of genetic gain. Both the TSR analysis and the one reported here employed the same approaches to incorporating genetic gain into managed yield curves, with the attendant changes to greenup and minimum harvest ages. However the TSR2 analysis employed the original analysis unit designations, with no seed planning zone resolution. While long-term effects were comparable, short-term effects were different. However, differences in inputs and timber flow objectives make it difficult to make a direct comparison between the two analyses. To make a valid comparison, the genetic gain analysis prepared for this project was modified to reflect the TSR2 differences noted earlier, specifically;

- Watershed green-up heights were changed from 9-meters to 6-meters; and
- Minimum harvest ages for managed stands were recalibrated to reflect TSR2 protocol.

The timber flow objectives used in the TSR2 genetic gain sensitivity *(Arrow Timber Supply Area, Analysis Report, April 2000, Section 5.9*) were employed. The results of this modified analysis projected for the 250-year time horizon are depicted in Figure 7, along with the new base and genetic runs from this analysis.

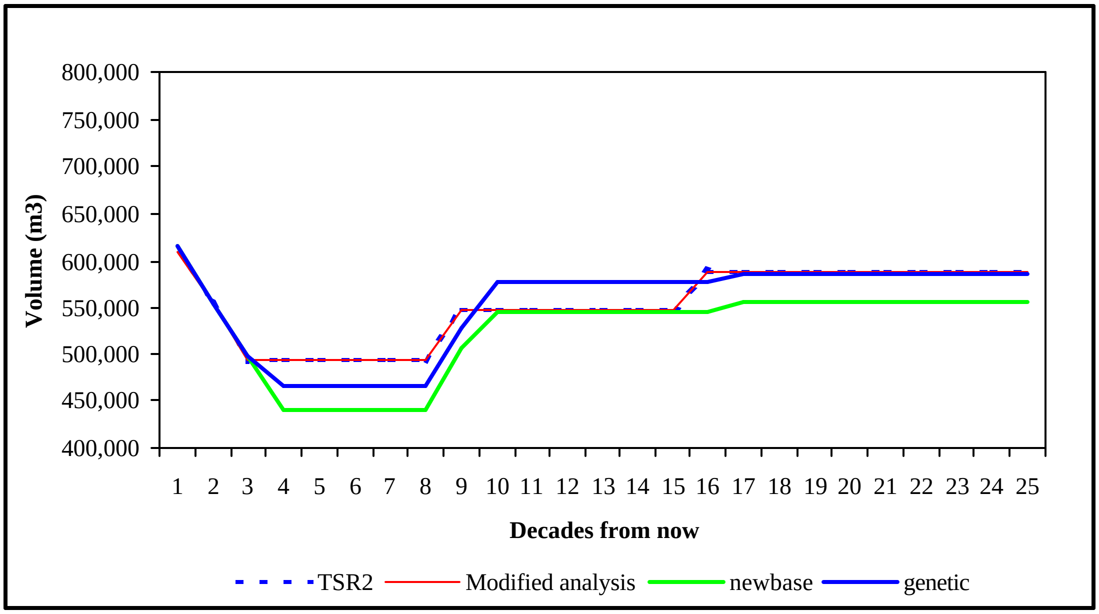

Figure 7. Harvest flow – Comparison with TSR2

The modified analysis demonstrated results comparable to those achieved in the TSR2 analysis. This is not surprising, as both of these analysis employed comparable assumptions with respect to watershed greenup, minimum harvest age and genetic gain. The only difference was in the resolution of the genetic gain assumptions. This difference did not materially affect timber flow.

While the genetic analysis demonstrated a significant mid-term gain, this gain was measured against the IFPA base case which was more constrained in the mid-term by greenup and minimum harvest age factors than was the TSR. The genetic improvements mitigated these factors, providing the marginal gain in decades 4-8. Expressed another way, had the genetic analysis employed the more aggressive minimum harvest age and watershed greenup assumptions employed in TSR2, the gain shown in decades 10-15 could have been realized earlier.

5. DISCUSSION

The analyses presented in this report demonstrate a clear, positive impact on timber flow within the Arrow TSA associated with the seed orchard program. Previous analyses of genetic improvement effects have focused on long-term timber supply gains associated with increased yields. However, the analyses presented in this report show gains as early as decade 4. This results from the combined effects of increases in yield, reductions in minimum harvest age, and earlier greenup ages. All three factors contribute to earlier availability of harvestable volumes from plantations, which permits an increase in short-term harvest levels.

The timing and magnitude of these timber supply impacts is directly related to the causes, timing and magnitude of constraints affecting timber flow. In the Arrow TSA, these constraints are most severe in decades 3, 8 and 12. In other TSAs, the causes, timing and nature of these "pressure points" may be entirely different. Therefore, the impacts shown in these analyses cannot be extrapolated to other areas.

A key objective of this study was to properly geo-reference genetic gain expectations to the planning zones and elevational bands associated with the seed orchard program. As described in this report, gains vary significantly across elevational bands, and therefore this resolution is key to the reliability and credibility of the conclusions drawn. In incorporating this resolution into the analysis, it became apparent that the regeneration strategy developed for the TSA required the same level of geo-referencing. The estimates of planted species percentages, while reasonable TSA wide averages, did not adequately reflect the variation expected at different elevations. The regeneration strategy was therefore modified to reflect this. The spatial resolution issue is not unique to this particular example. In general, such issues become more critical as the spatial resolution of timber supply analyses becomes finer. The input assumptions for broad-based zonal analyses cannot be unilaterally applied to more spatially explicit analyses.

Increased early height growth is a key factor in realizing genetic gain improvements. However, in this analysis, the implementation of this factor was compromised by the fact that the resolution at which greenup constraints are applied does not match the resolution at which the growth impacts are applied. In FSSIM, greenup requirements are modeled as age-based constraints. Therefore, greenup height requirements must be translated into corresponding ages at greenup. These ages are applied uniformly to the corresponding resource emphasis zones. While area-weighting can be used to account for variation across analysis units, it would be preferable to track height growth separately for each analysis unit, and employ a height-based constraint. In this way, any effects on height growth associated with changes in analysis unit characteristics could be more directly incorporated into the analysis.

The main value in this analysis lies in the more explicit accounting of factors which may alter the timber supply impacts. These factors include:

- Variation in genetic gain associated with elevational differences;
- Allowance for future increases in orchard production;
- Reconciliation of seed supply/demand budgets;
- Consideration of all stand-level factors impacted by genetic gain expectations; and
- Examination of timber supply sensitivity to changes in improved seed supplies.

Explicit incorporation of these factors greatly reduces uncertainty around expected benefits, and therefore improves the basis for strategic program planning. It does not follow that their use will provide substantially different results than the more general approaches currently employed in the TSR process. This issue was in fact demonstrated in this analysis. The difference is similar to the sampling intensity problem. Two samples of different sizes may yield the same average, but the larger sample may result in a narrower confidence interval.

One should not draw the conclusion that a more detailed approach such as the one presented in this analysis will always demonstrate larger/earlier timber supply impacts. The opposite could very well be true, depending upon the landbase in question, and particularly the dynamics of the factors which are constraining timber supply.