Appendix 7: Stand Survey & Growth Modeling for the Fort St. John TSA

Development of Models to Predict PMV from MSQ Statistics for Deciduous Stands

Contract Report for Canadian Forest products Ltd Fort St. John, BC

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1.0 Introduction

This report describes the creation and application of set of models intended to support development of Mean Stocked Quadrant (MSQ) surveys and related stocking standards for deciduous stands in the Peace River region of northeastern British Columbia. It should be considered as an addendum to *Stand Survey & Growth Modeling for the Fort St. John TSA* (J. S. Thrower and Assoc. 2003), and it is assumed here that readers are familiar with the contents of that document. The basic theory and field methods described in the antecedent report continue largely unchanged, with the exception of a few minor alterations as noted in section 2.0

2.0 Deciduous versus Conifer MSQ Assessments

There are two primary differences between conifer and deciduous MSQ surveys and proposed stocking standards:

1. Where conifer stands are assessed at year 15, deciduous stands are assessed at year 10.
2. For conifer stands, management-induced acceleration in growth of newly planted trees is reflected in a reduced number of years to breast height and is recognized through application of the *effective age* concept. Uncertainties in age determination for trembling aspen make this impractical. Corresponding changes have been necessitated in the deciduous compilation procedure, where impacts of *effective age* have been eliminated.

A further addition for deciduous stands is the option for 3 different plot sizes: 30 m^2 (3.09 m radius), 40 m^2 (3.57 m radius) and 50 m^2 (3.99 m radius). However, as of Feb 28, 2013, no decisions have been made with regard to administrative acceptability of plot sizes other than 50 m^2.

3.0 Model Fitting

Models to predict yield from MSQ statistics were generated in a 4-step process:

1. A set of 80 stem maps was generated using routines developed by Farnden (2009). Density[1] levels of root suckers varied in 10 steps from 100 to 51,200 trees/ha, with each density level replicated in 4 spatial patterns (Figures 1 and 2) and 2 temporal patterns of suckering.
2. Stand growth originating from each of the stem maps was simulated using the Tree and Stand Simulator (TASS v. 2) model. Growth of each stand was replicated at 5 levels of site index ranging from 15 to 27 m, with generation of final models expanded to 1 m increments through interpolation.

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[1] Stand densities in the modeling environment represent only those trees that would be considered as "acceptable" or "countable" in a field survey – see Section 5.0 for a further discussion.

3. Stem maps at age 10 were extracted from the TASS output, and simulations were run to generate a sample of 5000 MSQ plots from each stand, using three variations on plot size (30, 40 and 50 m2). The mean of the 5000 plots was assumed to be the true mean for the population for each plot size.

4. The mean MSQ for each stand was used in a modeling exercise to predict merchantable yield at a reference age of 80 years.

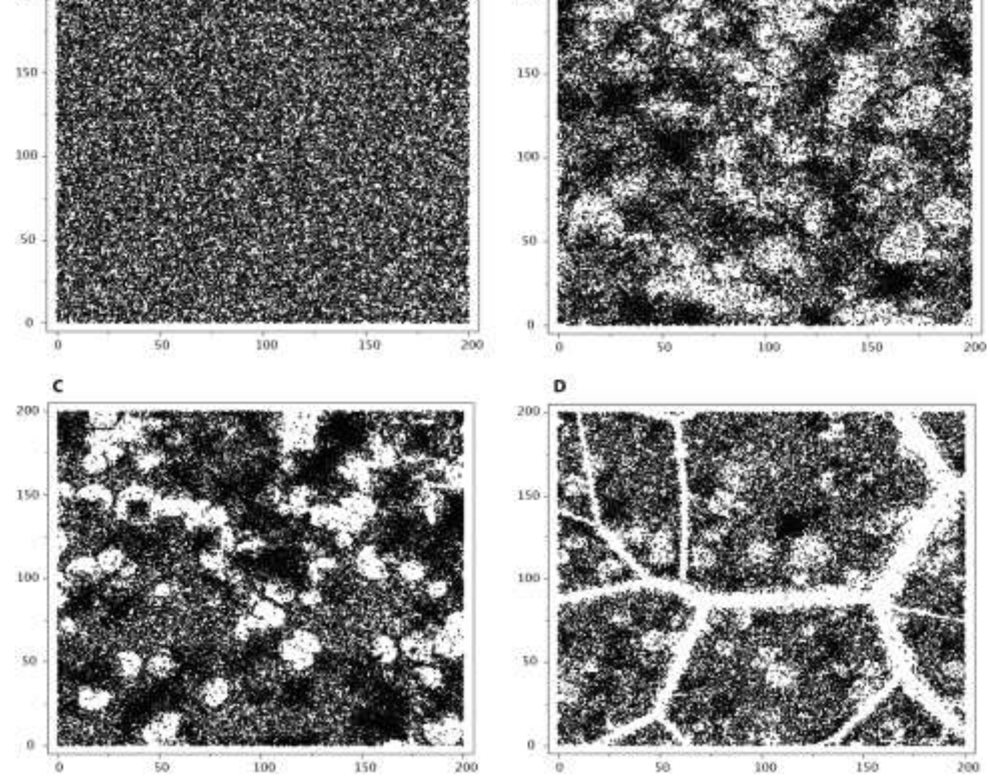


Figure 1. Stem maps illustrating the 4 simulated spatial patterns used to generate deciduous MSQ models, in this case for stands with 12,800 suckers per hectare. The scale is in metres, and each dot represents a tree location. The pattern in (A) represents a completely random distribution, (B) and (C) represent increasing levels of clumping, and (D) builds upon (B) with the addition of linear features such as wet draws and harvest trails that could impact on stocking levels.

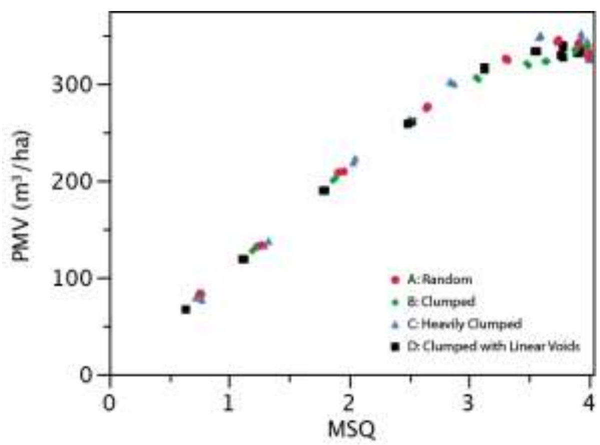


Figure 2. Impact of spatial pattern on relationship between MSQ and PMV for SI_{50} = 21. The four spatial patterns correspond to those illustrated in Figure 1, with various points representing variations in establishment density.

A variety of model forms was investigated, with an imposed requirement to "run through zero". The selected model takes the form:

$$PMV = b_0\left(1 - e^{-b_1 \times MSQ^{b_2}}\right)^{b_3}$$

where b_0 is a horizontal asymptote representing the maximum achievable yield (FMV) under full stocking, and where the remaining parameters control a set of sigmoidal curve shapes. Note that for all models, PMV ⇒ FMV as MSQ ⇒ 4. Parameters and fit statistics for the resulting models are provided for SI_{50}=21 i n Table 1, with parameter estimates for the remaining models provided in Appendix 1. A tab le of PMV values by MSQ, SI and plot size is provided in Appendix 2.

Table 1. Parameter estimates and fit statistics for models predicting yield at age 80 for site index = 21 m using MSQ values as predictors.

Plot Size	bo	b1	b2	b3	RMSE	Pseudo R^2
30 m^2	**334.7**	**0.02673**	**4.119**	**0.2165**	**7.05**	**0.994**
40 m^2	**335.0**	**0.002654**	**5.681**	**0.1662**	**6.53**	**0.995**
50 m^2	**335.4**	**0.0001903**	**7.463**	**0.1345**	**6.04**	**0.996**

In the process of developing the deciduous MSQ models, it became apparent that the relations hips between PMV and MSQ were strongly polymorphic by site index (see Figure 3). This findin g contrasts with the situation for conifer stands where the relationships are assumed to be anamorphic, and PMV could be scaled by site index from a single curve shape. If the

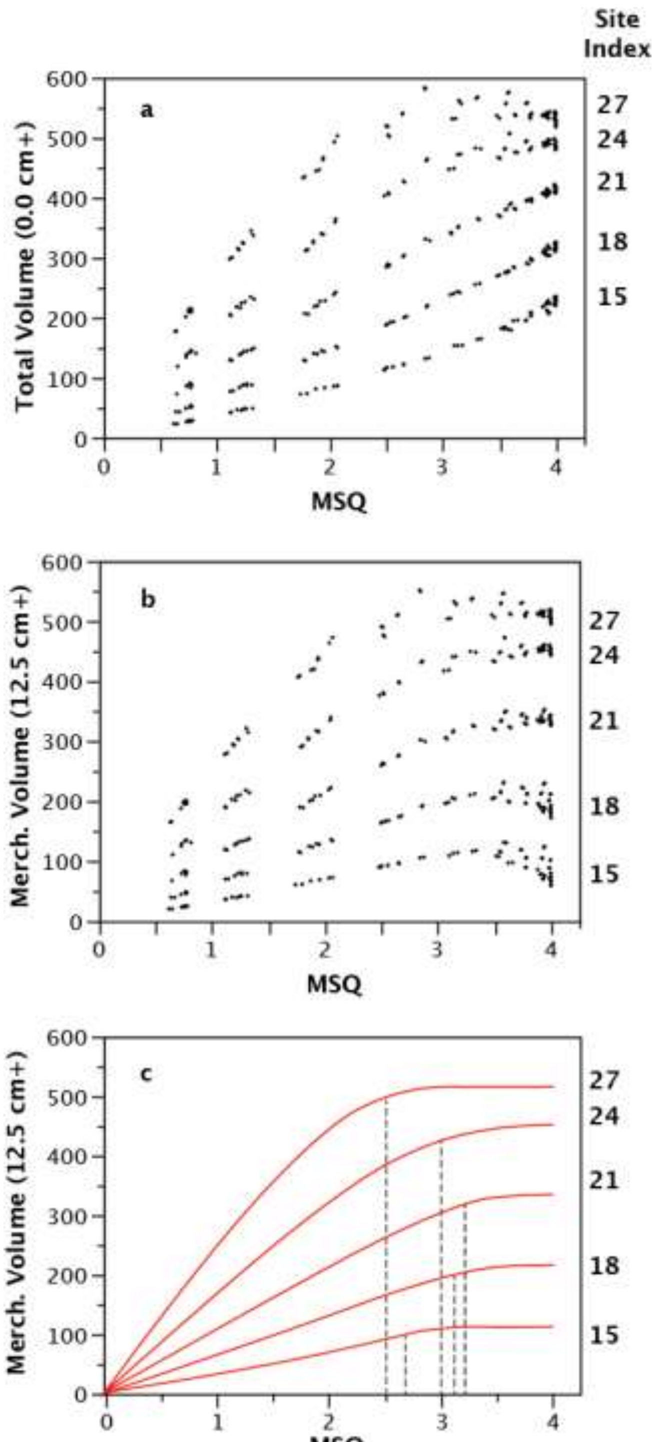

Site
Index
Total Volume (0.0 cm+)
a
27
24
21
18
15
MSQ
Merch. Volume (12.5 cm+)
b
c
0
100
200
300
400
500
600
1
2
3
4

Figure 3a. Impact of growth rates on PMV curve shape, b ased on *total* volume. At very high site indices (e.g. SI = 27 m), it takes fewer trees than at lower site indices to maximi ze use of available growing space. For SI = 21 and

lower, total yield continues to increase right up to MSQ = 4, but yield plateaus at lower MSQ's for the higher SI's.

Figure 3b. Impact of merchantability limits on PMV curve shape. For the lowest site indices, PMV values (merchantabl e as opposed to total volume) start to decline at the highest MSQ values. This effect results from a significant proportion of trees falling below

the merchantable dbh limit. This trend is exacerbated for s tands with the highest stand densities, which correspondin gly experience the highest risk of merchantable yield declin es. This effect is largely absent for site indices 24 and 27.

Figure 3c. Impact of site index and merchantability limits on TMV thresholds. PMV curves have been fit to the data p oints from 3b. Any stands established at densities above 10, 000 trees/ha for SI's 15 and 18 have been ignored to avoid t he merch volume drop-
off associated with high MSQ values shown in Fig 3b above . Relative to relationships for SI=21, SI's 24 and 27 experienc e lower TMV values as a result of improve growing space oc cupancy by fewer trees, while SI's 15 and 18 experience low er TMV's as a result of the merchantable yield reductions as sociated with high establishment densities (which are stron gly correlated to high MSQ's).

conifer approach were to be followed for deciduous stands, the result would be biased outcomes for some site indices, as no one curve would be an appropriate surrogate for all sites.

The net outcome is that there is no single reference site index that can adequately represent t he full range of site indices that might be experienced under operational conditions. For exam ple, the selection of a circum-
median SI = 21 m as the reference SI would result in a stocking standard that is higher than nec essary for better and poorer sites (Fig 3c), based on the concept of potential yield performanc e. Such an outcome would place an overly restrictive

restocking requirement on licensees working under this system. There
for, despite the difficulty in estimating aspen site index, it is recommended that SI be included i n this system as an input parameter.

In order to utilize site index within the PMV/MSQ assessment procedure, a reasonably reliable estimae of age is required. There are at least two options for achieving this including:

1. assuming that total age is equal to years since harvest (10 years) and that SI is then Simply a function of height, and
2. counting age using bud scale scars on a branch whose origin on the stem is immediately below breast height, or

The first of these options is the most likely to be easily applied in the field and is recommended. Based on values derived from the computer program Site Tools, a function to derive site index from total height assuming a total age of 10 years was developed as

$$SI = 2.54 + 4.15 \times HT - 0.0845 \times HT^2$$

where HT is the stand top height (in metres) based on a sample of the fattest tree in each of a set of 0.01 ha plots. The validity of this model is restricted to a SI_{50} range from 14 to 28 m. Given that total age is fixed in this method at 10 years, care will be needed to avoid sampling trees that were already established prior to harvest. *Such trees will typically be recognized as emergents*, or trees that are obvious ly taller than the main canopy. In some cases, it may be possible to confirm that a tree is too old by counting bud scale scars on branches.

Some concern has been expressed that SI values determined for aspen at young ages using th e currently recommended height/age curves will be biased on the high side, based on experien ce with long term monitoring plots starting from sucker regeneration (pers. comm. Richard Ka bzems). For application of the PMV/MSQ models described in this paper, any such bias will have a minimal impact on decisions regarding acceptability of stocking levels. Of greater concern i s the entry of these SI values into the Results database and ultimately into the forest inventory , where they will impact future timber supply calculations. A review of this issue with recommendations for operational application and research needs is recommended.

4.0 Well spaced; Conversion to MSQ

In order to explore the relationships between MSQ and WS stocking, an additional set of survey simulations was run on each simulated stand. For each of 4 variations on minimum

inter-
tree distance, 500 plots were assessed at random locations with the mean for each survey/stand combination assumed to be the true mean for the population. The current stocking standard for deciduous stands, specified in the Fort St. John Pilot Project SFMP, is based on well spaced stocking using a minimum inter-tree distance (mitd) of 0.5 m and an M value of 50. The TSS is implied to be 10,000 WS trees/ha, with the minimum specified as 4,000 WS trees/ha.

In moving to a stocking standard based on MSQ values, a conversion function is desirable to facilitate the transition. Such a function was derived based on simulated survey outcomes using both systems as illustrated in Figure 4. The resulting equation is a modified Gompertz function where the curve is fixed to "go through zero" and an extra parameter is added as an exponent to the "x" value to allow greater flexibility. The resulting equation is:

$$MSQ = 4.00 * e^{-e^{2-1.85\left(\frac{WS}{200}\right)^{0.322}}}$$

(—)!

with fit statistics of RMSE= 0.073 and pseudo-R^2 = 0.99.

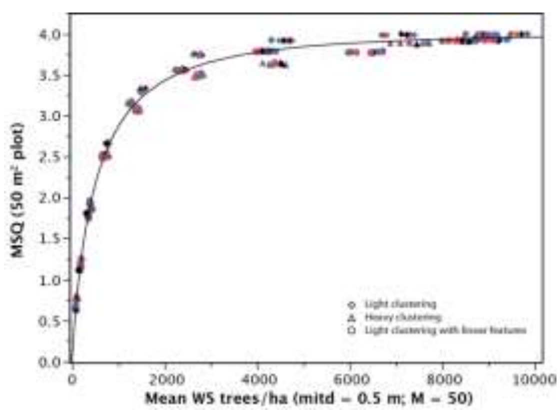


Figure 4. Comparison of simulated WS and MSQ survey outcomes. Spatial patterns correspond to those illustrated in Figures 1B to 1D. Stands with a random spatial pattern were not included.

The reciprocal function is: $$WS = 200\left(\frac{2 - ln\left(-ln\left(\frac{MSQ}{4}\right)\right)}{1.85}\right)^{3.11}$$

Both of these functions were found to be insensitive to site index, but somewhat sensitive to s
patial pattern. The function predicting MSQ from WS trees will slightly overestimate MSQ for r
elatively uniform stands, and underestimate MSQ for heavily clustered stands (spatial pattern
c in Fig. 1

In exploring the relationships between the current WS stocking standards and the proposed MS
Q standards, it became apparent that the current deciduous WS standards are poorly suited to
evaluating reforestation success using future yield as a criteria for success. The rationale for thi
s conclusion is illustrated in Fig. 6, where TASS-
predicted future yields are plotted against simulated survey outcomes. It is apparent that yields
are maximized for WS values well below the minimum threshold (MSS) of 4000 WS/ha (mitd=0
.5; M = 50). The implication suggested here is that, using a yield-
based reforestation objective, many stands with WS values below

4000 will be rejected as NSR when they are actually capable of producing perfectly
acceptable timber crops. It is also apparent that the use of an mitd as low as 0.5 m results in c
ounting of a large number of redundant WS trees that have no impact on yield.

A yield function based on an mitd of 2.0 m and an M value of 6 is provided in Fig. 6 for co
mparison. From a yield-
based perspective, this option provides equivalent or better precision, while providing a
much simpler and cost effective means of assessing stocking.

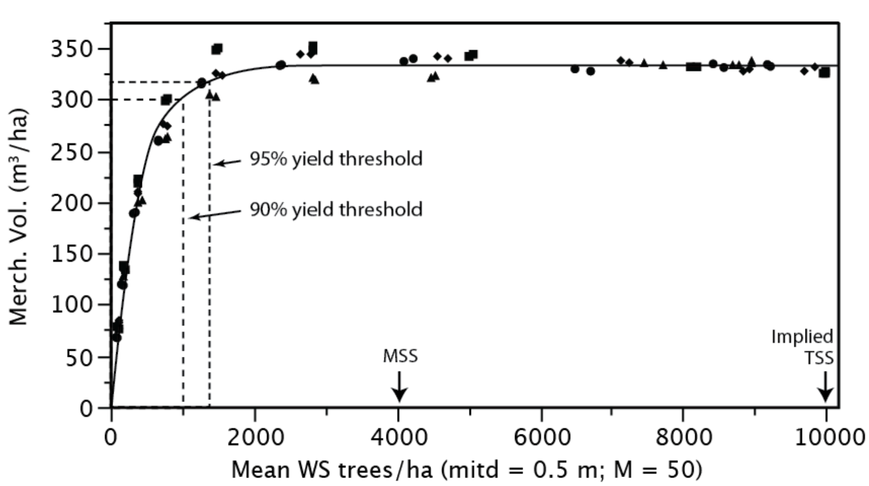


Figure 5. Predicted yield by WS stocking for current stocking standards (MSS = minimum WS). Based on this relationship, it appears that a 0.95 volume threshold would be achieved at approximately 1400 WS trees/ha. This is roughly equivalent to 2000 to 3000 countable/acceptable trees/ha depending on tree spatial pattern.

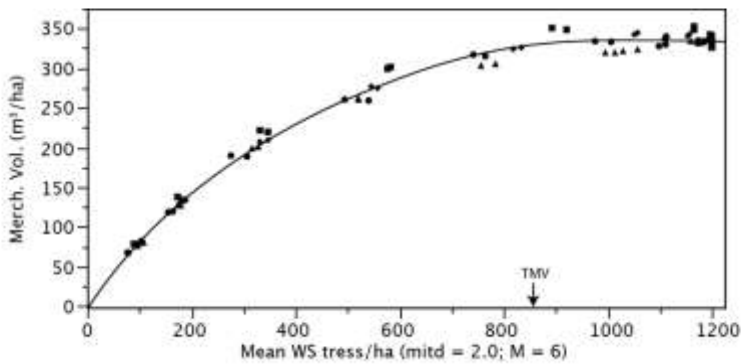


Figure 6. Predicted yield by WS stocking assuming mitd = 2.0 m and M = 6. Based on this relationship, it appears that a 0.95 volume threshold would be achieved at approximately 850 WS trees/ha, or 2000 to 3000 countable/acceptable trees/ha depending on tree spatial pattern.

5.0 Acceptable and Countable Trees

In predicting tree and stand growth using an individual tree model, there are a certain number of poor quality trees whose presence and growth are not well represented in simulations. These trees include those that are genetically inferior or seriously maladapted to the site, or are seriously damaged by agents such as disease, browsing ungulates or hail. For the current project such trees were assumed to have no impact on long term stand dynamics and were eliminate from simulations at the outset. To be compatible, field surveys must follow a similar

strategy, and such trees must be ignored in all plot tallies. This is commonly achieved using the concepts of "acceptable" and "countable" trees. In order to be tallied, a tree must meet certain criteria:

1. it must be free of unacceptable damage, and

2. it must be of sufficient vigour and relative size (i.e. > some percentage of top height) that it could form part of the main tree canopy in the future; for trembling aspen this is particularly important because (a) the species is shade intolerant and (b) the species rarely suckers more than 2 years after disturbance, such that trees well behind in height at year 10 are highly likely to have poor long term growth characteristics .

Defining acceptability criteria for aspen is beyond the scope of the current project –if not already available they should be developed by agreement between the Fort St. John Pilot Project licensees and the BC Ministry of Forests, Lands and Natural Resource Operations.

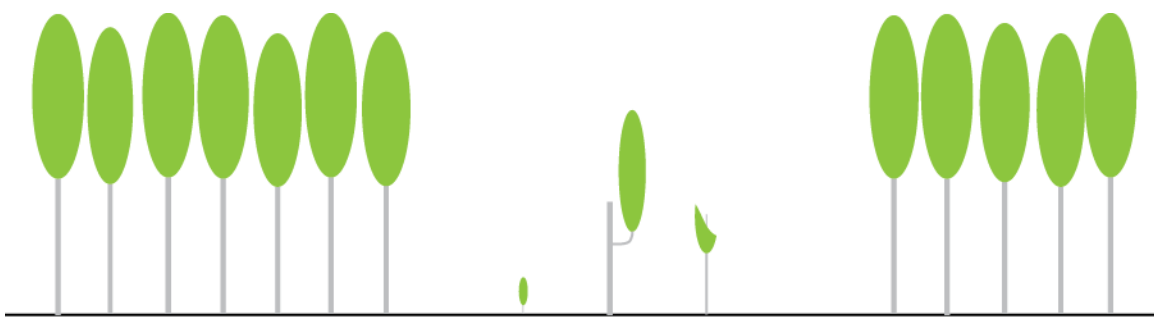


Figure 7. Examples of poor quality trees that should be ineligible for contributing to the stocking of an otherwise unstocked gap. Tree a is of similar age as the rest of the trees but has very low vigour, tree b has sustained serious stem damage and tree c is being continuously browsed by ungulates.

6.0 Impacts of Uncertainty in the TASS Model

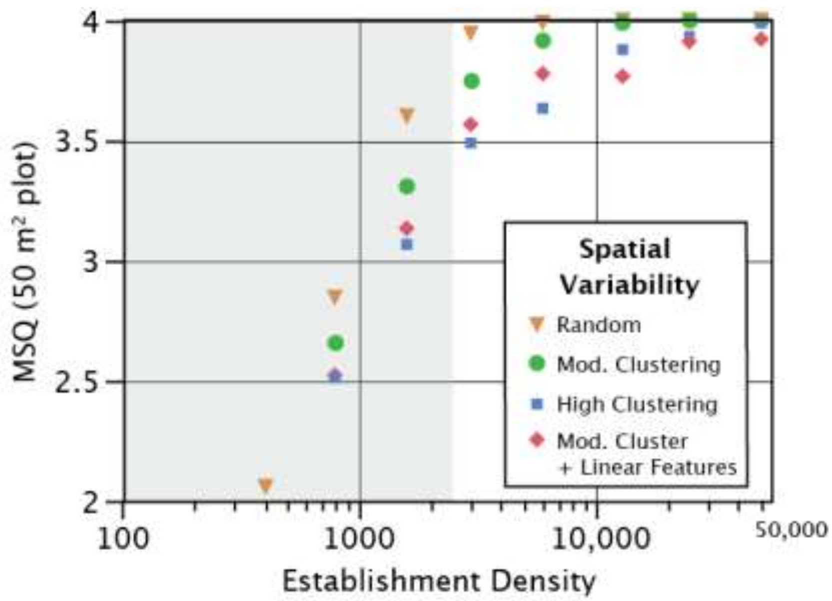
The modeling exercise used to develop the MSQ equations in this report depends heavily on the TASS growth model developed by the BC Ministry of Forests, Lands and Natural Resource Operations. It is important to recognize that in building this model, there was no data available for stands at densities less than approximately 2500 trees/ha, and very little data for young stands in general. As a result, some of the model behaviour at low densities and young ages is based on theory and experience with other species rather than on strong empirical evidence.

As illustrated in Figure 8, the density ranges over which critical stocking decisions are being made falls within the range of densities for which there was no calibration data.

Is this a critical problem? Probably not, for the following reasons:

1. A strength off models such as TASS is that they allow us utilize well known principles of forest stand dynamics that apply to all species as a general framework, with adjustments made for individual species. This gen erality of model construction greatly facilitates interpolation and extrapolation to scen arios where empirical data is weak or missing.
2. At the threshold density for which there is empirical data (2500 trees/ha), the model is predicting yields that are only slightly below the maximum achieved with full stocking.
3. We know from experience with a wide range of species that there is no threshold below which yield drops suddenly with small decreases in establishment density; the drop-off starts slowly and approaches a near-linear pattern as one approaches closer and closer to zero.

Such models are the outcome of extensive work by highly skilled individuals, and generally represent the best information available.



4
3.5
3
2.5
2
MSQ (50 m² plot)
100
1000
10,000
50,000
Establishment Density
Spatial Variability
Random
Mod. Clustering
High Clustering
Mod. Cluster
+ Linear Features

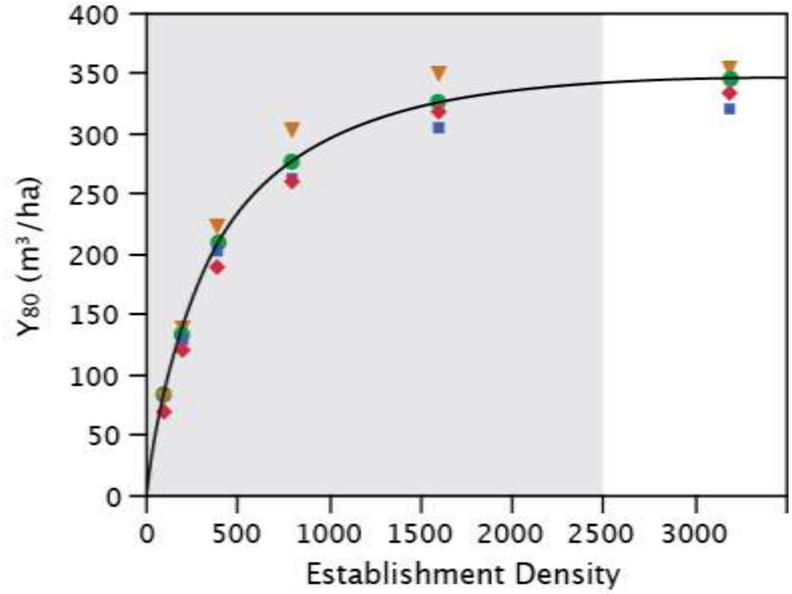


Figure 8. Comparison of total stand densities as modeled in TASS with MSQ values (top) and merchantable yield for SI_{50} = 21 (bottom). The relationships between these measures vary with spatial pattern, represented here using the four patterns from Figure 1. The grey zones represent stand densities for which there was no calibration data available for TASS. Note that critical MSQ threshold values for stocking acceptability range from 2.5 to 3.25, depending on SI (from Figure 3c). Note also that equivalent total stand densities in the field will be higher when the presence of trees with unacceptable levels of vigour and damage are included in the tally.

7.0 Transfer of Risk

The concept of *free growing* in the administration of forest regeneration in British Columbia is a milestone by which the Crown accepts that a harvested unit is acceptably regenerated, and there is minimal risk of future reductions in stocking. In assessing future regeneration performance, the stocking survey is designed to account for the yield impacts of unstocked gaps present at the time of assessment. This includes features such as those characterized by MacIsaac et al. (2006) as persistent preharvest natural gaps, postharvest wet areas, harvest disturbance gaps such as in-block roads, landings and burn piles, and postharvest regeneration voids.

The stocking survey cannot account for stocking issues that may become apparent after the free growing declaration. After this point, the Crown implicitly accepts the risks and consequences for any further damage. To this end, desired conditions at the time of transfer must be defined such that a majority of stands will have a minimal risk of declining to an unacceptable condition. It is important to recognize here that the long term minimally acceptable condition is not the same as that of the free growing threshold, but that the free growing threshold already has an implied safety buffer built in. It must also be recognized, however, that the post-free growing risks and the magnitude of the safety buffer have never been explicitly recognized or quantified in BC. Recent experience with the realization of extensive post-free growing damage to lodgepole pine has brought this issue to the forefront. The degree to which we understand that further stocking losses (as opposed to ongoing and expected self-thinning) might occur needs to be further discussed, and monitoring plots such as those being deployed in the nascent Stand Development Monitoring program will play an important role.

6.0 Summary and Conclusions

It appears from the results of analyses presented in this report that an MSQ-based stocking standard for deciduous (primarily aspen) stands is a viable approach to the administration of reforestation performance by licensees. In comparison to the similar system for conifer stands, there are a few changes necessitated by uncertainty in age determination and t he polymorphic nature of the PMV/MSQ relationships by site index. There may also be some work still required to define acceptable/countable stem criteria. Despite an appearance of increased uncertainty for the deciduous MSQ assessment procedure over that for conifer stands, the proposed MSQ standards are a superior approach to the current implementation of WS-based standards.

References

J.S. Thrower and Assoc 2003. *Stand survey & growth modeling for the Fort St. John TSA*. Contract report to Canadian Forest Products ltd., Chetwynd BC.

MacIsaac DA; Comeau PG; Macdonald SE 2006. *Dynamics of regeneration gaps following harvest of aspen stands.* Canadian Journal of Forest Research 36:1818-1833

Appendix 1: PMV Parameters by Plot Size and Site Index

Data for PMV models were generated using TASS and survey simulations for site indices 15, 18, 21,24 and a27, and an initial set of models were produced. Using these, PMV values were generated for each 0.1 increment of MSQ, and PMV values for th e remaining SI's were interpolated (or extrapolated for SI's 14 and 28) at each 0.1 incremen t of MSQ. The derived values were then used to generate PMV models for the remaining SI 's.

Table 2-1. PMV equation parameters by SI for 50 m^2 plots

SI	bo	b1	b2	b3
14	79.0	1.665×10^{-17}	34.07	0.03534
15	112.0	1.018×10^{-11}	22.92	0.04937
16	146.2	3.377×10^{-6}	11.19	0.09910
17	181.0	3.726×10^{-5}	8.914	0.1225
18	216.6	7.281×10^{-5}	8.215	0.1312
19	255.7	1.085×10^{-4}	7.897	0.1318
20	295.3	1.483×10^{-4}	7.653	0.1329
21	335.4	1.903×10^{-4}	7.463	0.1345
22	374.0	.001333	5.990	0.1625
24	451.2	0.007873	4.741	0.2018
25	471.7	0.02754	3.918	0.2438
26	492.1	0.03591	3.974	0.2371
27	515.0	0.01824	4.994	0.1789
28	538.5	.004895	6.844	0.1237

Table 2-2. PMV equation parameters by SI for 40 m^2 plots

SI	bo	b1	b2	b3
14	78.7	8.798×10^{-17}	38.64	0.02882
15	112.0	1.887×10^{-17}	15.46	0.06871
16	146.3	1.348×10^{-4}	8.693	0.1207
19	255.7	0.001137	6.402	0.1535
21	335.0	0.002654	5.681	0.1662

Table 2-3. PMV equation parameters by SI For 30 m^2 plots

SI	b0	b1	b2	b3
14	77.86	2.209×10^{-7}	17.86	0.0572
16	146.5	0.004269	6.197	0.1562
17	181.2	0.008118	5.386	0.1765
18	215.0	0.009751	5.098	0.1833
19	255.7	0.01520	4.691	0.1955
20	295.3	0.02095	4.399	0.2065
21	334.7	0.02673	4.119	0.2165
22	373.7	0.05679	3.565	0.2487
23	412.4	0.1012	3.111	0.2868
24	450.3	0.1566	2.788	0.3273
25	471.9	0.3297	2.295	0.4272
27	514.7	0.2149	3.459	0.2421
28	537.7	0.05459	6.0230	0.1167

Appendix 2: PMV Values by Site Index and MSQ

Table 2-1. PMV by MSQ and Site Index for 50 m^2 plot size.

2.1	49	74	95	116	138	166	194	222	260	298	336	376	417	459	499
2.2	52	78	100	122	145	174	203	233	271	310	349	389	429	471	512
2.3	55	82	105	128	152	182	212	243	282	322	362	401	440	482	521
2.4	58	86	110	134	158	190	221	253	293	333	374	412	450	491	528
2.5	61	91	115	140	165	197	230	263	303	344	385	422	459	498	533
2.6	64	95	120	146	172	205	238	272	313	354	395	431	466	504	536
2.7	67	99	125	151	178	212	246	281	322	363	405	438	473	508	538
2.8	70	102	129	156	184	219	254	290	331	372	413	445	478	511	538
2.9	73	106	133	161	190	225	262	298	339	380	421	451	482	513	538
3.0	75	109	137	166	195	232	268	306	346	386	427	456	485	514	538
3.1	78	111	140	170	200	237	274	312	352	392	433	460	487	514	538
3.2	79	112	143	173	204	242	280	318	357	397	438	463	489	515	538
3.3	79	112	144	176	208	246	284	323	362	401	441	466	490	515	538
3.4	79	112	145	178	211	249	288	327	366	405	444	468	491	515	538
3.5	79	112	146	179	213	252	291	330	368	407	447	469	491	515	538
3.6	79	112	146	180	215	253	293	332	370	409	448	470	492	515	538
3.7	79	112	146	181	216	254	294	334	372	410	449	471	492	515	539
3.8	79	112	146	181	216	255	295	335	373	411	450	471	492	515	539
3.9	79	112	146	181	216	255	295	335	373	412	451	471	492	515	539
4.0	79	112	146	181	217	256	295	335	374	412	451	471	492	515	539

Table 2-2. PMV by MSQ and Site Index for 40 m^2 plot size.

	Site index														
MSQ	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
1.0	27	39	50	61	73	90	108	125	150	176	200	232	259	290	321
1.1	30	43	55	68	80	99	118	137	164	191	218	252	281	314	346
1.2	33	47	60	74	88	108	128	148	177	206	234	271	303	337	370
1.3	36	51	66	80	95	117	138	160	190	221	251	290	323	359	393
1.4	39	55	71	87	102	126	149	171	204	236	267	308	342	380	415
1.5	43	59	76	93	110	134	159	183	216	250	283	325	360	399	436
1.6	46	64	82	100	117	143	169	194	229	264	298	341	378	418	456
1.7	49	68	87	106	125	152	179	205	241	278	313	356	393	435	474
1.8	52	72	92	112	132	160	188	216	254	291	328	371	408	450	490
1.9	55	76	98	119	139	169	198	227	265	304	341	385	422	463	503
2.0	59	81	103	125	147	177	208	238	277	316	355	397	434	475	514
2.1	62	85	108	131	154	185	217	248	288	328	367	409	444	485	523
2.2	65	89	113	137	161	193	226	258	299	339	379	419	454	493	529
2.3	69	93	118	143	167	201	234	268	309	349	390	428	462	499	533
2.4	72	97	123	149	174	209	243	277	318	359	399	436	469	505	536
2.5	75	101	128	154	180	216	251	286	327	368	408	444	474	508	537
2.6	78	105	132	159	186	222	258	294	335	376	416	450	479	511	537
2.7	79	108	136	164	192	229	265	301	342	383	423	455	483	513	537
2.8	79	110	139	168	197	234	271	308	349	389	430	459	485	514	537
2.9	79	111	141	171	201	239	276	314	354	395	435	462	488	514	537
3.0	79	112	143	174	205	243	281	319	359	399	439	465	489	515	537
3.1	79	112	145	177	208	247	285	323	363	403	442	467	490	515	537
3.2	79	112	146	178	211	250	288	327	366	406	445	469	491	515	537
3.3	79	112	146	180	213	252	291	329	369	408	447	470	492	515	537
3.4	79	112	146	180	214	253	292	331	370	409	448	471	492	515	537
3.5	79	112	146	181	215	254	294	333	372	411	449	471	492	515	537
3.6	79	112	146	181	215	255	294	334	373	411	450	471	492	515	538
3.7	79	112	146	181	215	255	295	334	373	412	450	472	493	515	538
3.8	79	112	146	181	216	256	295	335	373	412	450	472	493	515	538
3.9	79	112	146	181	216	256	295	335	374	412	450	472	493	515	538
4.0	79	112	146	181	216	256	295	335	374	412	450	472	493	515	538

Table 2-3. PMV by MSQ and Site Index for 30 m2 plot size.

	Site index														
MSQ	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1.0	32	44	62	77	92	113	133	152	182	211	239	274	309	346	382
1.1	36	49	68	85	100	123	144	166	197	228	259	296	333	371	407
1.2	39	53	74	92	109	133	156	179	212	245	278	317	356	394	431
1.3	42	57	80	99	117	143	168	191	227	262	296	336	376	415	454
1.4	46	62	86	106	125	152	179	204	241	277	313	354	394	435	474
1.5	49	66	92	113	133	162	190	216	255	292	329	370	411	452	492
1.6	52	70	98	120	141	171	200	228	268	306	344	385	425	466	507
1.7	56	75	103	127	149	180	211	239	280	319	358	398	438	479	519
1.8	59	79	109	133	157	189	220	250	292	332	371	410	448	489	527
1.9	62	83	114	139	164	197	230	260	303	343	383	420	458	496	533
2.0	66	87	119	145	171	205	239	270	313	353	393	429	465	503	536
2.1	69	91	124	151	177	213	247	279	322	363	403	437	471	507	537
2.2	72	95	128	156	183	220	255	288	331	371	411	444	477	510	538
2.3	75	99	132	161	189	226	262	295	338	378	418	450	481	512	538
2.4	77	102	136	165	194	232	268	302	345	385	424	454	484	513	538
2.5	78	105	139	169	199	237	274	309	351	390	430	458	486	514	538
2.6	78	107	141	172	202	241	279	314	356	395	434	461	488	514	538
2.7	78	109	143	175	206	245	283	319	360	399	438	464	489	515	538
2.8	78	111	145	177	208	248	286	323	363	402	441	466	490	515	538
2.9	78	111	145	179	211	250	289	326	366	405	443	467	491	515	538
3.0	78	112	146	180	212	252	291	328	368	407	445	469	492	515	538
3.1	78	112	146	180	213	253	292	330	370	408	447	469	492	515	538
3.2	78	112	146	181	214	254	293	332	371	410	448	470	492	515	538
3.3	78	112	146	181	214	255	294	333	372	411	448	471	492	515	538
3.4	78	112	146	181	215	255	295	334	373	411	449	471	492	515	538
3.5	78	112	146	181	215	255	295	334	373	412	449	471	492	515	538
3.6	78	112	146	181	215	256	295	334	373	412	450	472	492	515	538
3.7	78	112	146	181	215	256	295	334	373	412	450	472	492	515	538
3.8	78	112	146	181	215	256	295	335	374	412	450	472	492	515	538
3.9	78	112	146	181	215	256	295	335	374	412	450	472	492	515	538
4.0	78	112	146	181	215	256	295	335	374	412	450	472	492	515	538