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Accuracy of Check Modeling and Its Effect on Lumber Value Recovery

by

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Summary

The objective of this study was to quantify the uplift in the value of lumber recovered from MPB-killed trees that could be achieved using various methods of check modeling and improved log breakdown optimization.

Using true shape scanners and semi automated check detection, models of 45 sample logs were created and processed with OPTITEK®, Forintek's sawmill simulation program.

For a typical B.C. interior sawmill sawing lodgepole pine and mountain pine beetle (MPB)-killed logs, and using profile scanning at the edger and trimmer, the estimated loss was $46/m^3 of log volume. Additional check detection to profile scanning at these machines reduced the loss to $38/m^3.

The performance of primary log breakdown optimization systems coupled with emerging check detection machine vision technology, was compared with that of current true shape scanning technologies to estimate salvageable loss proportions. The machine vision system, using cameras to collect data on the extent of checking from the surface and both ends of the log, and using corrected regression equation to estimate check depth, was the most efficient. With check detection at edging and trimming the salvageable proportion was estimated as 35.7% of the total loss, this reduces to 28.1% without check detection.

For a sawmill processing a log volume of 900,000 m^3 annually, of which 25% are damaged by MPB, the use of the most efficient new or emerging machine vision systems, with and without check detection at edging and trimming, would result in annual gains of about 3.1 and 2.9 million dollars respectively.

The salvageable proportions from the other machine vision systems, inspecting only one log end; two log ends; and both ends and side of the log, were less pronounced. The salvageable proportions were within the range of 14.1 - 17% for sawmills with check detection at their edger and trimmer operations. The same percent range for sawmills without check detection down stream was in the range of 6.1 - 11.6%.

Acknowledgements

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1 Introduction

Sawmillers, system integrators and software developers have been trying to cope with the problems of MPB-killed wood to be processed in B.C.'s interior sawmills. Radial checking and blue stain are the two problems arising in lodgepole pine after attack by the mountain pine beetle. This project addresses the radial checking problem. The size, location and depth of the checks affect final lumber grade and volume recovery, and hence, the maximum value of lumber that can be recovered from any particular log. The rotation orientation of major checks in the log is crucial from a value recovery view point. Rotating the log to an orientation in which the check is at 12 o'clock or 3 o'clock can result in significant value recovery difference. Thus the intention of detecting checks in logs and using the check orientation information in log rotation optimization is understandable.

Automated machine vision systems to inspect logs entering the sawmill and to provide speedy information about the size, location and depth of the checks are under development. These machine vision systems use cameras in 3 major locations relative to the log. Two cameras inspect the leading and trailing log ends and the third camera (or group of cameras) inspects the log surface for checks. Unfortunately, the cameras inspecting the log surface cannot see the depth of radial checking. However, in the first phase of this study, (Orbay, 2006) regression equations estimating the check depth in MPB-attacked logs were developed. Digital check images, provided by cameras at different locations, combined with regression estimated check depth, lead to different check models. Forintek's sawing simulation program, OPTITEK®, was used to quantify how various check-modeling scenarios affect the efficiency of log breakdown optimization.

Is it enough to inspect only one end of the log? Or can we benefit from installing additional cameras inspecting the surface and the other end of the log? Can the use of regression equations, estimating radial check depth, enhance the performance of machine vision systems? Can check modeling, sawing optimization, and ultimately, product value recovery, benefit from the information provided by machine vision systems? The purpose of this study is to answer these questions. Sawmill simulation is used to investigate how the performance of an average B.C. interior sawmill responds to various machine vision systems using different check modeling methods.

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3 Objective

The objective of this study is to quantify the achievable uplift in the value of lumber recovered from MPB-killed trees using various methods of check modeling and improved log breakdown optimization.

4 Study Methods – Simulation with OPTITEK®

4.1 Logs

Forty-five MPB-killed sample logs with heavy checking were selected. Measurements of external log shape, check size and location were taken and processed to provide accurate representations of the surface and check profiles of the real logs for the simulation. Log surface profiles were created by scanning the logs with a true-shape laser scanner system located in Forintek's pilot plant. A custom interactive vision system obtained check trajectory and pith location, these were combined with manual measurements of check depth to provide check profiles. The true shape profile and internal check data were combined to build log models. Appendix 1 shows shape characteristics and check parameters of the resulting forty-five sample log models.

The method of log modeling was validated by Forintek's CT Scanning Facility. Five out of the 45 sample logs were CT scanned and cross-sectional images created. Cross-sectional images from log images created by the log modeling method were extracted, overlaid and compared to CT scanned cross-sectional images. Figure 1 shows an example of the comparison. The white points, generated by the log data collection method are laid over the corresponding CT image. All comparisons showed excellent log modeling accuracy and were deemed to be acceptable.

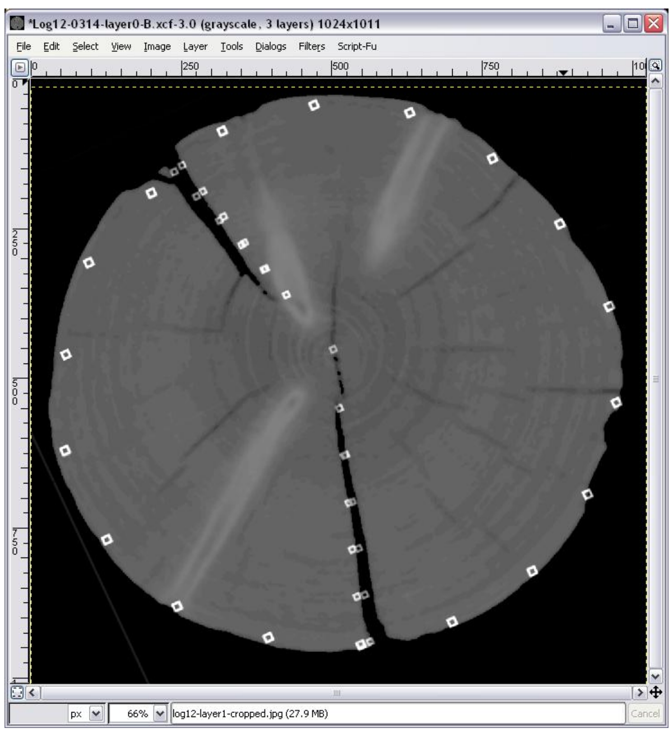


Figure 1 Comparing CT images and measured log data

Table 1 Four simulated machine vision systems

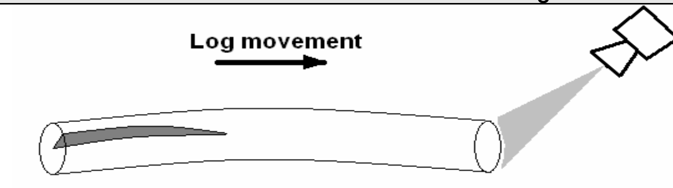
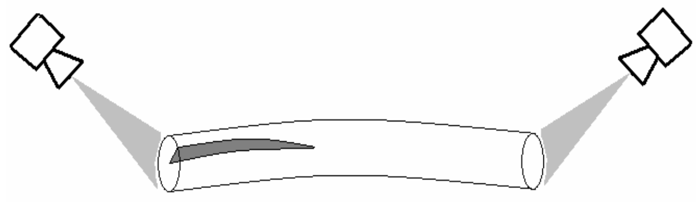
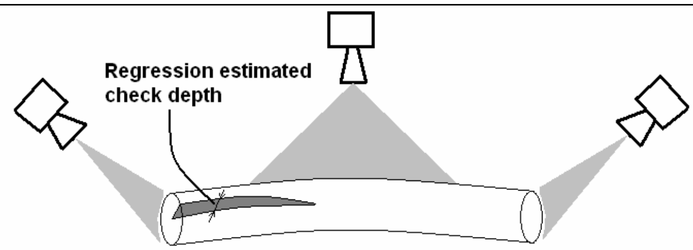
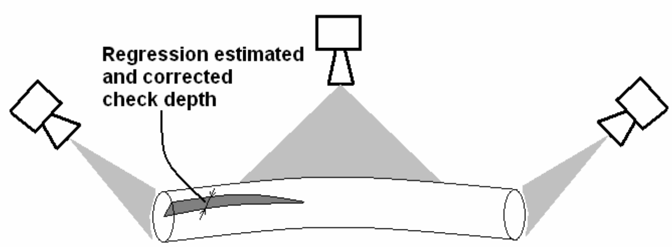
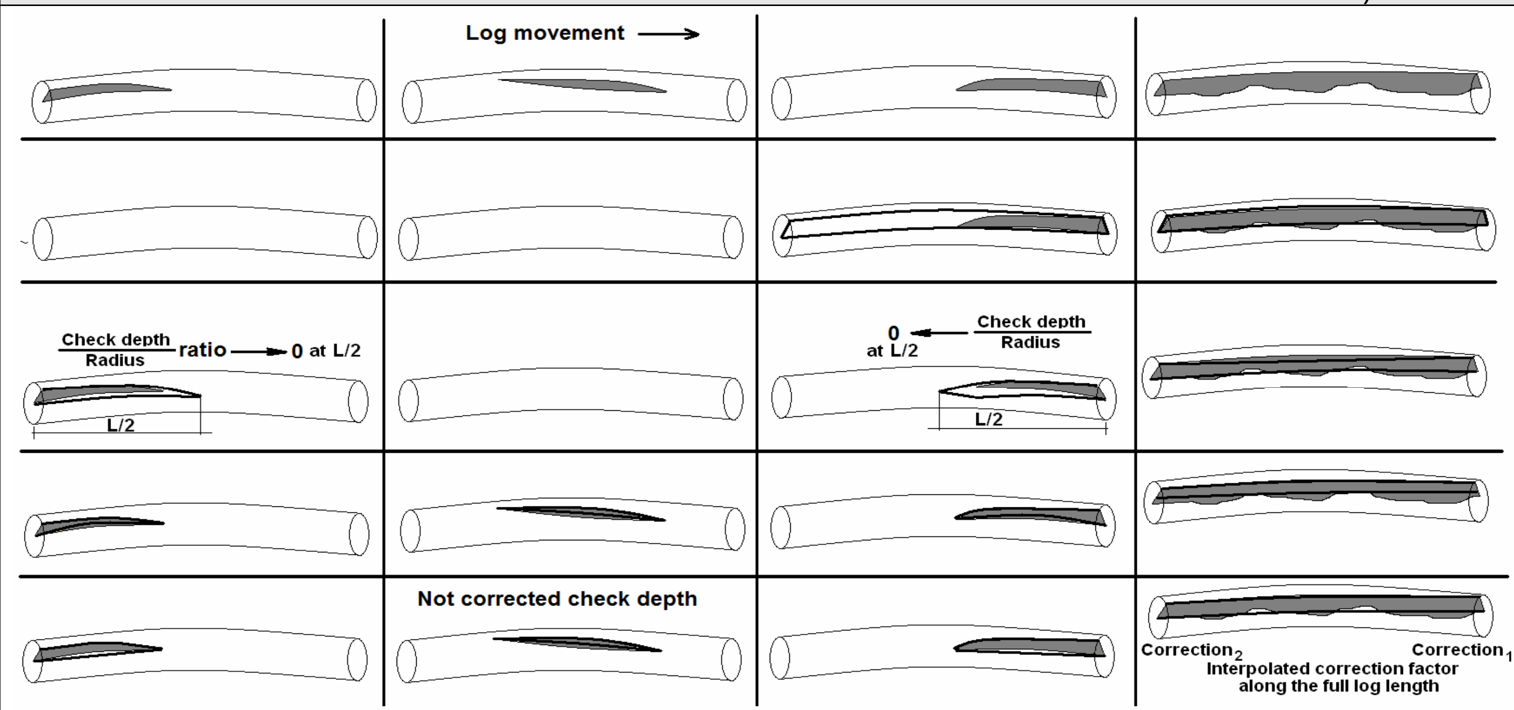
MVS description	MVS code	Camera locations relative to the log
MVS inspects only the leading log end	1E	
MVS inspects both log ends	2E	
MVS inspects both log ends and log surface. Check depth is estimated by a regression equation.	2ES	
MVS inspects both log ends and log surface. Check depth is estimated by a regression equation and corrected.	2ESC	

Table 2 graphically summarizes the log/check modeling methods of the study. The first row of the table shows the four possible check placements within the log. Rows 2 – 5 show how checks are modeled in accordance with combinations of MVS's and check placements. In all check models the discrepancy between actual and modeled check shape is shown by comparing shaded and thick contour line checks.

Check models in row 2 (MVS 1E) are built based on the information provided by only one camera. Checks visible by the camera are assumed to run full length through the log. The camera misses the check placement in cases 1 and 2 hence these log models do not contain checks.

Table 2 Log/check models

MVS code	Case 1: Check is at trailing end	Case 2: Check is at the middle (not visible on log ends)	Case 3: Check is at leading end	Case 4: Check runs through full log length (visible on both log ends)
Real log				
1E				
2E				
2ES				
2ESC				



Check models in row 3 are built based on the information provided by two cameras. If the MVS sees a matching number of checks at log ends then the checks are connected assuming constant spirality. Check depth changes along the length of the log is also assumed constant. If a check is visible by only one camera then the check is assumed to run half way along the length of the log.

Log/check models in rows 4 and 5 correspond to MVS with cameras detecting checks on both log ends and on the log surface. Check depths are estimated with the regression equation shown below, (Orbay, 2006).

$$\hat{d} = 3.02272 + 7.80801\, x_1 + 0.230782\, x_2 - 0.33893\, x_1^2 - 0.00242\, x_5^2$$

Where $\hat{d}$ - Check-depth, mm
x_1 - Check-width, mm
x_2 - Log diameter, cm
x_5 - Sapwood depth, mm.

The only difference between 2ES and 2ESC is that the latter applies a correction factor to the estimated check depth. The correction factors are calculated as the ratio of estimated and actual check depths detected at the end of the logs.

It should be noted that the methods of creating check models, summarized in Table 2, are subjective and other approaches could be examined. For example, what if we assume that a check visible at the leading end of the log gradually diminishes to the mid point as opposed to assuming it runs the total length with constant check depth?

The averages of all check parameters (Table 3) provide a comprehensive picture about the impact of different models on check parameters. The differences in the number of checks, check length, check depth and check spirality are considerable. Appendix 2 provides more detailed insight into how modeling affects check parameters by showing the image of a real log (sample log L01) with its two real checks and the corresponding 4 models of these real checks “seen” by MVS’s 1E, 2E, 2ES, and 2ESC. Pertinent check parameters are tabulated below each graph to show the impact of modeling on check characteristics.

Table 3 Averages of real and modeled check parameters of 45 sample logs

Parameters of	- - - - - Averages of - - - - -			
	Number of checks	Check length, (as % of log length)	Check depth (as % of radius)	Spirality (absolute values) (degr/m)
real checks	2.40	47.61	45.30	22.96
check models of MVS 1E	1.21	100.00	64.23	0.00
check models of MVS 2E	1.40	78.61	55.59	15.87
check models of MVS 2ES	2.40	47.84	25.21	23.17
check models of MVS 2ESC	2.40	47.84	45.14	23.17

4.2 Sawmill Specifications

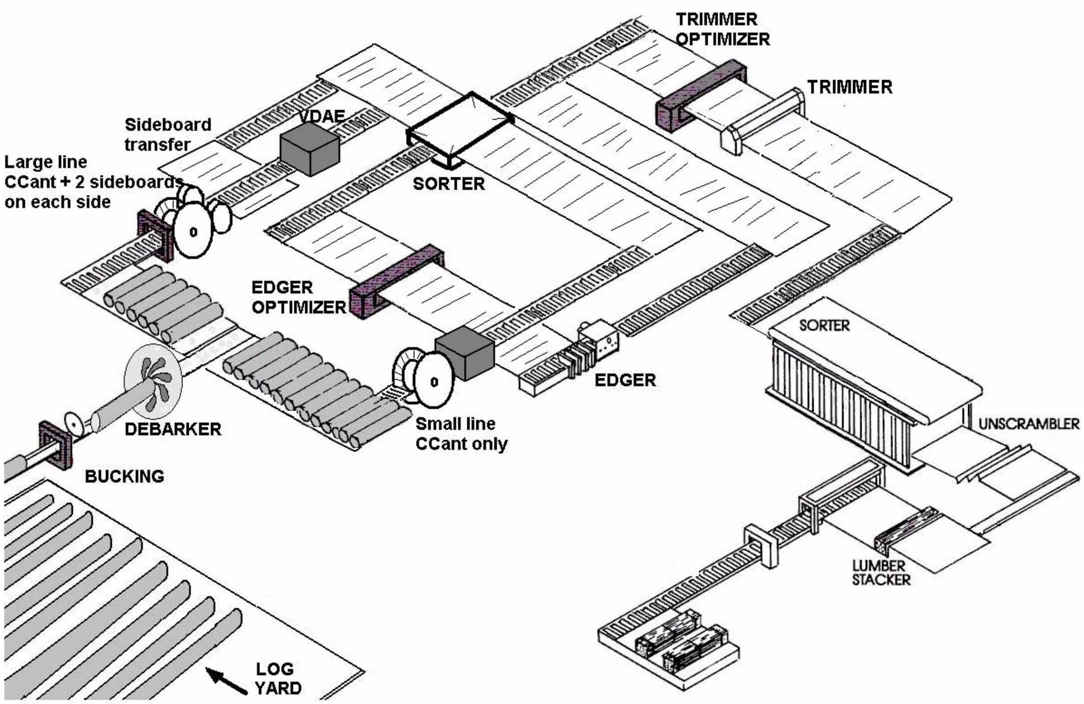


Figure 2 Sawmill layout

Ten sawmill configurations were modeled as a function of MVS's and if check detection is used in edger and trimmer optimization (Table 4). The first configuration, shown in Figure 2 and described here, is referred to as current technology since it mimics the operation of a sawmill currently representative of the industry in the B.C. interior. In the modeling of this current technology sawlogs were processed at two production lines; sawlogs with equal or larger than 9" small end diameter (SED) were sent to the large log line and smaller logs were sent to the small log line. Both of the log infeed systems were equipped with a true-shape scanner and an automatic log turner which rotated logs in horns-down orientation. The large log line utilized a three-sided canter and circular saws cutting a maximum of two sideboards on each side of the center cant. Depending on log size, the bottom chipping head profile-chipped a "2x3" or a "2x4" spline board. The small-log line was a 2-sided canter, coupled with a vertical double-arbor gang saw, producing lumber pieces from the center cant only.

Boards were sawn to final sizes by an optimized board edger and an optimized trimmer with moving fence. Optimum board positioning at the board edger was simulated by choosing from 5 possible split taper positions, in half-inch steps, within the offset range of minus one-inch to plus one-inch. Fence movement at the optimized trimmer was simulated by allowing movement in four-inch increments within a range of zero to 24 inches. Trimmed board lengths ranged from 8- to 20-feet.

Simulated improvements to this current technology were the addition of MVS's to detect checks at the primary breakdown machines and adding check detection systems to the downstream operation of edging and trimming. The other 9 mill configurations are characterized in Table 4 by the changes in configuration relative to current technology. Accordingly, the technologies whose performances were evaluated by OPTITEK® simulation are listed.

Table 4 Parameters of the10 simulated sawmill technologies

Technology code	Log scanner	Rotation optimization?	Scanner at Edger/Trimmer
CT_NoCD	TS	HD	Profile
CT_WCD	TS	HD	Profile+CD
1E_NoCD	TS+Camera_1End	Yes *	Profile
1E_WCD	TS+Camera_1End	Yes	Profile+CD
2E_NoCD	TS+Camera_2End	Yes	Profile
2E_WCD	TS+Camera_2End	Yes	Profile+CD
2ES_NoCD	TS+Camera_2End+Log Surface	Yes	Profile
2ES_WCD	TS+Camera_2End+Log Surface	Yes	Profile+CD
2ESC_NoCD	TS+Camera_2End+Log Surface	Yes	Profile
2ESC_WCD	TS+Camera_2End+Log Surface	Yes	Profile+CD

Legend:
CT - Current technology; TS – True shape; 1E – Camera at 1End of the log; 2E – Camera at 2Ends of the log; 2ES – Camera at 2Ends and Side of the log + Check depth estimation; 2ESC – Camera at 2Ends and Side of the log + Corrected check depth estimation; HD – Horns Down; CD – Check Detection; NoCD – No downstream check detection; WCD - With downstream check detection.
*** Note**: The simulation of rotation optimization evaluated log orientations by an increment of 10 degree. Thus a set of 36 orientations were evaluated for each log.

4.3 Products

The simulated sawmill was designed to produce dimension lumber for the North American market so the product mix included lumber with a nominal thickness of 2-inches and nominal widths of 3-, 4-, 6-, 8-, and 10-inches. Nominal targeted lengths ranged from 8- to 20-feet in increments of 2-feet. Table 5 shows the rough green target size for each of the nominal sizes. Two additional products were included in the product mix: an appearance grade, commonly referred to in the industry as "J-grade", and a strength grade known as MSR (machine-stress-rated).

Table 5 Nominal and rough green target sizes

	Lumber sizes (inches)		Lumber lengths	
	Nominal	Rough green target	Nominal (feet)	Rough green target (inches)
Thickness	2	1.67	8	97.25
Widths	3	3.00	10	121.45
	4	3.85	12	145.65
	6	5.80	14	169.85
	8	7.60	16	194.05
	10	9.75	18	218.25
			20	242.50

The grade rules for the dimension lumber included in the product mix are derived from those defined by the National Lumber Grades Authority (NLGA) and are shown in Table 6. The grade rules for the J-grade and MSR grades, also in Table 6, were determined through consultations with several sawmills that produce such products.

Table 6 Lumber grades used in sawing simulation

OPTI-TEK® Grade	Industry Grade	Max Wane (%)			Max. Shake				Max. Splits
		T	W	L	L	W	Thr	Edg	
1	J-grade	0	0	0	24”	1/32”	NP	NP	NP
2	MSR	25	25	100	24”	NL	NP	NP	Pc W
3	No.2&btr	33	33	100	36” or ¼ L 24”	NL NL	NP Yes	Yes NP	1.5 Pc W
4	No.3	50	50	100	1/3 L	NL	Yes	Yes	1/6 Pc L
5	Economy	50	75	100	80%	NL	Yes	Yes	1/3 Pc L

Notes: T=thickness; W=width; L=length; Thr=through; Edg=edge; NP=not permitted; NL=no limit; Pc = piece

Lumber prices per thousand board feet (Mfbm) along with corresponding piece values are listed by lumber size and grade in Appendix 3. The grading subroutine of OPTITEK® considers only the defects listed in Table 6, however, other defects such as knots are also important in setting the grade of a piece of lumber. It was thus necessary that piece values be calculated as weighted averages using grade outturns typical of those experienced by sawmills in the interior of B.C. A detailed description of the piece value calculation is provided in Appendix 4.

Chips and sawdust were considered to be saleable by-products and their value was included in all of the considered solutions. By-product prices of the simulation are shown in Table 7.

Table 7 By-product prices

By-product	$/Bone Dry Unit	$/Metric Tonne	$/dm^3 of Solid Wood
Chip	52.00	47.77	19.50
Sawdust	8.50	7.81	3.20

A basic wood density of 409 kg/m^3 was used to convert lodgepole pine fibre volume data to fibre weight.

When interpreting the simulation results it should be borne in mind that the input files of OPTITEK® mimic specific parameters of sawmilling. Thus the estimated value recoveries, losses caused by MPB and their salvageable proportions are driven by mill machinery, lumber prices and product size inputs (Appendix 3).

4.4 Simulation Approach

The simulation mimicked the sawing optimization and log breakdown of a real sawmill equipped with MVS. Both external log shapes and checks visible on log surface are scanned and true-shape log models, including imperfect check models, are created. Sawing optimization uses these models to make sawing decisions, however the actual sawing is executed on logs with "real" checks. These separate stages of primary log breakdown were simulated accordingly.

5 Results and Discussion

Eleven scenarios of the ten MVS technologies were simulated to provide estimated recoveries for a comparative analysis of system performances (Table 8 and Figure 3). The first three scenarios simulated healthy and damaged log breakdown of current technology with rotating logs to the horns-down orientation. The results of these three simulation runs provided information for calculating the $ losses due to the radial checking caused by the MPB. The additional eight scenarios simulated the breakdown of damaged logs when the breakdown optimization was assisted with emerging technologies of MVS's using various check models. The results of these eight simulation runs enabled us to analyse how much can be salvaged from the losses caused by MPB by using MVS-assisted break down optimization. Figure 3 also shows how losses and product value recovery uplifts achievable with MVS's were calculated.

Table 8 Average production values per log by sawmill technology type

Simulation scenario	Description of simulation scenario	Average product value recoveries, $/log
CT_NoCD_H	Current Technology_ No Down Stream Check Detection_Healthy log.	13.62
CT_NoCD_D	Current Technology_No Down Stream Check Detection_Damaged log.	6.98
CT_WCD_D	Current Technology_With Down Stream Check Detection_Damaged log.	8.16
1E_NoCD_D	MVS with camera at 1 end_No Down Stream Check Detection_Damaged log.	7.75
1E_WCD_D	MVS with camera at 1 end_With Down Stream Check Detection_Damaged log.	9.09
2E_NoCD_D	MVS with camera at 2 ends_No Down Stream Check Detection_Damaged log.	7.38
2E_WCD_D	MVS with camera at 2 ends_With Down Stream Check Detection_Damaged log.	8.95
2ES_NoCD_D	MVS with camera at 2 ends and surface_No Down Stream Check Detection_Damaged log.	7.44
2ES_WCD_D	MVS with camera at 2 ends and surface_With Down Stream Check Detection_Damaged log.	8.93
2ESC_NoCD_D	MVS with camera at 2 ends and surface, Corrected check depth estimation_No Down Stream Check Detection_Damaged log.	8.84
2ESC_WCD_D	MVS with camera at 2 ends and surface, Corrected check depth estimation_With Down Stream Check Detection_Damaged log.	10.11

Note: The recovery figures of this table are extracts from detailed OPTITEK® simulation results that are not included in this report. However, FORINTEK maintains all detailed OPTITEK® simulation results including lumber product mixes by sizes and grades, lumber value and volume recoveries and by-products and will provide these if requested.

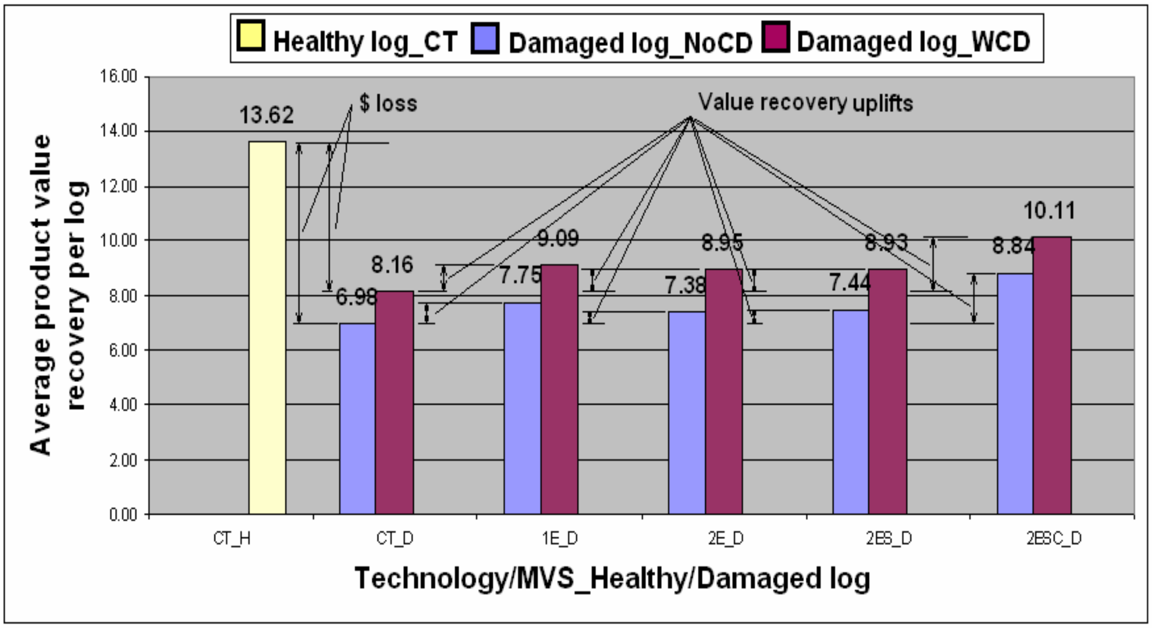


Figure 3 The impact of check modeling on product value recovery

For the cases of with and without check detection at edging and trimming, the average $ losses due to radial checking caused by the MPB on the average were $5.46 and $6.64 per log, 40.1% and 48.8 % of product value recoverable from healthy logs. The losses were statistically significant and calculated as the difference between product values recoverable from healthy and MPB-damaged logs. The 95% confidence intervals are (3.10, 7.83) and (4.33, 8.96) respectively, for these two cases.

For a sawmill processing 900,000 m^3 of logs per year the revenue losses are severe amounting to about 8.5 and 10.4 million$ annually for the cases with and without check detection at edging and trimming. These values are obtained by converting the $/log losses to $\$/m^3$ of log volume values of 37.99 and 46.22 for those two cases and that 25% of the logs have a MPB damage level similar to our sample.

Table 9 lists the product value recovery uplifts achievable by improved breakdown optimization, assisted with new machine vision technologies, relative to current value recovery levels. The 95% confidence intervals of the recovery uplift estimates are also included.

Table 9 Value recovery increments achievable by new MVS technologie.

Simulation scenarios of comparison	Average value recovery increments, $/log	Average value recovery increments as % of total loss	95% Confidence Interval of the Difference, $/log	
			Lower	Upper
(1E_NoCD_D) - (CT_NoCD_D)	0.77	11.6	-1.08	2.63
(1E_WCD_D) - (CT_WCD_D)	0.93	17.0	-1.09	2.94
(2E_NoCD_D) - (CT_NoCD_D)	0.40	6.1	-1.42	2.23
(2E_WCD_D) - (CT_WCD_D)	0.78	14.3	-1.26	2.82
(2ES_NoCD_D) - (CT_NoCD_D)	0.46	7.0	-1.41	2.33
(2ES_WCD_D) - (CT_WCD_D)	0.77	14.1	-1.27	2.81
(2ESC_NoCD_D) - (CT_NoCD_D)	1.87	28.1	-0.05	3.78
(2ESC_WCD_D) - (CT_WCD_D)	1.95	35.7	-0.14	4.04

Note: Detailed results of the statistical analysis are in Appendix 5.

It is important to note that the MVS's with cameras detecting the surface and both log ends, and with the corrected regression equation gave the best result (Table 9). Their statistically significant recovery uplifts were $1.95 and $1.87 per log, respectively, for the cases with and without check detection at edging and trimming. A remarkable proportion of the total loss, 35.7% and 28.1% can be saved with or without downstream check detection. The 95% confidence intervals are (-0.14, 4.04) and (-0.05, 3.78) $/log, respectively, for the same two cases. The uplifts of the other MVS's 1E, 2E and 2ES were less pronounced. The recovery gains are within the range of 14.1% to 17% for sawmills with check scanners at their down stream operation. The same range for sawmills that do not use check scanners at their edger and trimmer is in the range of 6.1% to 11.6%.

Assuming the same production parameters as before, i.e., a log volume of 900,000 m^3 processed annually and that 25% of the logs have a MPB damage level similar to our sample, and converting the two uplifts of $1.95 and $1.87 per log to gains of 13.56 and 12.94 $/lm^3 of volume, the statistically significant annual gains are about 2.9 and 3.1 million$.

Table 10 summarizes the losses and their salvageable proportions for sawmills processing log supplies with damage levels in the range of 5% to 35%.

Table 10 Annual losses* due to MPB-damage in a typical B.C. interior sawmill

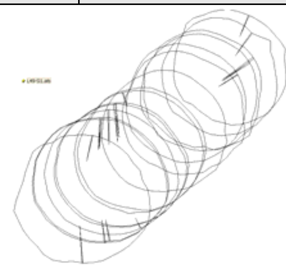
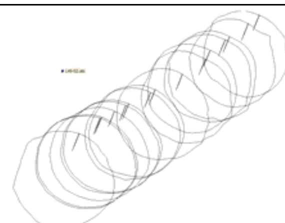
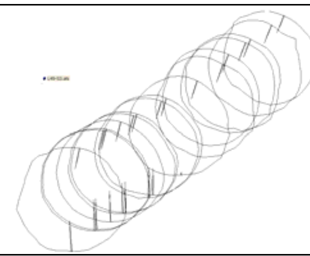
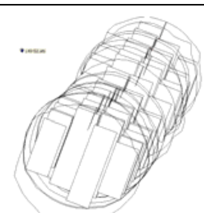
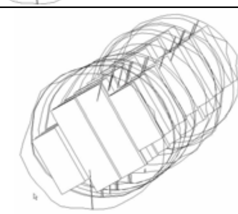
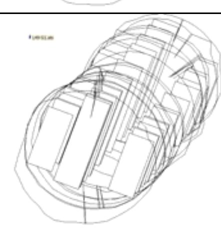
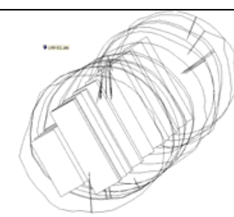
Proportion of MPB-damaged log volume (%)	Volume of MPB-killed wood processed annually (thousand-m³)	No check detection at edging and trimming		With check detection at edging and trimming	
		Annual $loss, (millions)	Salvageable $loss by the best MVS (millions)	Annual $loss (millions)	Salvageable $loss by the best MVS (millions)
5	45	2.1	0.6	1.7	0.6
10	90	4.2	1.2	3.4	1.2
15	135	6.2	1.8	5.1	1.8
20	180	8.3	2.3	6.8	2.4
25	225	10.4	2.9	8.5	3.1
30	270	12.5	3.5	10.3	3.7
35	315	14.6	4.1	12.0	4.3

*Note: Assuming identical check severity as was observed in the sample logs, Table 3.

Results of the simulation have also shown that check models of MVS's 2E, and 2ES were not as good as 1E though the difference between them is statistically insignificant (Table 3, Figure 3). This is somewhat surprising because one might think that more cameras can collect more information about checks, and models using this information should lead to better product recoveries, however, this is not always the case, and sometimes "better" check models lead to poorer sawing decisions and less product value recovery. The reason behind this is that check models derived from the information provided by cameras, inspecting both leading and trailing ends of the log, do not necessarily mimic real checks better than models derived from information provided by one camera. The efficiency of the check model also depends on the location and sizes of the actual checks.

As an example of this unexpected effect of check modeling on recovery, Table 11 shows the actual image of sample log L49 and the corresponding log/check models of MVS's 1E and 2E (first two rows of the Table 11). The third row shows the sawing solutions optimized by using the models and the 4th row the real log with lumber recovered by the sawing solutions of row 3. Comparing the product figures at the bottom of the table one can see that MVS 1E performed better by $3.19 per log. Fundamental differences between the 2 log models of row 2 are that MVS 1E created only one check model because it "sees" only the leading end of the log. Though MVS 2E can see both log ends it combined the two upper checks into one check and lengthened the lower check. Consequently the sawing decisions based on the two different models are different. In particular, different log rotations were chosen and the sawing patterns ended up in different orientation relative to the checks and log shell. The different sawing decisions resulted in different product value recoveries, $8.70 and $5.51 (Table 11). In the case of MVS 2E 2 pieces of lumber were produced, whereas MVS 1E produced 3 pieces.

Table 11 The impact of check modeling on product recovery, sample log L49

Description	1E	2E
Actual log with actual (measured) checks resulting from true-shape scanning and semi-automated check measurements.		
Log/check models		
Sawing solutions optimized based on log/check models		
Products recovered from actual log		
Lumber value, $	7.42	3.92
Chip value, $	1.27	1.58
Sawdust value, $	0.02	0.02
Total value, $	8.70	5.51

6 Conclusions

The estimated loss in a typical B.C. interior sawmill sawing green and MPB-killed lodgepole pine logs, and using profile scanning at the edger and trimmer, was $46/m^3 of log volume. Additional check detection to profile scanning at the edger and trimmer reduced the loss to $38/m^3.

Performance of primary log breakdown optimization systems, assisted with emerging machine vision, was compared with that of current technologies to estimate salvageable loss proportions. The machine vision system, using cameras to collect data on the extent of checking from the surface and both log ends of the log and using a corrected regression equation to estimate check depth, was the most efficient system. With check detection at edging and trimming the salvageable proportion was estimated as 35.7% of the total loss, this dropped to 28.1% without it.

For a sawmill processing a log volume of 900,000 m^3 annually, of which 25% are damaged by the MPB, the use of the most efficient emerging machine vision systems with and without check detection at edging and trimming, would result in annual gains of about 3.1 and 2.9 million $ respectively.

The salvageable proportions of the other machine vision systems, inspecting only one log end, two log ends, and both ends and side of the log, were less pronounced. The salvageable proportions were within the range of 14.1 - 17% for sawmills with check detection at their down stream operation. The same percent range for sawmills without check detection at their edger and trimmer was in the range of 6.1 - 11.6%.

7 Recommendations

The use of MVS to collect check data from both log ends and from the log surface, with corrected regression estimated check depth, is highly recommended.

Though the other MVS's have lessened the $loss caused by MPB, their efficiency is less pronounced. Their application in sawmills, intending to lessen recovery loss caused by the MPB, should be carefully investigated.

It is recommended that the other regression equation developed in the first phase of this project, which does not use check width as an independent variable, should be evaluated. Also, as recommended by the industry, the performance of MVS using log surface scanning alone, should be evaluated.

8 References

1. R.W. Nielson, J.Dobie, D.M. Wright: Conversion Factors for the Forest Products Industry in Western Canada. Special Publication No. SP-24R. 1985.
2. Forintek Canada Corp.: Optitek Manual, 2006.
3. L. Orbay: A Statistical Method of Determining Check Depth in MPB Affected Logs. Forestry Innovation Investment, 2006.

Appendix I

External Shape Characteristics and Check Parameters

Table A1-1: External shape characteristics of 45 sample logs

Log code	DSE	DLE	Sweep	Taper	Length	Volume
	(cm)	(cm)	(cm/m)	(cm/m)	(m)	(dm3)
L01	21.1	23.1	0.7	0.7	3.15	125.4
L02	24.3	27.0	1.1	0.8	3.19	164.7
L03	26.2	33.2	1.4	2.3	3.09	199.4
L04	22.7	25.1	1.6	0.8	3.10	144.1
L05	18.3	21.4	1.1	1.0	3.16	99.8
L06	12.7	16.4	0.5	1.0	3.83	64.9
L07	18.0	19.3	0.3	0.4	3.11	86.4
L08	31.6	34.7	0.6	1.0	3.11	261.8
L09	33.4	39.4	0.2	1.9	3.17	314.5
L10	20.0	25.0	0.7	1.3	3.94	161.6
L11	21.3	23.9	0.5	0.9	3.10	130.7
L12	23.4	26.5	0.4	1.0	3.16	164.0
L13	21.9	24.3	0.7	0.8	3.07	132.0
L14	13.1	18.1	0.8	1.3	3.70	74.2
L15	27.0	30.4	0.7	1.1	3.15	209.6
L16	28.5	30.8	0.8	0.7	3.16	234.6
L17	22.9	28.2	0.9	1.7	3.09	170.0
L18	16.1	18.0	0.5	0.6	3.13	72.6
L19	20.0	22.0	0.2	0.6	3.17	113.4
L20	18.1	21.9	0.6	1.2	3.16	101.0
L21	24.1	27.1	0.3	1.0	3.08	171.6
L22	23.4	25.7	0.2	0.8	2.95	143.9
L23	27.2	27.8	0.2	0.2	3.12	205.2
L24	24.7	26.6	0.3	0.6	3.11	169.6
L25	19.7	21.4	1.0	0.5	3.23	112.3
L26	16.9	21.0	0.5	1.2	3.29	99.0
L27	21.2	23.6	0.3	0.8	3.02	117.7
L28	26.6	28.3	0.3	0.6	3.04	179.3
L29	18.5	20.6	0.3	0.9	2.48	78.3
L30	32.2	34.8	0.5	0.8	3.08	267.7
L31	24.3	26.8	0.2	0.8	3.08	163.2
L32	18.7	22.4	0.8	1.4	2.58	88.4
L33	21.8	24.4	0.6	0.8	3.14	145.2
L34	27.8	29.3	0.5	0.5	3.08	220.0
L35	21.6	23.1	0.5	0.5	2.78	106.9
L36	26.8	28.7	0.3	0.6	3.13	186.1
L37	26.0	28.2	0.4	0.9	2.53	156.0
L38	20.6	23.1	0.6	0.9	2.94	115.9
L39	22.8	28.7	1.3	2.2	2.65	133.0
L40	16.7	18.4	0.7	0.5	3.78	100.1
L41	27.9	29.9	0.4	0.8	2.48	172.8
L47	12.5	15.5	0.4	1.2	2.48	38.6
L48	15.9	19.1	0.6	1.1	2.98	74.0
L49	18.8	21.5	0.2	0.8	3.45	114.8

Log code	DSE (cm)	DLE (cm)	Sweep (cm/m)	Taper (cm/m)	Length (m)	Volume (dm3)
L50	17.6	20.4	0.4	0.9	3.06	86.2
Average:	22.1	25.0	0.6	0.9	3.1	143.8
Min:	12.5	15.5	0.2	0.2	2.5	38.6
Max:	33.4	39.4	1.6	2.3	3.9	314.5

Table A1-2: Parameters of actual checks by sample log

Log code	Number of checks	- - - - - - - - Check - - - - - - - - -				Angular location (degr, CW)	Spirality (degr/m)
		Length (as % of log length)	Start (as % of log length)	Depth (as % of radius)	Depth(in)		
L01-S1	2	54.5	0.0	61.6	2.79	345.4	-39.7
		59.5	40.5	62.1	2.71	18.0	-34.7
L02-S1	2	100.0	0.0	62.2	3.15	344.5	-31.1
		50.2	0.0	46.5	2.43	198.7	-5.3
L03-S1	2	100.0	0.0	62.8	3.50	341.4	-17.5
		90.1	9.9	52.7	2.89	206.4	-14.2
L04-S1	1	77.8	0.0	62.2	3.05	205.8	-31.6
L05-S1	1	100.0	0.0	89.9	3.55	38.5	-33.2
L06-S1	2	48.9	46.9	57.3	1.56	96.1	2.8
		50.6	0.0	62.4	1.93	113.1	21.7
L07-S1	1	41.1	58.9	33.3	1.21	110.4	-3.8
L08-S1	5	69.3	0.0	34.5	2.27	163.6	4.0
		36.2	63.8	34.8	2.21	196.1	-1.6
		45.2	33.8	28.3	1.81	217.0	-5.3
		25.3	0.0	46.0	3.08	50.9	9.7
		79.3	20.7	39.2	2.52	29.7	4.7
L09-S1	4	76.2	0.0	21.9	1.57	117.4	24.0
		30.3	69.7	31.3	2.10	76.7	32.6
		55.7	5.0	21.2	1.51	202.9	6.8
		38.0	62.0	20.6	1.40	173.7	-7.2
L10-S1	2	56.6	0.0	60.5	2.85	306.1	-21.0
		37.7	35.0	42.7	1.93	178.9	-10.5
L11-S1	1	100.0	0.0	74.4	3.42	53.1	24.8
L12-S1	1	76.3	0.0	46.6	2.46	8.8	-33.3
L13-S1	2	59.4	0.0	39.3	1.87	345.9	4.4
		61.5	0.0	37.2	1.77	66.5	1.5
L14-S1	1	30.1	0.0	50.0	1.77	29.5	13.3
L15-S1	3	34.8	65.2	35.9	2.02	30.0	-2.8
		66.1	0.0	33.8	1.96	72.2	-0.7
		100.0	0.0	57.4	3.30	219.2	12.3
L16-S1	2	100.0	0.0	62.2	3.75	298.6	2.3
		48.1	0.0	49.0	2.98	65.7	-9.0
L17-S1	2	73.4	0.0	33.3	1.79	29.0	8.2
		100.0	0.0	56.9	2.97	117.3	7.3
L18-S1	5	6.3	0.0	35.7	1.24	77.0	15.2

Log code	Number of checks	- - - - - - - - Check - - - - - - - - -				Angular location (degr, CW)	Spirality (degr/m)
		Length (as % of log length)	Start (as % of log length)	Depth (as % of radius)	Depth(in)		
		30.0	19.3	33.6	1.15	71.2	-34.1
		24.5	0.0	53.3	1.87	136.3	-4.6
		13.1	55.0	24.9	0.85	28.5	-45.6
		19.7	80.3	55.2	1.79	25.4	-19.6
L19-S1	2	26.3	73.7	69.9	2.87	301.0	-18.2
		90.5	0.0	59.9	2.55	129.6	-20.5
L20-S1	2	24.9	0.0	45.8	1.93	199.8	-23.4
		84.7	15.3	50.8	2.03	192.7	12.2
L21-S1	4	24.6	8.3	5.7	0.32	52.7	13.8
		20.2	79.8	34.1	1.76	49.8	3.2
		8.3	0.0	20.4	1.13	137.9	41.1
		100.0	0.0	36.4	1.95	181.8	10.5
L22-S1	5	85.9	0.0	75.3	3.75	159.1	10.3
		11.3	23.1	17.5	0.88	201.2	-16.9
		51.6	0.0	79.7	4.00	3.0	21.8
		22.6	52.3	29.3	1.43	353.5	29.0
		47.7	52.3	62.1	2.99	57.5	17.3
L23-S1	1	100.0	0.0	68.5	3.95	44.6	6.3
L24-S1	2	76.2	0.0	56.3	2.96	243.7	6.4
		65.8	34.2	38.3	1.98	135.4	-2.8
L25-S1	3	45.0	0.0	52.8	2.26	55.9	21.8
		36.2	33.9	32.4	1.38	123.6	49.5
		15.2	84.8	36.8	1.49	165.0	74.9
L26-S1	2	17.3	0.0	52.1	2.15	211.8	-59.8
		4.5	95.5	55.4	1.94	94.9	45.1
L27-S1	3	14.1	0.0	32.1	1.51	67.0	24.5
		38.6	15.3	36.4	1.61	152.6	32.7
		53.7	46.3	64.2	2.81	142.5	39.0
L28-S1	5	15.2	0.0	31.7	1.74	346.1	-56.9
		33.5	12.4	35.2	1.93	19.3	-70.3
		56.0	44.0	49.3	2.64	68.3	-61.7
		21.1	43.4	19.9	1.07	146.4	-38.8
		40.0	0.0	34.1	1.88	184.8	-28.7
L29-S1	2	43.4	0.0	46.0	1.87	142.3	-20.2
		56.6	43.4	54.2	2.10	110.6	-5.6
L30-S1	3	33.0	3.3	33.7	2.17	12.6	-16.2
		75.3	24.7	57.2	3.64	6.1	0.4
		100.0	0.0	59.7	3.83	101.8	0.2
L31-S1	3	29.4	0.0	50.0	2.64	23.0	-46.0
		15.9	26.9	25.9	1.34	48.3	-14.0
		8.4	91.6	63.9	3.23	55.7	-100.5
L32-S1	1	90.5	0.0	66.9	2.74	161.2	25.7
L33-S1	1	87.3	12.7	64.9	3.07	101.2	2.8
L34-S1	3	48.6	0.0	56.3	3.38	167.1	13.3

Log code	Number of checks	- - - - - - - - Check - - - - - - - - - Length (as % of log length)	Start (as % of log length)	Depth (as % of radius)	Depth(in)	Angular location (degr, CW)	Spirality (degr/m)
		35.9	32.1	28.6	1.74	131.4	20.0
		50.1	49.9	58.1	3.40	193.1	2.4
L35-S1	5	23.9	0.0	17.4	0.79	73.4	3.6
		72.9	0.0	43.6	1.96	132.7	7.3
		39.4	40.3	38.3	1.70	119.3	-2.2
		27.8	72.2	47.4	2.09	97.0	-6.8
		17.6	82.4	37.6	1.66	116.8	-11.8
L36-S1	2	100.0	0.0	78.1	4.29	50.7	0.6
		19.3	0.0	50.5	2.84	142.6	8.1
L37-S1	3	47.3	3.8	44.5	2.49	60.7	22.0
		20.9	50.5	32.6	1.80	88.6	28.7
		32.1	67.9	37.3	2.00	117.3	32.4
L38-S1	3	20.6	0.0	36.5	1.67	14.2	-63.2
		31.2	20.6	20.4	0.90	13.5	-23.0
		100.0	0.0	57.6	2.52	112.2	-27.6
L39-S1	2	7.5	0.0	6.6	0.38	212.0	-2.9
		58.4	19.0	15.2	0.75	125.8	-7.5
L40-S1	1	60.1	11.2	51.3	1.89	92.6	-13.2
L41-S1	2	39.0	29.7	36.7	2.15	137.1	-43.8
		11.0	0.0	43.0	2.59	164.3	1.5
L47-S1	1	6.6	39.3	53.7	1.50	35.2	117.9
L48-S1	4	27.3	10.1	63.9	2.35	28.4	24.4
		21.1	53.0	60.2	2.11	76.2	67.9
		6.3	80.8	44.5	1.50	67.0	32.2
		19.0	0.0	40.8	1.51	188.7	119.8
L49-S1	3	37.5	0.0	46.7	1.99	103.4	23.6
		19.4	0.0	35.8	1.54	266.7	35.6
		28.8	71.2	49.5	1.91	147.1	34.5
L50-S1	1	100.0	0.0	70.8	2.66	98.4	-13.3
Average:	2.40	47.61		45.30			22.96

Table A1-3: Parameters of modeled checks by sample logs – MVS 1E

Log code	Number of checks	- - - - - - - - Check - - - - - - - - -				Angular location (degr, CW)	Spirality (degr/m)
		Length (as % of log length)	Start (as % of log length)	Depth (as % of radius)	Depth (in)		
L01-S2	1	100	0	98.6	4.39	83.0	0
L02-S2	1	100	0	74.0	3.76	83.7	0
L03-S2	2	100	0	63.4	3.56	35.3	0
		100	0	75.3	4.25	245.9	0
L05-S2	1	100	0	94.4	3.72	143.4	0
L07-S2	1	100	0	48.8	1.81	115.3	0
L08-S2	2	100	0	66.5	4.32	197.9	0
		100	0	7.9	0.51	18.2	0
L09-S2	2	100	0	70.7	4.99	45.3	0
		100	0	11.4	0.81	182.4	0
L11-S2	1	100	0	61.4	2.82	336.3	0
L15-S2	2	100	0	66.3	3.80	33.1	0
		100	0	59.5	3.41	180.3	0
L16-S2	1	100	0	81.0	4.89	291.4	0
L17-S2	1	100	0	84.1	4.42	94.7	0
L18-S2	1	100	0	46.8	1.59	37.5	0
L19-S2	1	100	0	91.1	3.84	316.1	0
L20-S2	1	100	0	48.7	1.98	160.1	0
L21-S2	2	100	0	50.8	2.72	47.8	0
		100	0	28.6	1.53	149.4	0
L22-S2	1	100	0	79.5	3.92	33.2	0
L23-S2	1	100	0	66.5	3.83	24.9	0
L24-S2	1	100	0	83.9	4.38	141.3	0
L25-S2	1	100	0	39.9	1.67	128.1	0
L26-S2	1	100	0	82.1	3.14	88.2	0
L27-S2	1	100	0	73.4	3.28	79.2	0
L28-S2	1	100	0	77.2	4.19	173.4	0
L29-S2	1	100	0	57.2	2.27	118.4	0
L30-S2	2	100	0	63.5	4.09	5.3	0
		100	0	66.1	4.25	101.3	0
L31-S2	1	100	0	60.7	3.14	81.8	0
L33-S2	1	100	0	75.9	3.62	93.4	0
L34-S2	1	100	0	74.6	4.45	189.4	0
L35-S2	2	100	0	77.9	3.47	102.2	0
		100	0	51.7	2.31	122.5	0
L36-S2	1	100	0	83.8	4.61	48.9	0
L37-S2	1	100	0	76.6	4.23	91.0	0
L38-S2	1	100	0	46.7	2.05	193.4	0
L49-S2	1	100	0	38.1	1.55	112.7	0
L50-S2	1	100	0	64.6	2.42	138.9	0
Average:	1.21	100		64.23			0

Table A1-4: Parameters of modeled checks by sample logs – MVS 2E

Log code	Number of checks	- - - - - - - - Check - - - - - - - - -				Angular location (degr, CW)	Spirality (degr/m)
		Length (as % of log length)	Start (as % of log length)	Depth (as % of radius)	Depth (in)		
L01-S3	1	100.0	0.0	77.7	3.45	345.4	-31.0
L02-S3	2	100.0	0.0	82.0	4.17	198.7	36.1
		50.2	0.0	55.7	2.91	344.5	36.1
L03-S3	2	100.0	0.0	57.1	3.18	341.4	30.9
		50.7	49.3	57.1	3.06	83.7	30.9
L04-S3	1	54.9	0.0	53.1	2.62	205.8	0.0
L05-S3	1	100.0	0.0	100.3	3.96	38.5	-33.2
L06-S3	1	50.6	0.0	63.8	1.98	113.1	0.0
L07-S3	1	55.9	44.2	41.4	1.51	115.3	0.0
L08-S3	2	100.0	0.0	30.7	2.01	50.9	10.5
		100.0	0.0	60.2	3.91	163.6	-11.0
L09-S3	2	100.0	0.0	13.1	0.92	117.4	-20.5
		49.6	50.4	62.7	4.26	13.0	-20.5
L10-S3	1	50.4	0.0	45.1	2.13	306.1	0.0
L11-S3	1	100.0	0.0	64.9	2.99	53.1	24.8
L12-S3	1	54.4	0.0	53.2	2.83	8.8	0.0
L13-S3	2	44.6	0.0	38.4	1.83	66.5	0.0
		44.6	0.0	45.3	2.16	345.9	0.0
L14-S3	1	49.4	0.0	59.7	2.09	29.5	0.0
L15-S3	2	100.0	0.0	59.4	3.40	72.2	12.4
		100.0	0.0	58.5	3.35	219.2	12.3
L16-S3	2	100.0	0.0	84.9	5.12	65.7	42.4
		50.6	0.0	58.1	3.53	298.6	42.4
L17-S3	2	100.0	0.0	49.7	2.57	29.0	-21.3
		51.8	0.0	55.2	3.00	117.3	-21.3
L18-S3	2	100.0	0.0	52.2	1.78	77.0	12.6
		49.3	0.0	61.6	2.14	136.3	12.6
L19-S3	1	100.0	0.0	92.0	3.87	129.6	54.8
L20-S3	1	100.0	0.0	55.2	2.25	199.8	12.6
L21-S3	2	100.0	0.0	43.1	2.30	137.9	29.3
		100.0	0.0	21.0	1.12	181.8	10.5
L22-S3	2	100.0	0.0	80.1	3.95	3.0	-10.2
		51.6	0.0	73.1	3.68	159.1	-10.2
L23-S3	1	100.0	0.0	70.0	4.03	44.6	6.3
L24-S3	1	100.0	0.0	82.0	4.28	243.7	32.9
L25-S3	1	100.0	0.0	50.9	2.14	55.9	-22.3
L26-S3	1	100.0	0.0	71.2	2.71	211.7	37.5
L27-S3	1	100.0	0.0	52.2	2.32	67.0	-4.0
L28-S3	2	100.0	0.0	54.5	2.95	184.8	3.7
		45.9	0.0	39.8	2.19	346.1	3.7
L29-S3	1	100.0	0.0	60.3	2.39	142.3	9.6
L30-S3	2	100.0	0.0	50.1	3.21	101.8	0.2

Log code	Number of checks	- - - - - - - - Check - - - - - - - - - Length (as % of log length)	Start (as % of log length)	Depth (as % of radius)	Depth (in)	Angular location (degr, CW)	Spirality (degr/m)
		53.1	47.0	50.4	3.21	5.6	0.2
L31-S3	1	100.0	0.0	49.8	2.57	23.0	-19.1
L32-S3	1	51.0	0.0	34.3	1.46	161.2	0.0
L33-S3	1	49.6	50.4	63.7	2.97	93.4	0.0
L34-S3	1	100.0	0.0	72.7	4.33	167.1	-7.2
L35-S3	2	100.0	0.0	63.8	2.84	73.4	-10.4
		100.0	0.0	43.3	1.93	132.7	3.7
L36-S3	2	100.0	0.0	74.0	4.06	142.6	30.0
		43.9	0.0	85.5	4.77	50.8	30.0
L37-S3	1	49.6	50.5	59.5	3.24	91.0	0.0
L38-S3	2	100.0	0.0	57.7	2.53	14.2	-61.0
		51.8	0.0	12.9	0.58	112.2	-61.0
L39-S3	1	51.7	0.0	7.6	0.41	212.0	0.0
L41-S3	1	55.2	0.0	43.4	2.59	164.3	0.0
L48-S3	1	53.0	0.0	17.1	0.63	188.7	0.0
L49-S3	2	100.0	0.0	38.7	1.58	103.4	-2.7
		53.0	0.0	52.5	2.22	266.7	-2.7
L50-S3	1	100.0	0.0	72.0	2.70	98.4	-13.3
Average:	1.40	78.61		55.59			15.87

Table A1-5: Parameters of modeled checks by sample logs – MVS 2ES

Log code	Number of checks	- - - - - - - - Check - - - - - - - - - Length (as % of log length)	Start (as % of log length)	Depth (as % of radius)	Depth (in)	Angular location (degr, CW)	Spirality (degr/m)
L01-S4	2	54.5	0.0	23.7	1.08	345.4	-39.7
		59.5	40.5	26.0	1.12	18.0	-34.7
L02-S4	2	100.0	0.0	31.5	1.59	344.5	-31.1
		50.2	0.0	21.5	1.12	198.7	-5.3
L03-S4	2	100.0	0.0	30.7	1.73	341.4	-17.5
		90.1	9.9	16.8	0.91	206.5	-14.2
L04-S4	1	77.8	0.0	23.9	1.18	205.8	-31.6
L05-S4	1	100.0	0.0	43.1	1.70	38.5	-33.2
L06-S4	2	48.9	46.9	36.0	0.99	96.1	2.8
		50.6	0.0	35.8	1.11	113.1	21.7
L07-S4	1	41.1	58.9	29.3	1.07	110.4	-3.8
L08-S4	5	69.3	0.0	16.1	1.06	163.6	4.0
		36.2	63.8	19.3	1.22	196.1	-1.6
		45.2	33.8	9.7	0.62	217.0	-5.3
		25.3	0.0	21.7	1.45	50.9	9.7
		79.3	20.7	15.3	0.99	29.7	4.7
L09-S4	4	76.2	0.0	12.4	0.89	117.4	24.0

Log code	Number of checks	- - - - - - - - Check - - - - - - - - -				Angular location (degr, CW)	Spirality (degr/m)
		Length (as % of log length)	Start (as % of log length)	Depth (as % of radius)	Depth (in)		
		30.3	69.7	19.5	1.31	76.7	32.6
		55.7	5.0	11.8	0.85	202.9	6.8
		38.0	62.0	10.1	0.69	173.7	-7.2
L10-S4	2	56.6	0.0	26.3	1.26	306.1	-21.0
		37.7	35.0	16.1	0.73	178.9	-10.5
L11-S4	1	100.0	0.0	35.1	1.61	53.1	24.8
L12-S4	1	76.3	0.0	27.9	1.46	8.8	-33.3
L13-S4	2	59.4	0.0	9.5	0.45	345.9	4.4
		61.5	0.0	14.6	0.69	66.5	1.5
L14-S4	1	30.1	0.0	32.4	1.16	29.5	13.3
L15-S4	3	34.8	65.2	16.8	0.93	30.0	-2.8
		66.1	0.0	13.2	0.77	72.2	-0.7
		100.0	0.0	24.6	1.41	219.2	12.3
L16-S4	2	100.0	0.0	25.3	1.52	298.6	2.3
		48.1	0.0	23.9	1.46	65.7	-9.0
L17-S4	2	73.4	0.0	10.8	0.58	29.0	8.2
		100.0	0.0	31.1	1.63	117.3	7.3
L18-S4	5	6.3	0.0	34.0	1.19	77.0	15.2
		30.0	19.3	20.2	0.69	71.2	-34.1
		24.5	0.0	32.5	1.14	136.3	-4.6
		13.1	55.0	13.2	0.45	28.5	-45.6
		19.7	80.3	29.5	0.96	25.4	-19.6
L19-S4	2	26.3	73.7	44.8	1.83	301.0	-18.1
		90.5	0.0	31.6	1.35	129.6	-20.5
L20-S4	2	24.9	0.0	20.5	0.87	199.8	-23.4
		84.7	15.3	20.3	0.80	192.7	12.2
L21-S4	4	24.6	8.3	12.5	0.69	52.7	13.8
		20.2	79.8	26.9	1.38	49.8	3.2
		8.3	0.0	25.3	1.40	137.9	41.1
		100.0	0.0	22.0	1.18	181.8	10.5
L22-S4	5	85.9	0.0	38.1	1.89	159.1	10.3
		11.3	23.1	11.6	0.59	201.2	-16.9
		51.6	0.0	20.8	1.05	3.0	21.8
		22.6	52.3	22.1	1.08	353.5	29.0
		47.7	52.3	40.0	1.92	57.5	17.3
L23-S4	1	100.0	0.0	28.8	1.66	44.6	6.3
L24-S4	2	76.2	0.0	32.3	1.70	243.7	6.4
		65.8	34.2	33.7	1.74	135.4	-2.8
L25-S4	3	45.0	0.0	35.3	1.51	55.9	21.8
		36.2	33.9	18.0	0.77	123.6	49.5
		15.2	84.8	26.9	1.09	165.0	74.9
L26-S4	2	17.3	0.0	35.4	1.45	211.8	-59.8
		4.5	95.5	42.0	1.45	94.9	45.2
L27-S4	3	14.1	0.0	19.9	0.94	67.0	24.5

Log code	Number of checks	- - - - - - - - Check - - - - - - - - -				Angular location (degr, CW)	Spirality (degr/m)
		Length (as % of log length)	Start (as % of log length)	Depth (as % of radius)	Depth (in)		
		38.6	15.3	19.7	0.87	152.6	32.7
		53.7	46.3	37.6	1.64	142.5	39.0
L28-S4	5	15.2	0.0	20.9	1.15	346.1	-56.9
		33.5	12.4	21.2	1.16	19.3	-70.3
		56.0	44.0	28.5	1.52	68.3	-61.7
		21.1	43.4	13.6	0.73	146.4	-38.8
		40.0	0.0	21.2	1.17	184.8	-28.7
L29-S4	2	43.4	0.0	33.4	1.37	142.3	-20.2
		56.6	43.4	41.9	1.63	110.6	-5.6
L30-S4	3	33.0	3.3	14.4	0.92	12.6	-16.2
		75.3	24.7	25.6	1.63	6.1	0.4
		100.0	0.0	30.0	1.93	101.8	0.2
L31-S4	3	29.4	0.0	28.1	1.48	23.0	-46.0
		15.9	26.9	16.0	0.83	48.3	-14.0
		8.4	91.6	37.1	1.88	55.7	-100.5
L32-S4	1	90.5	0.0	34.3	1.41	161.2	25.7
L33-S4	1	87.3	12.7	42.5	2.01	101.2	2.8
L34-S4	3	48.6	0.0	28.6	1.72	167.1	13.3
		35.9	32.1	21.2	1.28	131.3	20.0
		50.1	49.9	31.0	1.82	193.1	2.4
L35-S4	5	23.9	0.0	21.5	0.98	73.4	3.6
		72.9	0.0	37.3	1.67	132.7	7.3
		39.4	40.3	31.1	1.38	119.3	-2.2
		27.8	72.2	36.2	1.59	97.0	-6.8
		17.6	82.4	34.8	1.54	116.8	-11.8
L36-S4	2	100.0	0.0	31.4	1.73	50.7	0.6
		19.3	0.0	34.6	1.95	142.6	8.1
L37-S4	3	47.3	3.8	9.4	0.52	60.7	22.0
		20.9	50.5	8.7	0.48	88.6	28.7
		32.1	67.9	22.2	1.17	117.3	32.4
L38-S4	3	20.6	0.0	36.7	1.68	14.2	-63.2
		31.2	20.6	15.1	0.66	13.5	-23.0
		100.0	0.0	32.3	1.41	112.2	-27.6
L39-S4	2	7.5	0.0	8.8	0.50	212.0	-2.9
		58.4	19.0	23.6	1.19	125.8	-7.5
L40-S4	1	60.1	11.2	25.5	0.94	92.6	-13.2
L41-S4	2	39.0	29.7	12.7	0.75	137.1	-43.8
		11.0	0.0	24.6	1.47	164.3	1.5
L47-S4	1	6.6	39.3	15.9	0.44	35.2	117.9
L48-S4	4	27.3	10.1	18.5	0.68	28.4	24.4
		21.1	53.0	31.1	1.09	76.2	67.9
		6.3	80.8	17.8	0.60	67.0	32.2
		19.0	0.0	16.5	0.61	188.7	119.8
L49-S4	3	37.5	0.0	24.9	1.06	103.4	23.6

Log code	Number of checks	- - - - - - - - Check - - - - - - - - - Length (as % of log length)	Start (as % of log length)	Depth (as % of radius)	Depth (in)	Angular location (degr, CW)	Spirality (degr/m)
		19.4	0.0	24.9	1.08	266.7	35.6
		28.8	71.2	25.9	1.00	147.1	34.5
L50-S4	1	100.0	0.0	53.5	2.01	98.4	-13.3
Average:	2.40	47.84		25.21			23.17

Table A1-6: Parameters of modeled checks by sample logs – MVS 2ESC

Log code	Number of checks	- - - - - - - - Check - - - - - - - - - Length (as % of log length)	Start (as % of log length)	Depth (as % of radius)	Depth (in)	Angular location (degr, CW)	Spirality (degr/m)
L01-S5	2	54.5	0.0	71.5	3.24	345.4	-39.7
		59.5	40.5	72.0	3.15	18.0	-34.7
L02-S5	2	100.0	0.0	62.2	3.16	344.5	-31.1
		50.2	0.0	55.5	2.89	198.7	-5.3
L03-S5	2	100.0	0.0	60.6	3.39	341.4	-17.5
		90.1	9.9	93.7	5.18	206.5	-14.2
L04-S5	1	77.8	0.0	63.1	3.08	205.8	-31.6
L05-S5	1	100.0	0.0	86.0	3.39	38.5	-33.2
L06-S5	2	48.9	46.9	37.0	1.02	96.1	2.8
		50.6	0.0	68.9	2.13	113.1	21.7
L07-S5	1	41.1	58.9	43.8	1.59	110.4	-3.8
L08-S5	5	69.3	0.0	36.0	2.37	163.6	4.0
		36.2	63.8	48.5	3.08	196.1	-1.6
		45.2	33.8	9.9	0.63	217.0	-5.3
		25.3	0.0	75.5	5.04	50.9	9.7
		79.3	20.7	18.7	1.20	29.7	4.7
L09-S5	4	76.2	0.0	13.6	0.97	117.4	24.0
		30.3	69.7	33.8	2.28	76.7	32.6
		55.7	5.0	11.1	0.80	202.9	6.8
		38.0	62.0	7.2	0.49	173.7	-7.2
L10-S5	2	56.6	0.0	35.5	1.69	306.1	-21.0
		37.7	35.0	14.8	0.67	178.9	-10.5
L11-S5	1	100.0	0.0	56.8	2.61	53.1	24.8
L12-S5	1	76.3	0.0	48.9	2.57	8.8	-33.3
L13-S5	2	59.4	0.0	19.3	0.92	345.9	4.4
		61.5	0.0	28.1	1.34	66.5	1.5
L14-S5	1	30.1	0.0	47.8	1.70	29.5	13.3
L15-S5	3	34.8	65.2	34.6	1.94	30.0	-2.8
		66.1	0.0	57.5	3.33	72.2	-0.7
		100.0	0.0	76.5	4.39	219.2	12.3
L16-S5	2	100.0	0.0	66.1	3.98	298.6	2.3
		48.1	0.0	74.9	4.55	65.7	-9.0

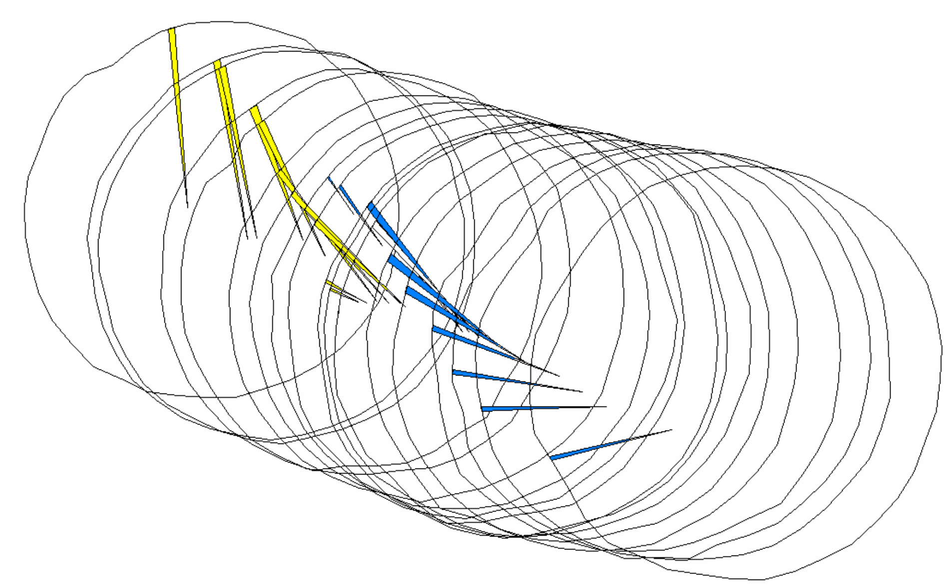
Log code	Number of checks	- - - - - - - - Check - - - - - - - - -				Angular location (degr, CW)	Spirality (degr/m)
		Length (as % of log length)	Start (as % of log length)	Depth (as % of radius)	Depth (in)		
L17-S5	2	73.4	0.0	22.8	1.22	29.0	8.2
		100.0	0.0	86.8	4.56	117.3	7.3
L18-S5	5	6.3	0.0	46.3	1.62	77.0	15.2
		30.0	19.3	20.2	0.69	71.2	-34.1
		24.5	0.0	63.7	2.23	136.3	-4.6
		13.1	55.0	13.4	0.45	28.5	-45.6
		19.7	80.3	40.3	1.31	25.4	-19.6
L19-S5	2	26.3	73.7	83.1	3.41	301.0	-18.1
		90.5	0.0	85.9	3.64	129.6	-20.5
L20-S5	2	24.9	0.0	66.2	2.78	199.8	-23.4
		84.7	15.3	36.3	1.44	192.7	12.2
L21-S5	4	24.6	8.3	11.8	0.65	52.7	13.8
		20.2	79.8	43.9	2.27	49.8	3.2
		8.3	0.0	31.9	1.77	137.9	41.1
		100.0	0.0	33.3	1.78	181.8	10.5
L22-S5	5	85.9	0.0	100.2	4.97	159.1	10.3
		11.3	23.1	11.6	0.59	201.2	-16.9
		51.6	0.0	43.6	2.19	3.0	21.8
		22.6	52.3	21.7	1.06	353.5	29.0
		47.7	52.3	68.7	3.31	57.5	17.3
L23-S5	1	100.0	0.0	61.1	3.52	44.6	6.3
L24-S5	2	76.2	0.0	60.0	3.15	243.7	6.4
		65.8	34.2	66.4	3.44	135.4	-2.8
L25-S5	3	45.0	0.0	59.5	2.55	55.9	21.8
		36.2	33.9	17.4	0.74	123.6	49.5
		15.2	84.8	27.8	1.13	165.0	74.9
L26-S5	2	17.3	0.0	55.3	2.28	211.8	-59.8
		4.5	95.5	85.0	3.02	94.9	45.1
L27-S5	3	14.1	0.0	32.6	1.53	67.0	24.5
		38.6	15.3	19.9	0.88	152.6	32.7
		53.7	46.3	65.8	2.88	142.5	39.0
L28-S5	5	15.2	0.0	37.7	2.08	346.1	-56.9
		33.5	12.4	20.8	1.14	19.3	-70.3
		56.0	44.0	57.3	3.07	68.3	-61.7
		21.1	43.4	13.8	0.74	146.4	-38.8
		40.0	0.0	36.7	2.03	184.8	-28.7
L29-S5	2	43.4	0.0	68.4	2.77	142.3	-20.2
		56.6	43.4	53.0	2.05	110.6	-5.6
L30-S5	3	33.0	3.3	15.8	1.02	12.6	-16.2
		75.3	24.7	46.8	2.98	6.1	0.4
		100.0	0.0	58.7	3.76	101.8	0.2
L31-S5	3	29.4	0.0	76.8	4.05	23.0	-46.0
		15.9	26.9	16.1	0.84	48.3	-14.0
		8.4	91.6	58.9	2.98	55.7	-100.5

Log code	Number of checks	- - - - - - - - Check - - - - - - - - -				Angular location (degr, CW)	Spirality (degr/m)
		Length (as % of log length)	Start (as % of log length)	Depth (as % of radius)	Depth (in)		
L32-S5	1	90.5	0.0	37.4	1.54	161.2	25.7
L33-S5	1	87.3	12.7	82.9	3.93	101.2	2.8
L34-S5	3	48.6	0.0	61.4	3.69	167.1	13.3
		35.9	32.1	21.3	1.29	131.3	20.0
		50.1	49.9	64.9	3.82	193.1	2.4
L35-S5	5	23.9	0.0	44.0	2.00	73.4	3.6
		72.9	0.0	34.1	1.53	132.7	7.3
		39.4	40.3	30.7	1.36	119.3	-2.2
		27.8	72.2	65.9	2.90	97.0	-6.8
		17.6	82.4	43.4	1.92	116.8	-11.8
L36-S5	2	100.0	0.0	81.6	4.48	50.7	0.6
		19.3	0.0	72.6	4.08	142.6	8.1
L37-S5	3	47.3	3.8	8.5	0.47	60.7	22.0
		20.9	50.5	9.0	0.50	88.6	28.7
		32.1	67.9	54.2	2.92	117.3	32.4
L38-S5	3	20.6	0.0	82.6	3.74	14.2	-63.2
		31.2	20.6	15.1	0.67	13.5	-23.0
		100.0	0.0	53.6	2.35	112.2	-27.6
L39-S5	2	7.5	0.0	6.3	0.36	212.0	-2.9
		58.4	19.0	23.5	1.18	125.8	-7.5
L40-S5	1	60.1	11.2	25.3	0.93	92.6	-13.2
L41-S5	2	39.0	29.7	11.6	0.68	137.1	-43.8
		11.0	0.0	49.1	2.95	164.3	1.5
L47-S5	1	6.6	39.3	16.3	0.45	35.2	117.9
L48-S5	4	27.3	10.1	18.7	0.69	28.4	24.4
		21.1	53.0	31.2	1.09	76.2	67.9
		6.3	80.8	17.7	0.60	67.0	32.2
		19.0	0.0	12.7	0.47	188.7	119.8
L49-S5	3	37.5	0.0	54.8	2.33	103.4	23.6
		19.4	0.0	53.6	2.30	266.7	35.6
		28.8	71.2	45.1	1.74	147.1	34.5
L50-S5	1	100.0	0.0	73.7	2.76	98.4	-13.3
Average:	2.40	47.84		45.14			23.17

Appendix II

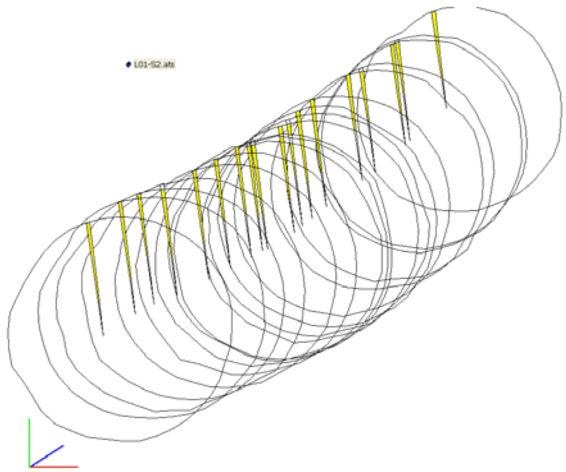
The Affects of Check Modeling on Check Parameters, Log L01

This appendix provides detailed insights how modeling affects check parameters by showing the image of a real log, sample log L01, with its two real checks (coloured by blue and yellow) and the corresponding 4 models of these real checks "seen" by MVS's 1E, 2E, 2ES, and 2ESC. Pertinent check parameters are tabulated below each graph to show the impact of check modeling on shape characteristics. Comparing the check parameters of these tables helps to observe how the important check parameters affecting lumber recoveries: the number of checks per log, check length, depth and spirality vary from model to model.



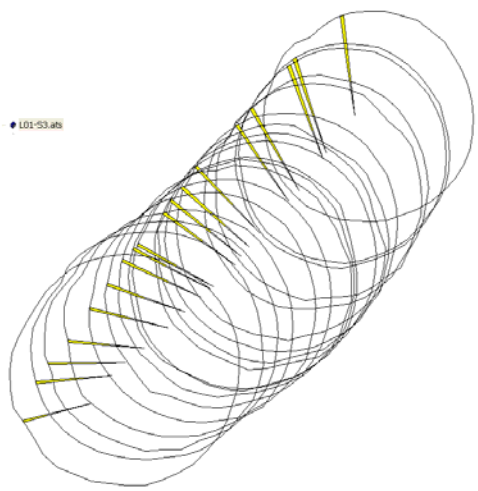
Logs and MVS code	Number of Checks	- - - - - - - - Check - - - - - - - - -				Angular location (degr, CW)	Spirality (degr/m)
		Length (as % of log length)	Start (as % of log length)	Depth (as % of radius)	Depth (in)		
Actual log L01	2	54.5	0	61.6	2.79	345.4	-39.7
		59.5	40.5	62.1	2.71	18.0	-34.7

Figure A2-1. OPTITEK® model of the actual log L01 with its real checks and corresponding check parameters.



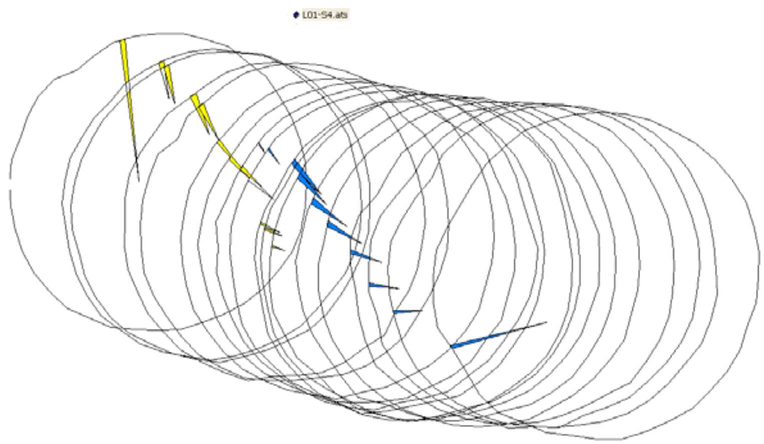
Logs and MVS code	Number of Checks	- - - - - - - - Check - - - - - - - - -				Angular location (degr, CW)	Spirality (degr/m)
		Length (as % of log length)	Start (as % of log length)	Depth (as % of radius)	Depth (in)		
L01-1E	1	100	0	98.6	4.39	83.0	0

Figure A2-2. Log\check model of MVS 1E (camera at one end) with corresponding check parameters.



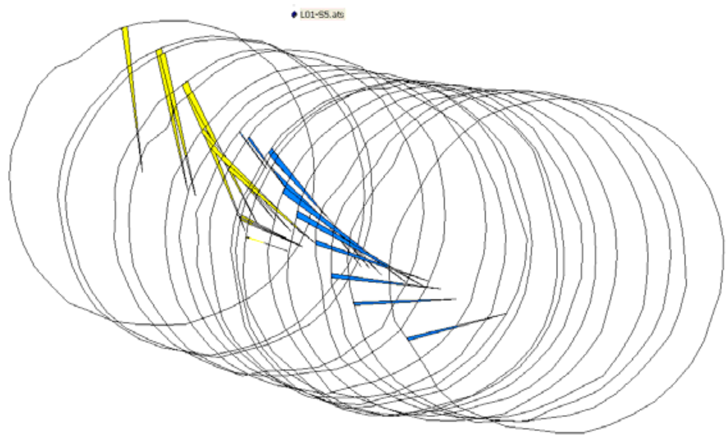
Logs and MVS code	Number of Checks	- - - - - - - - Check - - - - - - - - -				Angular location (degr, CW)	Spirality (degr/m)
		Length (as % of log length)	Start (as % of log length)	Depth (as % of radius)	Depth (in)		
L01-2E	1	100.0	0.0	77.7	3.45	345.4	-31.0

Figure A2-3. Log\check model of MVS 2E (camera at 2 ends) with corresponding check parameters.



Logs and MVS code	Number of Checks	- - - - - - - - Check - - - - - - - - -				Angular location (degr, CW)	Spirality (degr/m)
		Length (as % of log length)	Start (as % of log length)	Depth (as % of radius)	Depth (in)		
L01-2ES	2	54.5	0.0	23.7	1.08	345.4	-39.7
		59.5	40.5	26.0	1.12	18.0	-34.7

Figure A2-4. Log\check model of MVS 2ES (camera at 2 ends and surface) with corresponding check parameters.



Logs and MVS code	Number of Checks	- - - - - - - - Check - - - - - - - - -				Angular location (degr, CW)	Spirality (degr/m)
		Length (as % of log length)	Start (as % of log length)	Depth (as % of radius)	Depth (in)		
L01-2ESC	2	54.5	0.0	71.5	3.24	345.4	-39.7
		59.5	40.5	72.0	3.15	18.0	-34.7

Figure A2-5. Log\check model of MVS 2ESC with corresponding check parameters

Appendix III

Lumber Prices, Grade Outturns and Pieces Values

Table A3-1: Lumber prices (FOB Prince George, $CAN/Mfbm. Derived from industry publications and through consultations with industry advisors).

Size	2x3-8	2x3-10	2x3-12	2x3-14	2x3-16	2x3-18	2x3-20
J-Grade	NP	NP	NP	NP	NP	NP	NP
MSR	417	417	417	417	417	432	432
No2&Btr	285	310	311	325	355	325	310
#3 or Utility	216	236	237	248	272	248	236
Econ	138	138	138	138	138	138	138
	2x4-8	2x4-10	2x4-12	2x4-14	2x4-16	2x4-18	2x4-20
J-Grade	416	416	416	416	416	416	416
MSR	387	387	387	387	387	402	402
No2&Btr	320	345	346	360	390	360	345
No3	256	276	277	288	312	288	276
Econ	148	148	148	148	148	148	148
	2x6-8	2x6-10	2x6-12	2x6-14	2x6-16	2x6-18	2x6-20
J-Grade	398	398	398	398	398	398	398
MSR	379	379	379	379	379	379	379
No2&Btr	329	331	354	335	370	343	344
No3	205	207	222	209	231	214	215
Econ	122	122	122	122	122	122	122
	2x8-8	2x8-10	2x8-12	2x8-14	2x8-16	2x8-18	2x8-20
J-Grade	NP	398	398	398	398	398	398
MSR	430	430	430	430	430	445	445
No2&Btr	329	339	359	355	349	370	365
No3	211	218	231	228	225	238	235
Econ	140	140	140	140	140	140	140
	2x10-8	2x10-10	2x10-12	2x10-14	2x10-16	2x10-18	2x10-20
J-Grade	NP	346	418	461	380	372	367
MSR	NP	NP	NP	NP	NP	NP	NP
No2&Btr	331	336	408	451	370	362	357
No3	196	199	241	267	219	214	211
Econ	135	135	135	135	135	135	135

Note: NP – Not produced.

Table A3–2: Grade outturns used to calculate piece values.

		Percent					
		J-Grade	MSR	No2&Btr	No3	Econ	Total
2x3	8	0	38	45	13	4	100
	10	0	54	31	11	4	100
	12	0	51	33	13	3	100
	14	0	50	36	11	3	100
	16	0	42	43	14	1	100
	18	0	46	41	12	1	100
	20	0	46	41	12	1	100
2x4	8	3	14	41	30	12	100
	10	2	23	49	18	8	100
	12	4	35	40	15	6	100
	14	6	34	40	16	4	100
	16	9	37	38	13	3	100
	18	6	39	37	15	3	100
	20	9	46	31	12	2	100
2x6	8	3	14	37	26	20	100
	10	8	27	41	16	8	100
	12	10	24	48	13	5	100
	14	8	25	50	12	5	100
	16	15	29	40	13	3	100
	18	14	31	40	12	3	100
	20	15	38	35	10	2	100
2x8	8	0	0	59	29	12	100
	10	2	22	50	21	5	100
	12	5	25	49	18	3	100
	14	8	25	46	18	3	100
	16	11	29	43	15	2	100
	18	6	25	50	16	3	100
	20	12	31	43	12	2	100
2x10	8	0	0	64	30	6	100
	10	6	0	65	23	6	100
	12	7	0	70	18	5	100
	14	11	0	72	14	3	100
	16	11	0	72	14	3	100
	18	10	0	71	16	3	100
	20	7	0	79	12	3	100

Table A3-3: Piece values.

$/piece	J-Grade	MSR	No2&Btr	No3	Econ
2x3-8	1.28	1.28	1.08	0.85	0.55
2x3-10	1.76	1.76	1.47	1.16	0.69
2x3-12	2.10	2.10	1.78	1.40	0.83
2x3-14	2.50	2.50	2.18	1.71	0.97
2x3-16	2.94	2.94	2.73	2.17	1.11
2x3-18	3.27	3.27	2.82	2.22	1.24
2x3-20	3.55	3.55	2.99	2.35	1.38
2x4-8	1.56	1.55	1.49	1.30	0.79
2x4-10	2.19	2.18	2.11	1.77	0.99
2x4-12	2.73	2.72	2.59	2.15	1.19
2x4-14	3.29	3.27	3.17	2.64	1.38
2x4-16	3.99	3.96	3.95	3.28	1.58
2x4-18	4.35	4.34	4.11	3.41	1.78
2x4-20	4.87	4.85	4.43	3.65	1.98
2x6-8	2.12	2.11	2.04	1.51	0.97
2x6-10	3.13	3.11	2.94	2.00	1.22
2x6-12	4.03	4.01	3.91	2.60	1.46
2x6-14	4.55	4.53	4.33	2.87	1.70
2x6-16	5.62	5.58	5.51	3.65	1.95
2x6-18	6.12	6.07	5.78	3.81	2.19
2x6-20	6.96	6.91	6.54	4.26	2.44
2x8-8	2.90	2.90	2.90	2.16	1.49
2x8-10	4.33	4.32	4.05	2.86	1.86
2x8-12	5.58	5.57	5.27	3.65	2.23
2x8-14	6.49	6.48	6.07	4.21	2.60
2x8-16	7.58	7.57	6.97	4.76	2.98
2x8-18	8.70	8.69	8.21	5.65	3.35
2x8-20	9.96	9.95	9.20	6.21	3.72
2x10-8	3.72	3.72	3.72	2.56	1.80
2x10-10	4.89	4.87	4.87	3.25	2.25
2x10-12	7.29	7.28	7.28	4.72	2.70
2x10-14	9.73	9.70	9.70	6.13	3.14
2x10-16	9.15	9.12	9.12	5.77	3.59
2x10-18	9.98	9.95	9.95	6.35	4.04
2x10-20	11.11	11.09	11.09	6.96	4.49

Appendix IV

Optitek® Piece Value Calculation

Optitek needs piece values for value optimization purposes. These piece values were derived from $/Mfbm prices of lumber sizes and grades (Appendix 2) and historical grade outturns. Taking historical grade outturns into consideration was necessary because the Optitek grading subroutine takes only MPB defects into consideration. On the other hand there are other defects (e.g., knots) that affect lumber grade, which must also be taken into account. The piece values are weighted averages with weights of grade outturns.

To illustrate the method of piece value calculation, Figure A3-1 shows an MPB-killed log with resulting lumber pieces. Wane, blue stain and checks, the defects that limit the lumber grade that Optitek includes in its grading subroutine, - - are demonstrated.

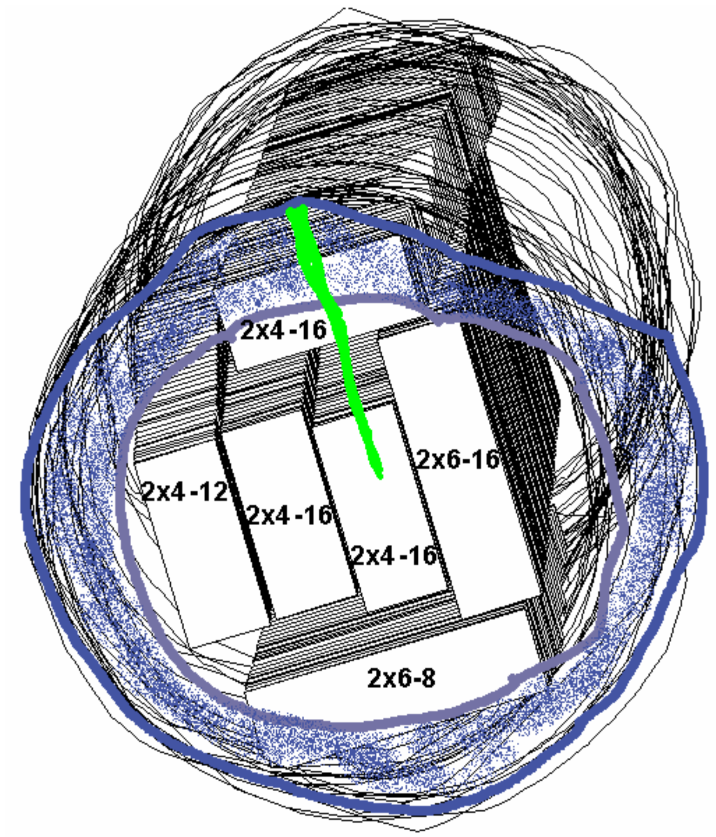


Figure A4-1: Sample log breakdown

For example, to calculate the value of the piece of 2x4-16, second from left in the center cant, we must know its nominal volume (10.67 fbm) and its weighted price per Mfbm. Since this piece has no grade limiting defects considered by Optitek, i.e., no wane, checks or bluestain, all of the grades listed in Table A4-1 are possible.

Table A4-1: Grade outturns and prices

Grade	Grade outturn %'s	Price
(1)	(2)	(3)
J-Grade	9	416
MSR	37	387
2&Better	38	390
No3	13	312
Economy	3	148
Total:	100	

Based on the grade outturns of Table A4-1 we assume that 100 pieces of 2x4-16 contain 9 pieces of J-Grade, 37 pieces of MSR, 38 pieces of 2&Better, 13 pieces of No3 and 3 pieces of Economy. Thus the calculation of the weighted average price of a 2x4-16, with the highest Optitek grade, per MFBM is as follows:

0.09 x 416 + 0.37 x 387 + . . . + 0.03 x 148 = $373.67/Mfbm.

The piece value of this 2x4-16 piece is:

(373.67 / 1000) x 10.67 = $3.99.

Note that in the above example we did not know anything about the actual defects of the 100 pieces. We only knew that since Optitek did not find any grade limiting defects (no wane, checks or bluestain), Optitek graded this piece as the highest Optitek grade. Consider another piece with defect, the 2x4-16 with the check (immediately to the right of the 2x4 piece used as an example above in Figure 1). Assuming that the grade is limited by this check to 2&Better, then the calculation leading to the weighted average price differs and includes the weights from Table A4-2:

0.84 x 390+0.13 x 312 + 0.03 x 148 = $372.39/Mfbm

Table A4-2

Grade	Grade outturn %'s	Price
(1)	(2)	(3)
2&Better	(9+37+38=) 84	390
No3	13	312
Economy	3	148
Total:	100	

The piece value of this 2x4-16 piece with the assumed defects is:

(372.39 / 1000) * 10.67 = $3.97.

Appendix V

Statistical Analysis of Product Value Recoveries Predicted by Optitek® Simulation

A statistical analysis was carried out about performance differences of pairs of machine vision systems. Raw data for the analysis are in Table A5_1.

Table A5_1. Total product values recovered from the 45 sample logs by MVS's.

Log code	CT_No CD_H	CT_No CD_D	CT_ WD_D	1E_ NoCD_D	1E_ WCD_D	2E_ NoCD_D	2E_ WCD_D	2ES_ NoCD_D	2ES_ WCD_D	2ESC_ NoCD_D	2ESC_ WCD_D
L50	6.61	2.99	2.99	3.45	3.45	4.33	4.33	2.73	2.73	4.37	5.73
L01	12.25	7.63	7.63	7.07	7.07	6.18	6.18	4.31	5.66	7.87	7.87
L04	13.02	7.25	7.25	7.25	7.25	8.07	8.07	7.42	7.42	7.41	9.65
L05	9.14	3.82	3.82	1.9	1.9	3.43	4.99	3.73	3.75	3.81	3.83
L06	5.6	3.18	3.18	3.66	3.66	3.66	3.66	2.34	2.34	3.64	3.66
L07	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06
L10	15.04	5.46	5.46	5.49	5.51	6.62	8.49	5.42	7.85	5.46	5.46
L11	13.71	4.36	7.87	4.36	7.87	7.15	10.79	8.27	9.15	6.34	6.34
L13	10.65	6.33	7.45	6.33	7.45	5.64	6.99	6.33	7.45	6.33	7.45
L14	7.05	7.05	7.05	4.8	6.65	4.8	6.65	4.8	6.65	7.05	7.05
L18	7.97	1.36	2.72	1.36	6.1	2.27	3.39	1.36	4	5.21	5.23
L19	11.51	2.14	5.31	6	7.82	5.54	5.54	5.93	7.75	8.75	8.75
L20	9.17	4.49	4.49	4.75	4.77	3.83	3.85	7.64	7.66	7.64	7.66
L25	10.77	3.42	5.91	3.63	5.56	2.05	5.11	2.13	5.98	8.95	8.95
L26	8.72	5.96	7.89	4.61	7.78	3.8	7.91	4.61	7.78	6.54	9.3
L27	9.61	4	4	6.5	6.5	6.06	6.07	4.05	5.4	5.39	8.56
L29	6.47	2.84	2.84	4.63	4.65	5.33	5.33	5.33	5.33	5.26	5.27
L32	6.66	3.03	3.03	4.77	4.77	4.83	4.85	4.14	4.14	4.85	4.85
L33	15.31	8.72	12.35	11.01	11.07	11.07	11.07	8.72	12.35	13.88	14.07
L35	8.37	4.73	6.55	6.51	7.63	4.69	7.17	6.95	8.07	4.49	7.65
L38	9	3.55	5.37	3.95	3.95	3.94	5.07	2.19	5.37	5.35	5.37
L39	9.96	7.46	7.46	8.09	8.09	8.09	8.09	7.47	7.47	6.13	6.13
L40	9.9	7.34	7.34	7.91	7.91	7.91	7.91	4.31	4.33	4.31	4.33
L47	3.2	1.85	1.85	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09
L48	5.9	2.73	2.73	2.74	4.55	1.39	2.75	1.39	2.75	1.39	2.75
L49	11.05	5.54	9.63	8.7	8.7	5.51	5.51	6.84	10.52	6.44	10.12
L02	15.47	5.05	6.99	4.42	10.22	5.83	7.42	5.05	11.06	7.77	11.63
L03	16.35	6.98	8.1	5.65	7.61	3.72	8.74	10.75	10.78	9.71	15.2
L08	30.32	11.41	15.21	14.17	14.21	12.54	17.19	8.71	9.83	6.77	10.67
L09	33.95	20.51	22.44	25.05	28.92	25.04	28.46	26.95	30.81	20.07	26.1
L12	15.46	7.77	7.77	12.25	12.27	12.39	14.32	8.89	8.89	15.45	15.45
L15	20.67	8.15	8.18	5.81	14.1	9.68	14.07	5.82	9.68	14.09	16.61
L16	25.07	15.47	15.49	11.74	13.67	8.18	11.65	11.74	13.67	16.68	18.31
L17	18.01	8.97	11.99	8.94	8.97	5.04	8.87	8.99	9	11.72	14.47
L21	13.91	9.6	12.3	10.04	12.75	7.69	10.39	8.98	10.11	10.32	10.32
L22	10.91	2.72	5.42	2.66	3.81	5.87	5.88	2.65	2.71	5.88	8.57
L23	24.96	15.35	15.37	15.35	17.21	21.09	25.52	15.34	19.19	25.52	25.52
L24	19.38	5.12	8.4	13.61	13.61	7.85	7.87	13.6	14.94	12.48	14.41
L28	15.03	5.05	5.07	8.3	8.33	8.3	8.34	5.9	7.7	6.95	8.19
L30	23.85	12.47	13.18	16.48	18.29	13.84	15.67	11.9	15.96	15.56	18.42

Log code	CT_No CD_H	CT_No CD_D	CT_ WD_D	1E_ NoCD_D	1E_ WCD_D	2E_ NoCD_D	2E_ WCD_D	2ES_ NoCD_D	2ES_ WCD_D	2ESC_ NoCD_D	2ESC_ WCD_D
L31	13.8	10.7	10.71	11.25	12.59	9.34	10.7	10.37	10.37	8.8	10.1
L34	18.55	7.94	7.96	13.03	15.54	6.66	10.52	9.3	12.03	14.31	14.33
L36	20.74	9.22	14.87	13.06	17.33	13.05	14.42	17.32	19.09	17.32	19.09
L37	14.21	11.04	11.04	4.3	5.65	7.88	9.64	11.01	11.02	8.63	8.63
L41	16.73	14.22	15.58	12.05	12.06	10.83	11.94	12.05	12.06	11.94	11.94

The meaning of abbreviations used to refer to sawmill technology and log condition combinations are the following:

Abbreviation	Description
CT_NoCD_H	Current Technology_No Down Stream Check Detection_Healthy log
CT_NoCD_D	Current Technology_No Down Stream Check Detection_Damaged log,
CT_WCD_D	Current Technology_With Down Stream Check Detection_Damaged log,
1E_NoCD_D	MVS with camera at 1 end_No Down Stream Check Detection_Damaged log,
1E_WCD_D	MVS with camera at 1 end_With Down Stream Check Detection_Damaged log,
`2E_NoCD_D	MVS with camera at 2 ends_No Down Stream Check Detection_Damaged log,
2E_WCD_D	MVS with camera at 2 ends_With Down Stream Check Detection_Damaged log,
2ES_NoCD_D	MVS with camera at 2 ends and surface_No Down Stream Check Detection_Damaged log,
2ES_WCD_D	MVS with camera at 2 ends and surface_With Down Stream Check Detection_Damaged log,
2ESC_NoCD_D	MVS with camera at 2 ends and surface, Corrected check depth estimation_No Down Stream Check Detection_Damaged log,
2ESC_WCD_D	MVS with camera at 2 ends and surface, Corrected check depth estimation_With Down Stream Check Detection_Damaged log.

The analysis investigated if the differences of questions 1-10 of Table A5_2 are significant and how large they are?

Table A5_2. Sawmill technology and log condition combinations

Code of question	Codes of sawmill technology log condition combinations to be compared
Q1	(CT_NoCD_H) – (CT_NoCD_D)
Q2	(CT_NoCD_H) – (CT_ WCD_D)
Q3	(1E_NoCD_D) - (CT_NoCD_D)
Q4	(1E_WCD_D) - (CT_WCD_D)
Q5	(2E_NoCD_D) - (CT_NoCD_D)
Q6	(2E_WCD_D) - (CT_WCD_D)
Q7	(2ES_NoCD_D) - (CT_NoCD_D)
Q8	(2ES_WCD_D) - (CT_WCD_D)
Q9	(2ESC_NoCD_D) - (CT_NoCD_D)
Q10	(2ESC_WCD_D) - (CT_WCD_D)

The analysis provided descriptive statistics for each sawmill technology and log condition combinations, Table A5_3.

Table A5_3. Descriptive statistics of product value recoveries predicted by OPTITEK® simulation.

Sawmill technology_Log condition combination	Number of sawlogs	Means of product values, $/log	Standard deviation of product values, $/log
CT_NoCD_H	45	13.6238	6.63279
CT_NoCD_D	45	6.9784	4.11069
CT_WCD_D	45	8.1622	4.42127
1E_NoCD_D	45	7.7507	4.71872
1E_WCD_D	45	9.0878	5.15859
2E_NoCD_D	45	7.3813	4.58011
2E_WCD_D	45	8.9451	5.26902
2ES_NoCD_D	45	7.4418	4.79259
2ES_WCD_D	45	8.9322	5.27412
2ESC_NoCD_D	45	8.8440	4.97779
2ESC_WCD_D	45	10.1142	5.50674

For each pair of sawmill technology and log condition combinations in Table A5_2, the means were compared using independent samples *t*-tests with a Type I error rate of $\alpha = .05$. The purpose was to test if significant difference between means exists. 95% confidence intervals of the differences were also calculated, Table A5-4.

Table A5_4. Statistical comparisons of means of sawmill technology and log condition combinations.

Code of question	Codes of sawmill technology_log condition combinations to be compared	Is the difference significant?	Mean Difference, $/log	Std.Error Difference, $/log	95% Confidence Interval of the Difference, $/log	
					Lower	Upper
Q1	(CT_NoCD_H) – (CT_NoCD_D)	Yes	6.64533	1.16325	4.32722	8.96344
Q2	(CT_NoCD_H) – (CT_ WCD_D)	Yes	5.46156	1.18829	3.09520	7.82791
Q3	(1E_NoCD_D) - (CT_NoCD_D)	No	0.77222	0.93291	-1.08222	2.62666
Q4	(1E_WCD_D) - (CT_WCD_D)	No	0.92556	1.01279	-1.08781	2.93892
Q5	(2E_NoCD_D) - (CT_NoCD_D)	No	0.40289	.91743	-1.42060	2.22637
Q6	(2E_WCD_D) - (CT_WCD_D)	No	0.78289	1.02535	-1.25563	2.82141
Q7	(2ES_NoCD_D) - (CT_NoCD_D)	No	0.46333	.94124	-1.40778	2.33445
Q8	(2ES_WCD_D) - (CT_WCD_D)	No	0.77000	1.02593	-1.26969	2.80969
Q9	(2ESC_NoCD_D) - (CT_NoCD_D)	Yes	1.86556	.96236	-0.04693	3.77804
Q10	(2ESC_WCD_D) - (CT_WCD_D)	Yes	1.95200	1.05274	-0.14010	4.04410