Rate of Weight Loss in Piled Pulpwood

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Abstract

Weight loss was monitored in piles of 100-inch and tree-length aspen and balsam fir pulpwood that was harvested during the spring and summer of 1984 in northern Minnesota. The rate of weight loss was found to be largely constant, though influenced by environmental factors. Equations were developed which describe weight loss under varying conditions of rainfall, temperature, and humidity.

RATE OF WEIGHT LOSS IN PILED PULPWOOD

Conversion factors used in calculating the value of weight scaled pulpwood are virtually all based on the green or freshly harvested weight of wood. However, when there are delays between the harvest and weight scaling operations, natural drying of wood reduces the weight of each unit of wood and invalidates the established conversion factors. When a set conversion factor based on green weight is used, the effect of any weight loss in a given quantity of wood is an underestimate of the amount of wood fiber measured. This study was conducted to assess the rate of weight loss in piled pulpwood and to determine the influence of factors such as temperature, humidity and rainfall, upon the rate of drying.

Procedure

Quantities of freshly harvested pulpwood were weighed upon delivery at selected wood concentration yards. Material was then piled. Some piles were located in shaded locations at the boundaries of the concentration yards, while others were placed on sites that were fully exposed to the elements. Periodic reweighing of piles was accomplished using a portable scale rigged in conjunction with a boom hoist. Weight loss was monitored in eighteen separate pulpwood piles. Both aspen and balsam fir, and 100-inch and tree length pulpwood were included in the study. At each site, detailed daily environmental records were maintained; factors measured included precipitation, humidity, and maximum and minimum temperatures.

All of the pulpwood involved in this study was harvested in the northern one-third of Minnesota between the months of April and September 1984.

Data was collected by Department of Natural Resources personnel working under the supervision of Gene Jamrock of the DNR office in Grand Rapids. Data was analyzed by a team of specialists from the Departments of Forest Products and Forest Resources in the University of Minnesota, College of Foresty in St. Paul. Industrial cooperators were Northwood Panel Products of Bemidji, Cole Forest Products and Blandin Paper Company of Grand Rapids, Rajala Timber Company of Deer River, Champion International Corporation of Two Harbors and Mizpah, and Superior Fiber Corporation of Superior, Wisconsin. The numbers of piles of each species monitored at each location is presented in Table 1.

Observations

A summary of observations for each of the pulpwood piles is presented in Table 2. Note that weight loss over a period of several weeks or months is substantial, though instances of weight gain are not uncommon.

Analysis

Exploratory Work The data was evaluated through various statistical techniques, with the objective of developing a model that accurately describes the rate of weight loss per cubic foot of wood. The Box-Cox transformation technique (Weisberg 1985) and the ACE algorithm (Breiman and Friedman 1985) were considered during exploratory work. The Box-Cox method could not be used because of zeros in weight loss/cubic foot measurements. The ACE algorithm showed

transformation of the independent variables, average high temperature, average high humidity, total weekly rainfall, and weight at the end of the previous week, to be unnecessary.

Modeling

The rate of weight loss was best described by time series models.

For Aspen: (Equation 1)
$$Weight_i = -305.80 + .999\ (Weight_{i-1}) - 1.786\ (AHT) + 4.160\ (AHH) + 18.033\ (\Sigma\ Rain)$$

For Balsam Fir: (Equation 2)
$$Weight_i = 233.10 + .947\ (Weight\ i-1) - 2.870\ (AHT) + 1.220\ (AHH) + 26.228\ (\Sigma\ Rain)$$

where,

$Weight_i$ = The weight at any given point in time (week i)

$Weight_{i-1}$ = The weight one week previously

AHT = Average high temperature over the seven days immediately preceding determination of weight i

AHH = Average high humidity over the seven days immediately preceding determination of weight i

Σ Rain = Total rainfall over the seven days immediately preceding determination of weight i

Rainfall and high humidity over the immediately preceding period tended to be associated with an increase in weight, while a period of high daily temperatures had a tendency to cause a weight reduction.

The R-squared values that correspond to the models derived are 0.99 for aspen and 0.98 for balsam fir, indicating that 99% and 98%, respectively, of the observed weight loss can be explained by the factors considered in the models; the average deviation of actual versus model-derived weight values was 107 pounds for aspen and 84 pounds for balsam fir. Though there are four variables included in the general model, most of the variability is accounted for in the $Weight_{i-1}$ term.

Use of the Durbin-Watson statistic (Johnston 1972) indicated no serial correlation in the residuals. Similarly, plots of standardized residuals versus time did not indicate a time trend.

Because much of the variability in weight is accounted for by the $Weight_{i-1}$ term, simple models were derived in which only one variable, $Weight_{i-1}$, was considered. These models are given by

For Aspen: (Equation 3)
$$Weight = .993\ (Weight_{i-1})$$

For Balsam Fir: (Equation 4)
$$Weight = .984\ (Weight_{i-1})$$

Given the range of conditions over which data in this study were collected, the weight of aspen in each succeeding week can be predicted as 99.3 percent of the weight in the preceding week. The aspen model, in other words, assumes a weekly weight loss rate of 0.7 percent. Similarly, the balsam fir model assumes a weekly weight loss rate of 1.6 percent.

Again, use of the Durbin-Watson statistic showed that errors were uncorrelated. As before, no time trend was indicated by a plot of residuals.

This simplified model yields an average deviation of actual versus model-derived weight values of 162 pounds for aspen and 117 pounds for balsam fir. Note that these average deviations are 51 and 39 percent higher than those associated with the more complex model.

Figures 1 - 15 are plots of observed and model-derived weight values for pulpwood piles monitored for more than two weeks.

Surprisingly, both models perform equally well in tracking weight loss in 100-inch and tree-length pulpwood. It was anticipated that the tree length material would lose weight more slowly, but this expectation was not supported by field observations.

Summary

The rate of weight loss in fresh-cut, piled pulpwood is largely constant, but is influenced by environmental conditions such as average daily high temperature, average high humidity, and total rainfall in the days immediately preceding measurement. Models were developed from a number of observations of Minnesota pulpwood species using these factors in predicting pulpwood weight after a period of drying. Given the conditions that existed when data were gathered, the models explain 98 percent or more of the variation in drying rate.

A less accurate but simpler method of estimating weight loss in aspen and balsam fir pulpwood assumes a weight loss rate of about 0.7 percent and 1.6 percent per week respectively. This rate of loss will understate the weight loss that occurs in hot, dry periods and will overstate the rate of weight loss in humid, rainy periods. This method, however, is reasonably accurate over the range of conditions observed in this study.

LITERATURE CITED

Breiman, L. and J.H. Friedman. 1985. Estimating Optimal Transformations for Multiple Regression and Correlation. Jour. Amer. Stat. Assoc. 80:580-598.

Johnston, J. 1972. Econometric Methods. 2nd Ed. New York: McGraw-Hill Book Company.

Weisberg, S. 1985. Applied Linear Regression. 2nd Ed. New York: John Wiley & Sons.

Table 1

Pulpwood Monitored For Weight Loss -
Quantity, Species, and Location

Location	Species	
	Aspen	Balsam Fir
	Values are numbers of piles and (approximate numbers of cords)	
Cole Forest Products, Grand Rapids	5	
Northwood Panel Products, Bemidji	5	
Rajala Timber Company, Deer River	5	
Blandin Paper Company, Grand Rapids		1
Louisiana Pacific Corp., Two Harbors		1
Mizpah		1

Table 2

Summary of Weight Loss and Accompanying Meteorological Data

Location	Species	Week	Weight of Pile at Beginning of Week (lbs)					Total Rainfall During Week (in.)	Average High Humidity During Week (%)	Average High Temperature During Week (°F)
			Pile Number							
			1	2	3	4	5			
Northwood Bemidji	Aspen	1	4725					1.12	90	81
		2	4825					1.87	100	77
		3	4625	3575				0.00	76	89
		4	4400	3275				1.74	100	82
		5	4300	3200				0.00	100	85
		6	4475	3400				0.41	98	85
		7	4375	3300				0.43	93	89
		8	4325	3275	4875			1.59	83	81
		9	4450	3400	4975			1.61	100	70
		10	4275	3150	4875			1.20	96	91
		11	4225	3150	4800			0.34	96	78
		12	4300	3250	4925	4450		1.86	96	67
		13	4150	3150	4725	4350		0.28	92	57
		14	4175	3250	4675	4350		0.08	92	70
		15	4275	3225	4750	4400		1.36	82	56
		16	4250	3175	4725	4375		0.99	92	51
		17	4225	3150	4725	4350	3850	0.11	90	47
		18	4200	3125	4700	4375	3825	0.12	83	53

Table 2. (cont'd) Summary of Weight Loss and Accompanying Meteorological Data

Location	Species	Week	Weight of Pile at Beginning of Week (lbs)					Total Rainfall During Week (in.)	Average High Humidity During Week (%)	Average High Temperature During Week (°F)
			Pile Number							
			1	2	3	4	5			
Cole Forest Products Grand Rapids	Aspen	1	4605					3.19	96	76
		2	4475					0.27	95	73
		3	4325					1.06	91	82
		4	4375					3.77	96	74
		5	4250					0.00	91	85
		6	4150	4050				0.38	92	87
		7	4150	4000				0.00	93	84
		8	4165	3975				5.00	93	82
		9	4085	3900				1.78	91	75
		10	3950	3800	4875			0.26	92	80
		11	3950	3675	4800			0.00	93	79
		12	4000	3700	4725			1.66	92	84
		13	3925	3650	4675			0.47	92	80
		14	3900	3675	4675			1.70	92	71
		15	3875	3625	4675	5200		0.91	92	57
		16	3900	3625	4600	5150		0.07	93	63
		17	3900	3725	4750	5175		1.67	92	60
		18	3875	3625	4625	5100		1.06	93	54
		19	3875	3625	4675	5100	4400	0.26	92	47
		20	3875	3575	4675	5150	4400	0.09	92	52

Table 2. (cont'd.) Summary of Weight Loss and Accompanying Meteorological Data

Location	Species	Week	Weight of Pile at Beginning of Week (lbs)					Total Rainfall During Week (in.)	Average High Humidity During Week (%)	Average High Temperature During Week (°F)
			Pile Number							
			1	2	3	4	5			
Rajala Deer River	Aspen	1	2875					2.15	93	73
		2	2900					0.70	100	74
		3	2700					0.03	83	80
		4	2725					2.58	100	75
		5	2650					0.00	94	87
		6	2625					0.33	100	85
		7	2525					0.00	100	83
		8	2550	3200				1.65	100	84
		9	2500	3150				1.31	98	89
		10	2475	3110	4150			0.18	100	81
		11	2475	3175	4100			0.49	95	79
		12	2500	3100	4150			0.59	100	86
		13	2450	3050	4050			0.46	96	82
		14	2600	3025	3975			0.63	94	73
		15	2400	3025	4025	3325		1.19	98	57
		16	2400	3000	4025	3325		0.06	100	69
		17	2425	3025	4050	3400		1.61	100	61
		18	2400	3000	4000	3300		1.00	93	54
		19	2400	2975	4025	3300	3225	0.40	100	49
		20	2400	3025	4025	3300	3225	0.10	98	55

Table 2. (cont'd.) Summary of Weight Loss and Accompanying Meteorological Data

Location	Species	Week	Weight of Pile at Beginning of Week (lbs)					Total Rainfall During Week (in.)	Average High Humidity During Week (%)	Average High Temperature During Week (°F)
			Pile Number							
			1	2	3	4	5			
Blandin Grand Rapids	Balsam fir	1	4825					0.15	81	64
		2	4725					0.93	91	51
		3	4750					1.79	93	58
		4	4625					1.09	87	66
		5	4550					0.34	93	70
		6	4525					0.00	99	65
		7	4525					3.98	98	79
		8	4425					2.02	96	70
		9	4400					0.47	97	73
		10	4375					0.94	97	77
		11	4150					0.73	96	78
		12	3900					0.23	98	85
		13	3950					0.06	97	78
		14	3875					0.18	96	84
		15	3775					0.12	97	84
		16	3750					1.00	96	85
		17	3700					0.11	97	82
		18	3600					0.38	100	79
		19	3475					0.23	100	76
		20	3475					0.07	98	70
		21	3575					0.75	100	63
		22	3525					0.00	100	71
		23	3475					0.93	91	55
		24	3275					0.00	93	61
		25	3425					0.07	100	63

Table 2. (cont'd) Summary of Weight Loss and Accompanying Meteorological Data

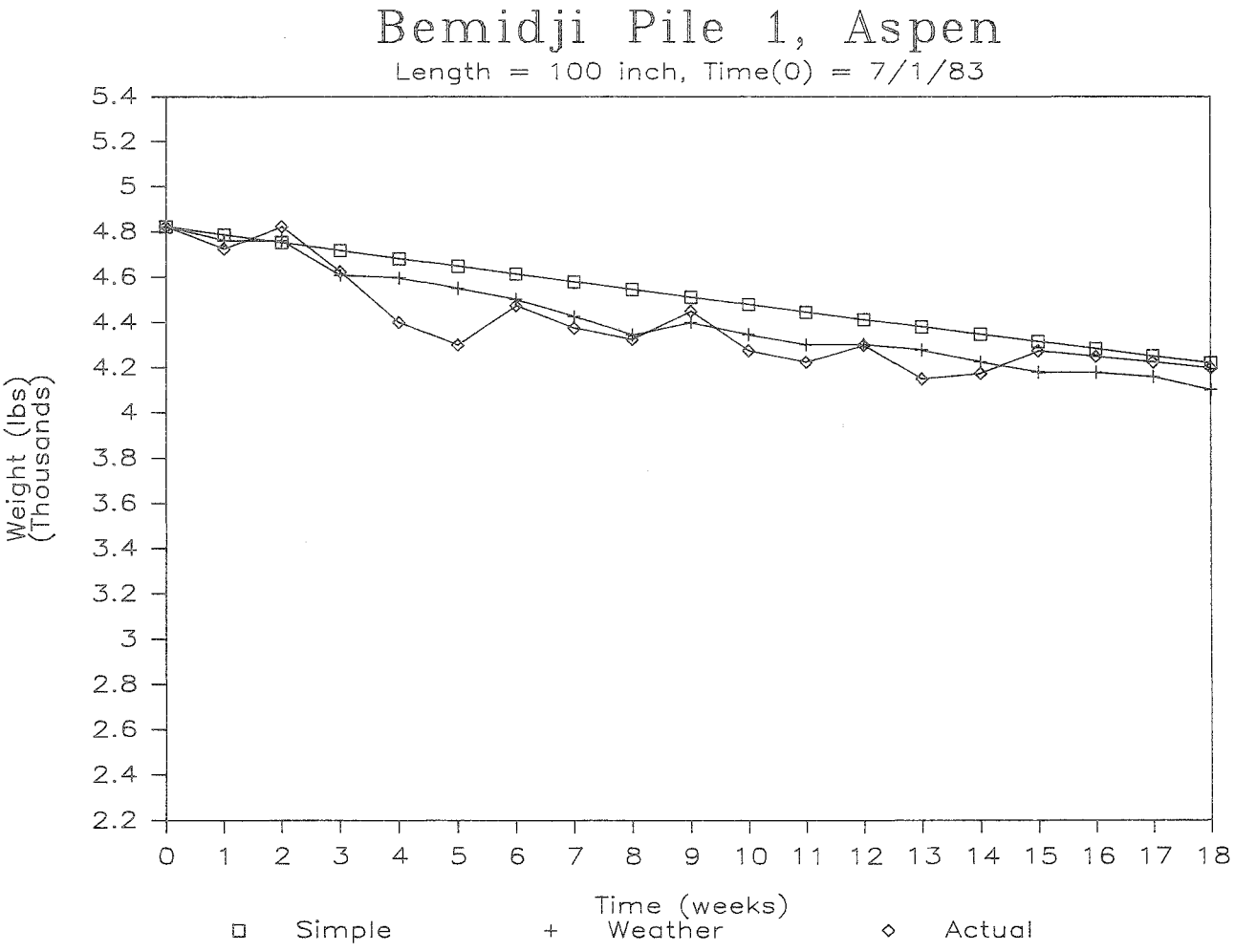
Location	Species	Week	Weight of Pile at Beginning of Week (lbs)					Total Rainfall During Week (in.)	Average High Humidity During Week (%)	Average High Temperature During Week (°F)
			Pile Number							
			1	2	3	4	5			
Champion International Two Harbors	Balsam fir	1	5125					1.70	66	62
		2	5050					0.32	86	47
		3	4975					1.74	90	58
		4	4800					0.80	71	65
		5	4800					0.73	84	66
		6	4775					0.04	83	67
		7	4725					2.78	96	77
		8	4675					2.16	100	70
		9	4650					1.29	98	70
		10	4500					0.65	96	77
		11	4425					0.31	86	77
		12	4400					0.33	100	80
		13	4300					0.35	93	77
		14	4250					0.18	96	80
		15	4075					0.37	96	79
		16	4100					3.90	95	83
		17	4000					0.34	98	79
		18	4025					0.50	98	79
		19	3850					0.40	91	81
		20	3550					1.50	97	65
		21	3825					0.87	94	65
		22	3850					0.00	90	74
		23	3825					0.68	94	59

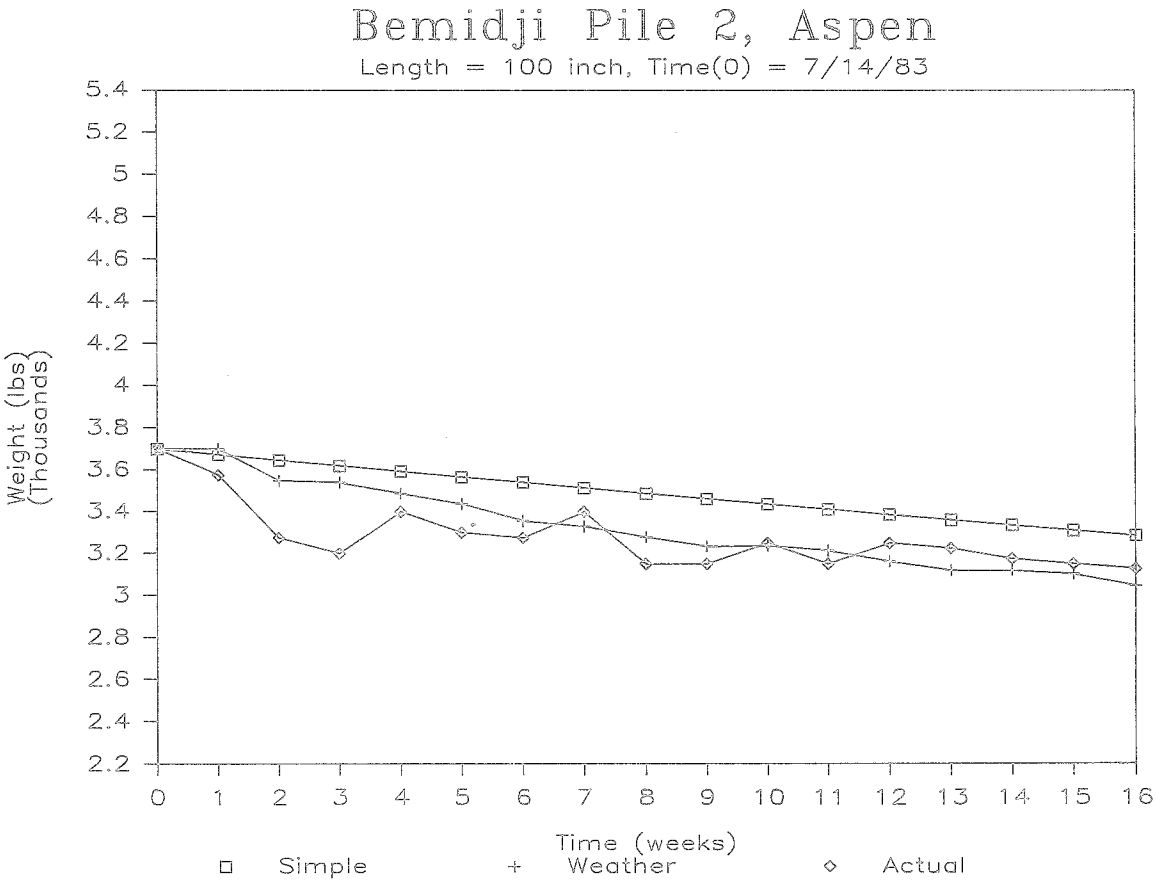
Table 2. (cont'd) Summary of Weight Loss and Accompanying Meteorological Data

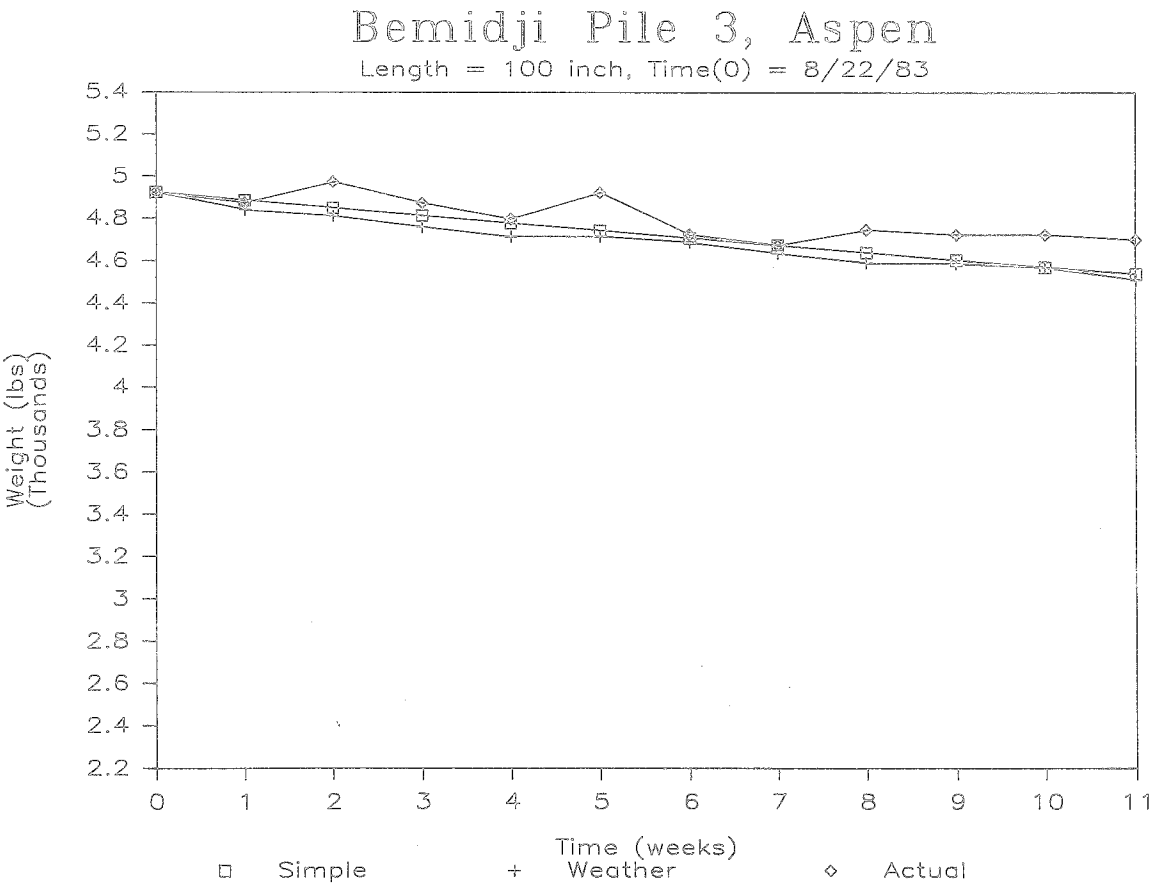
Location	Species	Week	Weight of Pile at Beginning of Week (lbs)					Total Rainfall During Week (in.)	Average High Humidity During Week (%)	Average High Temperature During Week (°F)
			Pile Number							
			1	2	3	4	5			
Champion International Mizpah	Balsam fir	1	4575					0.00	79	61
		2	4525					0.79	99	53
		3	4500					0.76	91	59
		4	4450					0.53	63	66
		5	4325					0.32	88	71
		6	4275					0.00	67	69
		7	4300					3.29	81	76
		8	4150					0.41	64	69
		9	4100					0.41	68	74
		10	3925					1.03	65	73
		11	4025					1.12	72	78
		12	3800					0.71	81	86
		13	3625					0.57	75	78
		14	3500					0.02	77	80
		15	3375					0.45	81	81
		16	3350					1.14	78	82
		17	3225					0.00	87	81
		18	3200					1.37	77	73
		19	3075					0.17	70	73
		20	3100					0.07	77	69
		21	3150					0.48	100	62
		22	3000					0.00	86	70
		23	3000					1.36	51	62
		24	2975					0.00	60	64
		25	2975					0.26	67	66

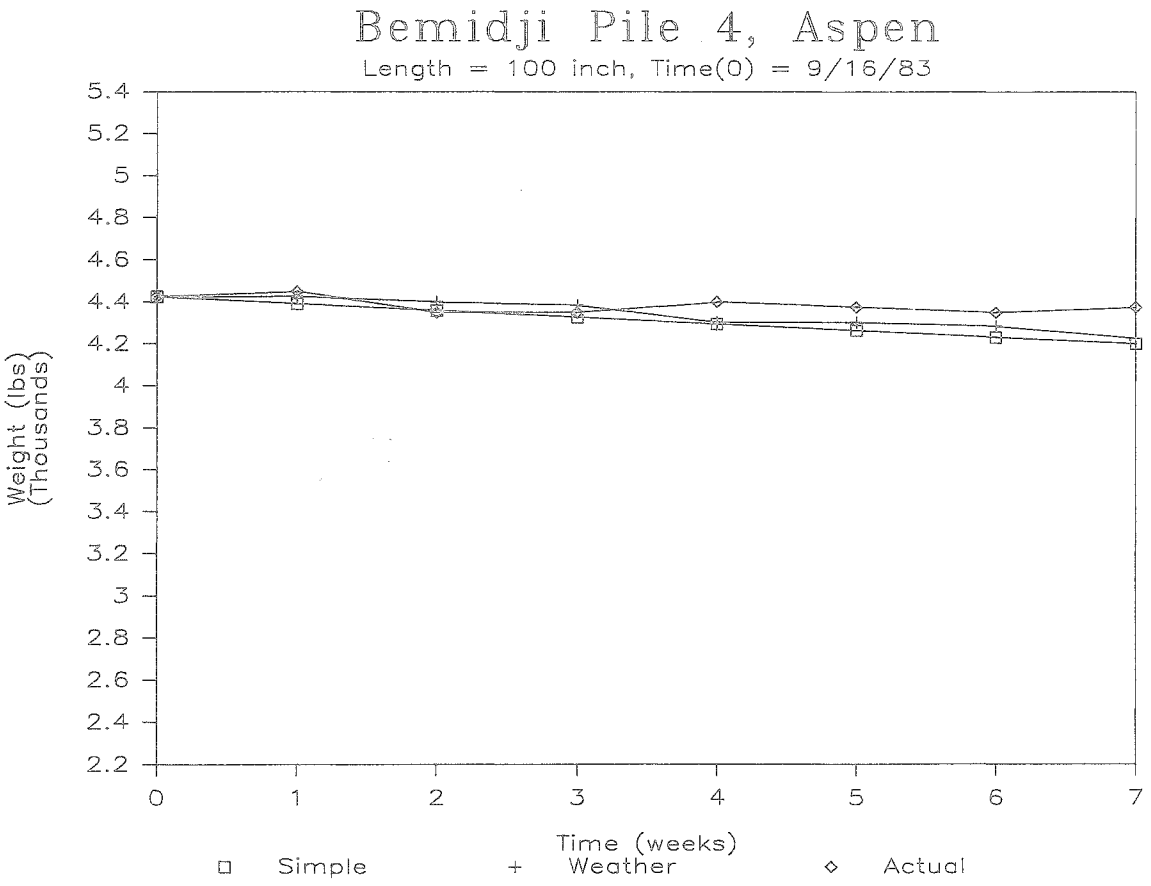
FIGURES

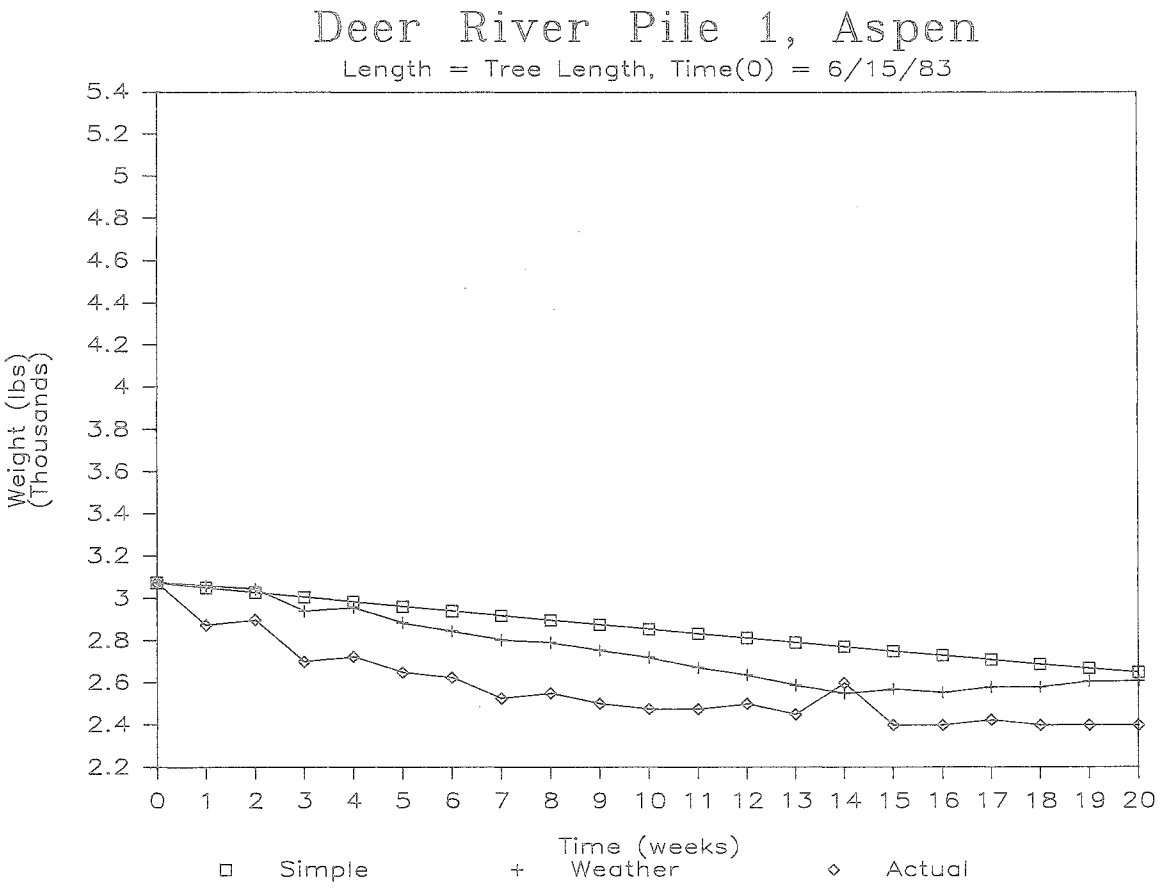
Figures 1-15 present weight versus time data. Measured (or actual) weight is plotted (◇), as are weights predicted using equation 1 or 2 (+), and weights predicted using the simpler models described by equations 3 or 4 (□).

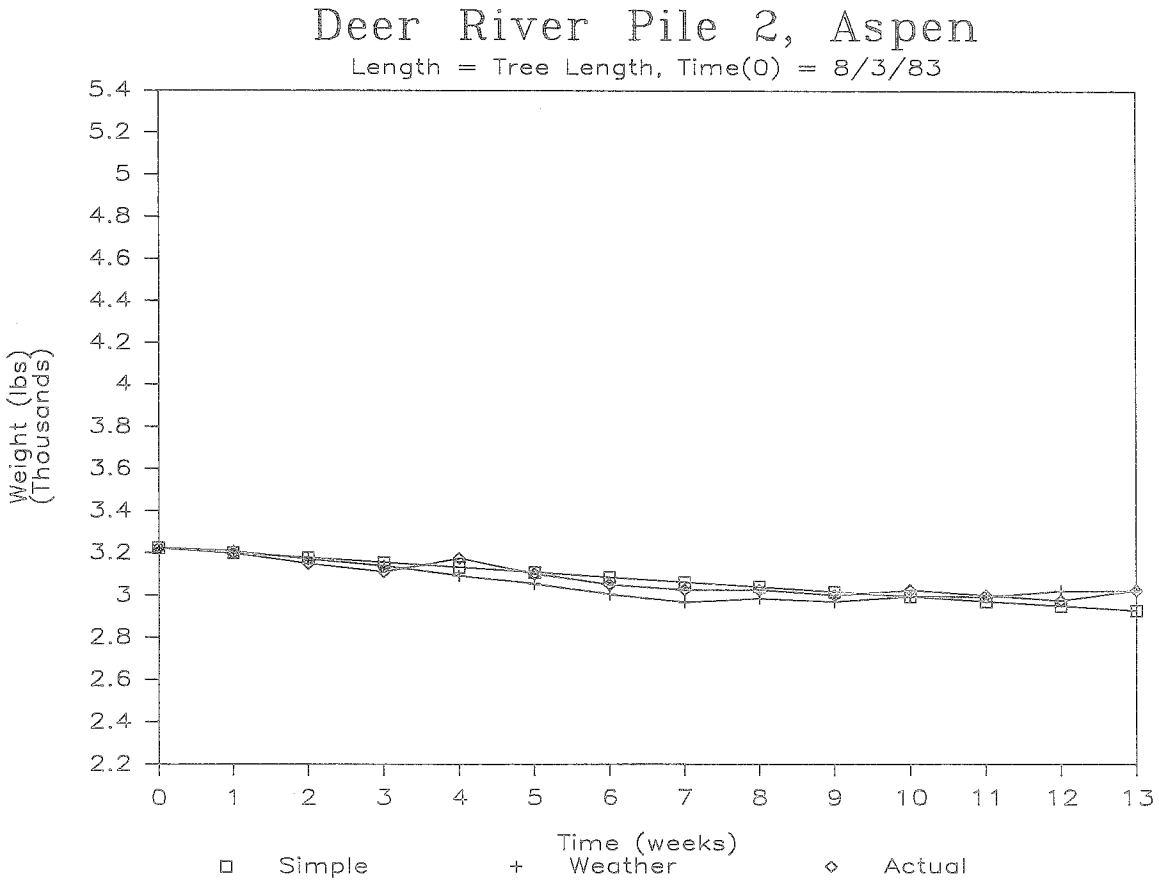


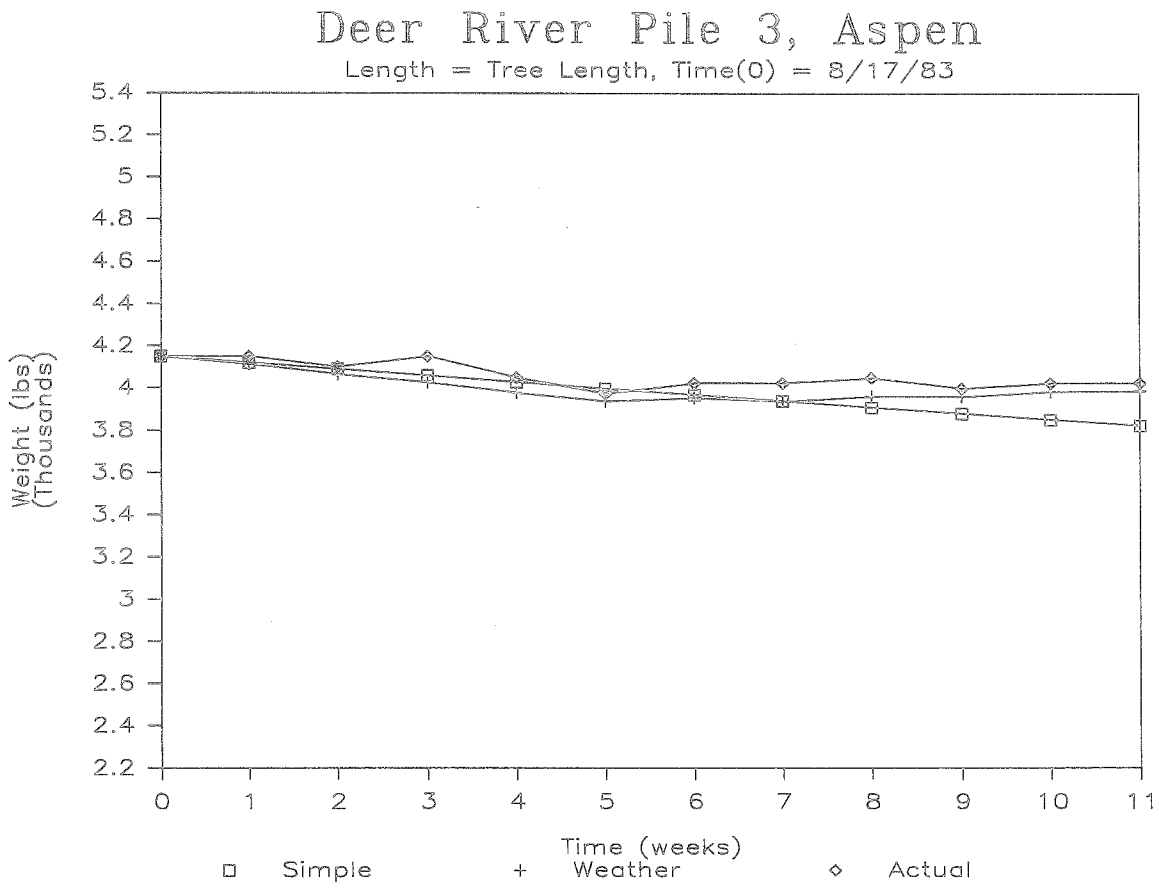

Bemidji Pile 2, Aspen
Length = 100 inch, Time(0) = 7/14/83
Weight (lbs)
(Thousands)
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Time (weeks)
Simple
Weather
Actual

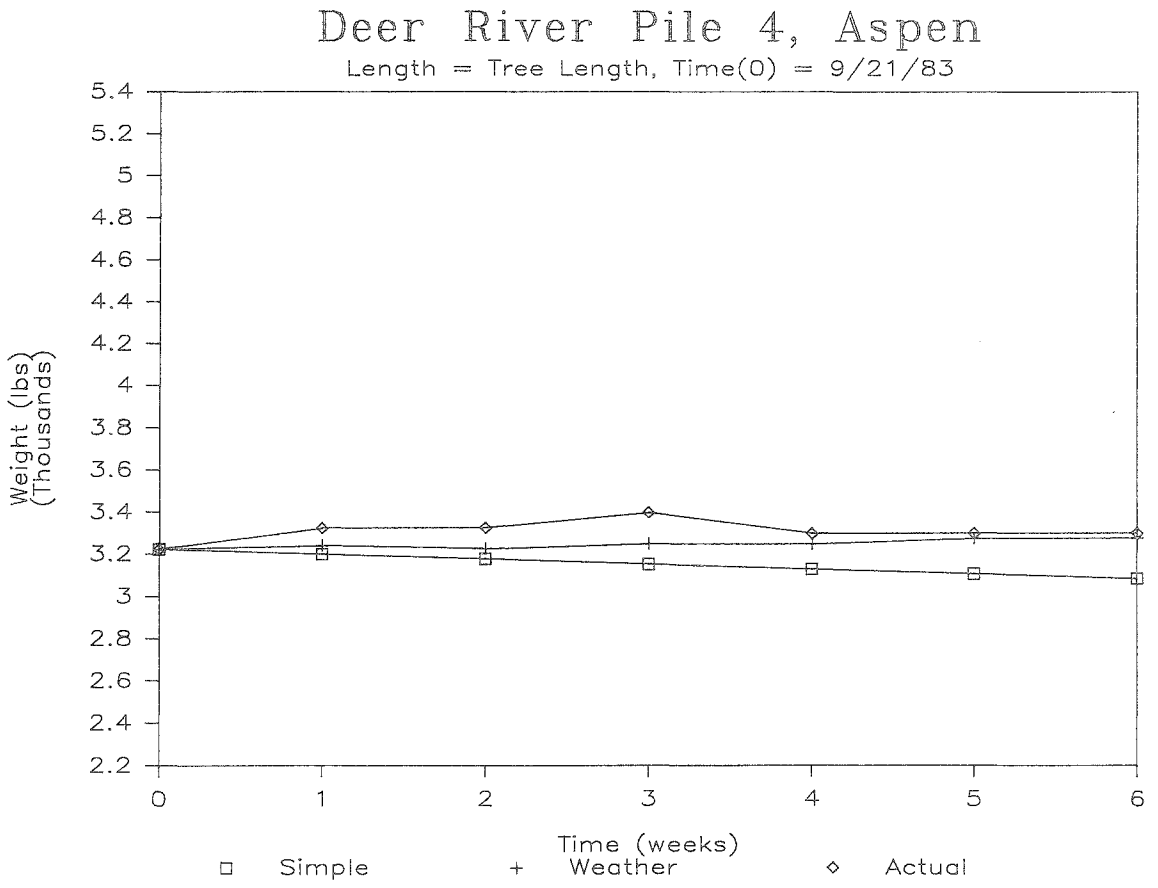

Bemidji Pile 3, Aspen
Length = 100 inch, Time(0) = 8/22/83
Weight (lbs)
(Thousands)
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
0 1 2 3 4 5 6 7 8 9 10 11
Time (weeks)
Simple
Weather
Actual

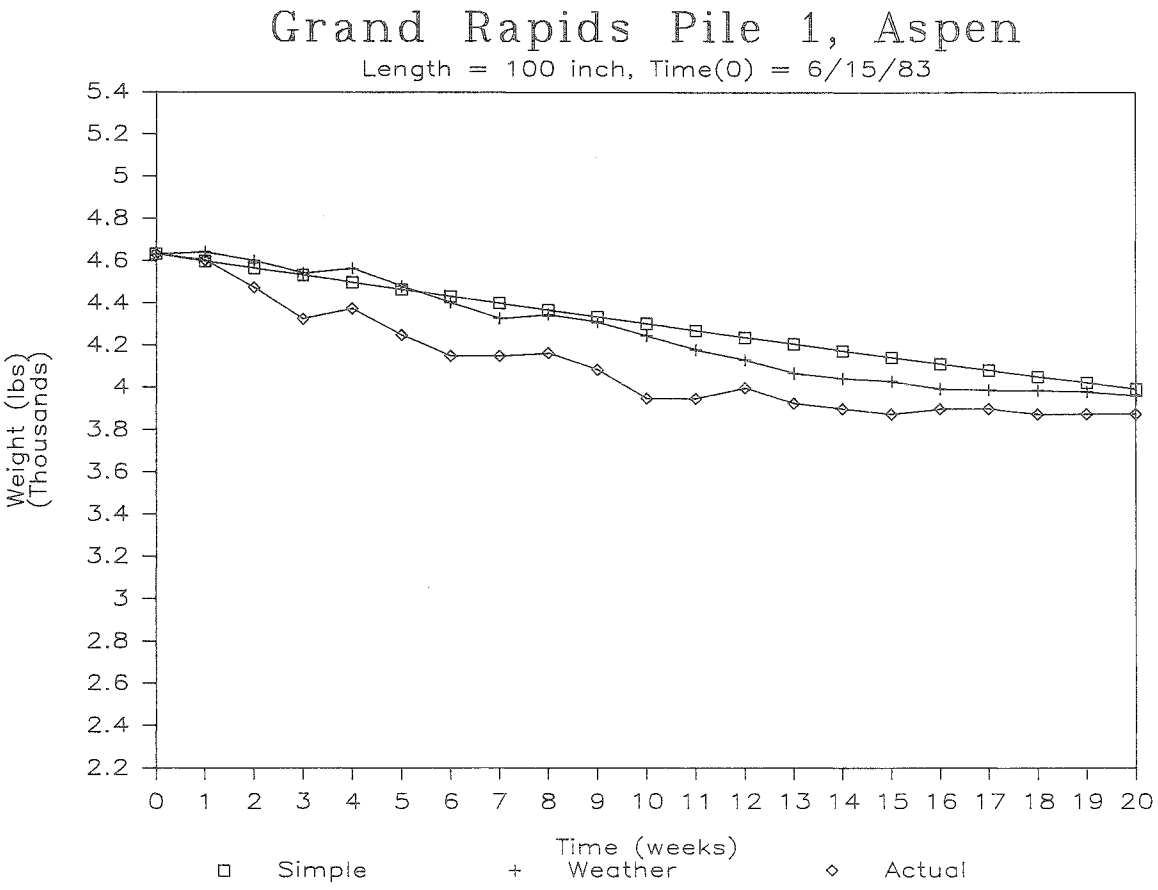

Bemidji Pile 4, Aspen
Length = 100 inch, Time(0) = 9/16/83
Weight (lbs) (Thousands)
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
0 1 2 3 4 5 6 7
Time (weeks)
□ Simple + Weather ◇ Actual

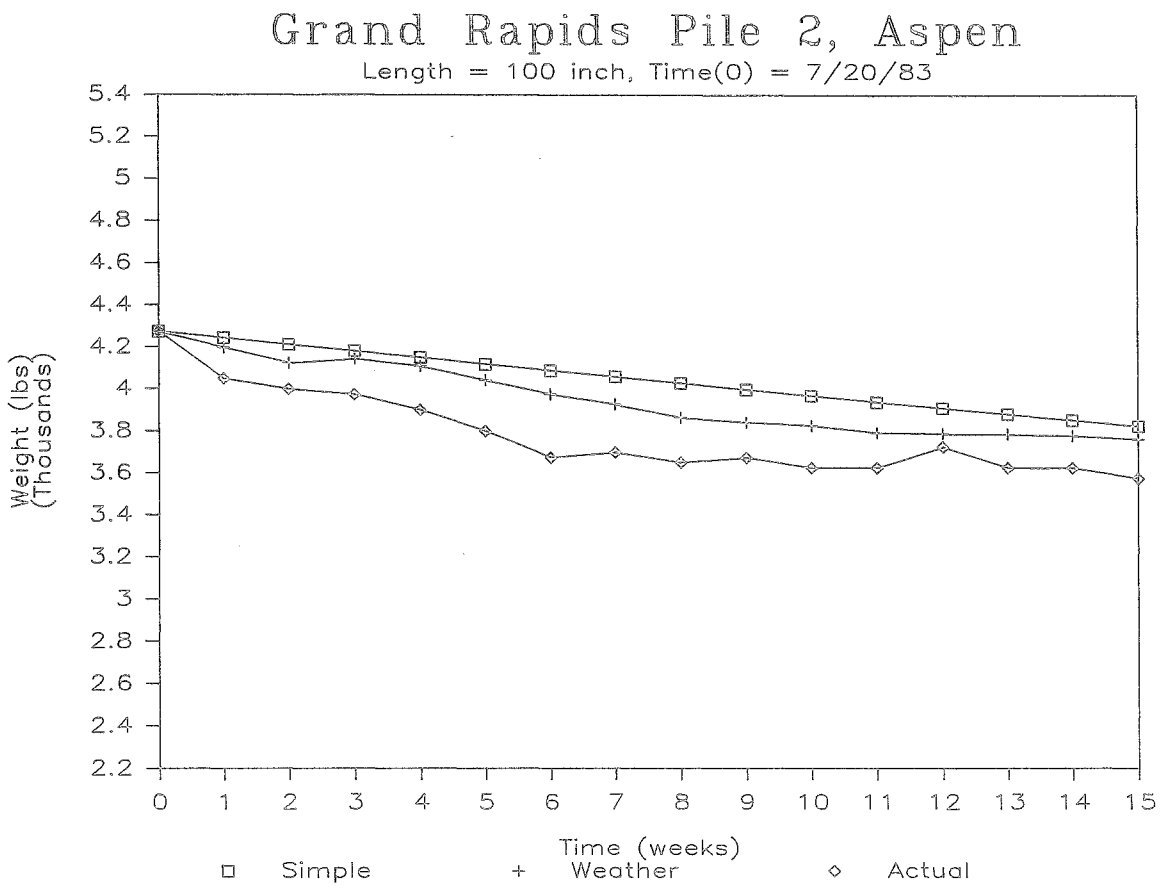

Deer River Pile 1, Aspen
Length = Tree Length, Time(0) = 6/15/83
Weight (lbs) (Thousands)
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Time (weeks)
□ Simple + Weather ◇ Actual

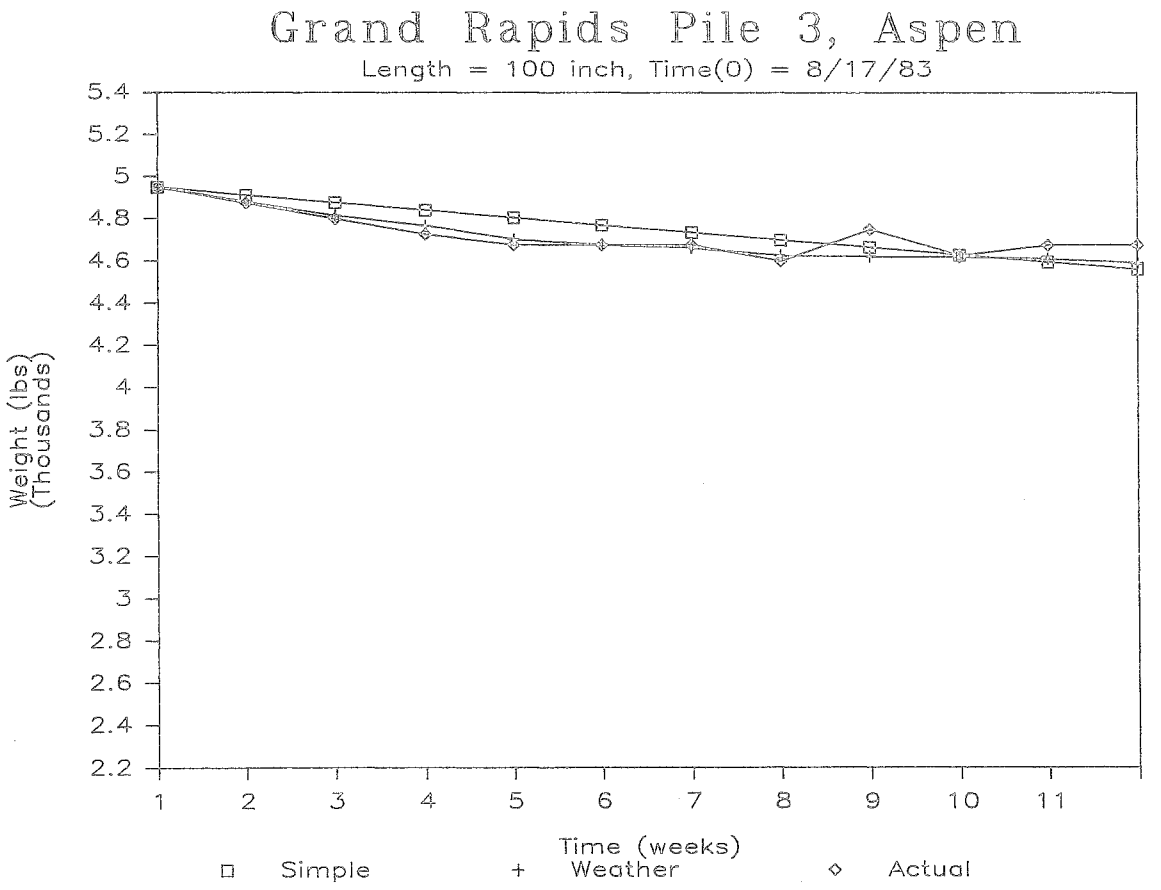

Deer River Pile 2, Aspen
Length = Tree Length, Time(0) = 8/3/83
Weight (lbs) (Thousands)
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Time (weeks)
Simple
Weather
Actual

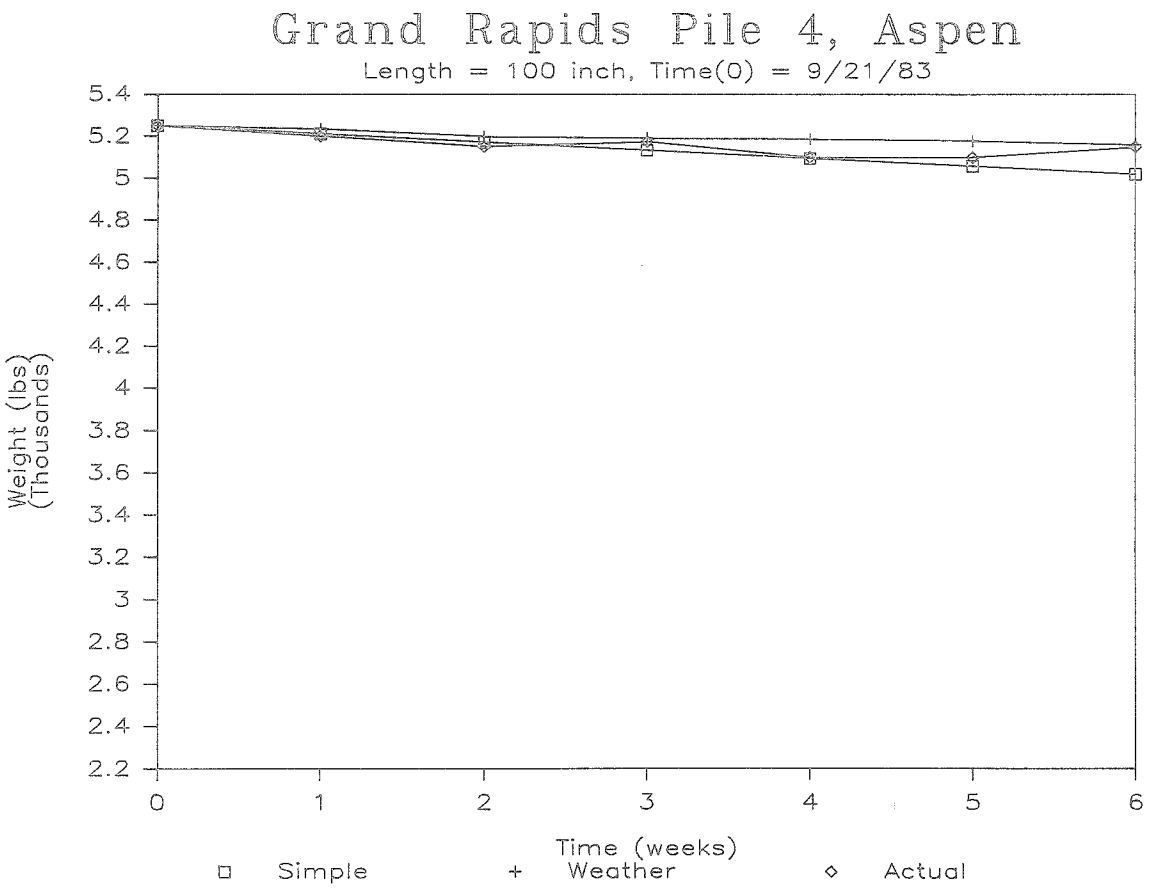

Deer River Pile 3, Aspen
Length = Tree Length, Time(0) = 8/17/83
Weight (lbs) (Thousands)
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
0 1 2 3 4 5 6 7 8 9 10 11
Time (weeks)
Simple
Weather
Actual

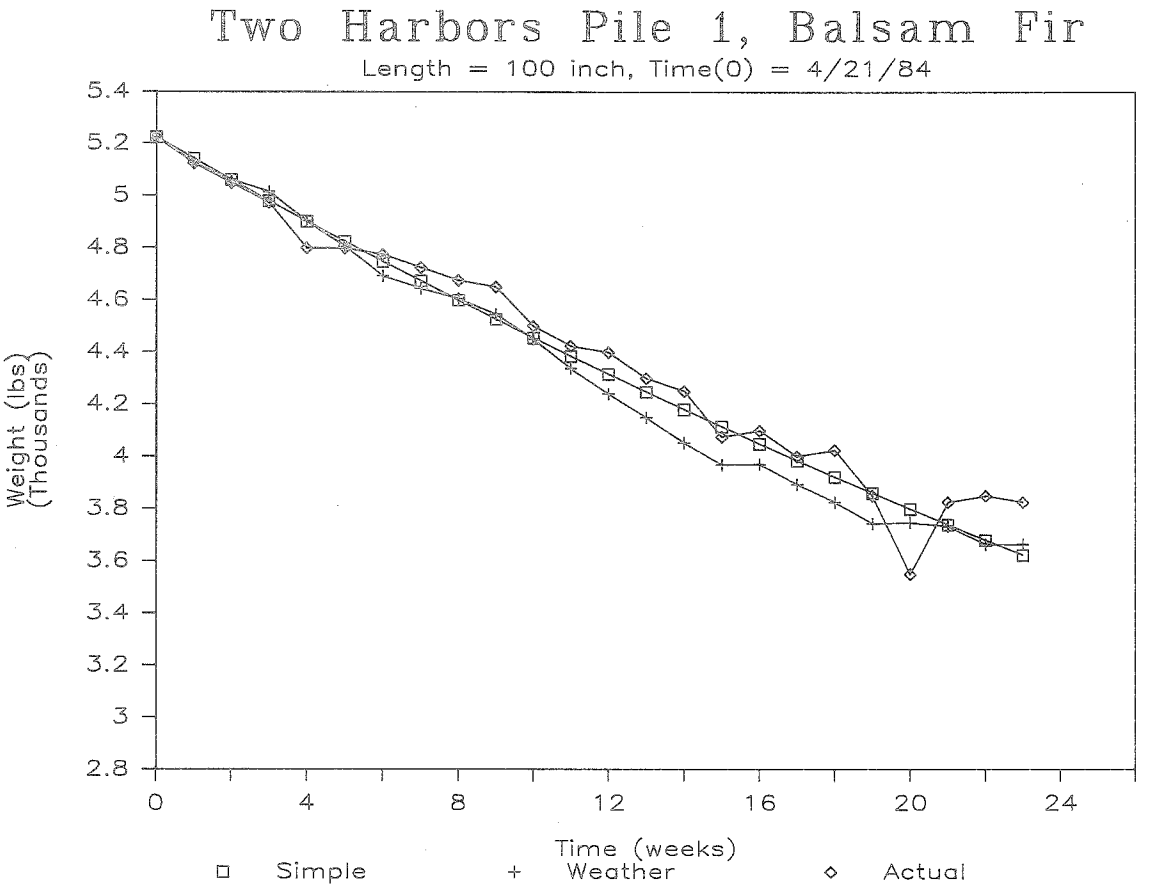

Deer River Pile 4, Aspen
Length = Tree Length, Time(0) = 9/21/83
Weight (lbs) (Thousands)
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
0 1 2 3 4 5 6
Time (weeks)
□ Simple + Weather ◇ Actual

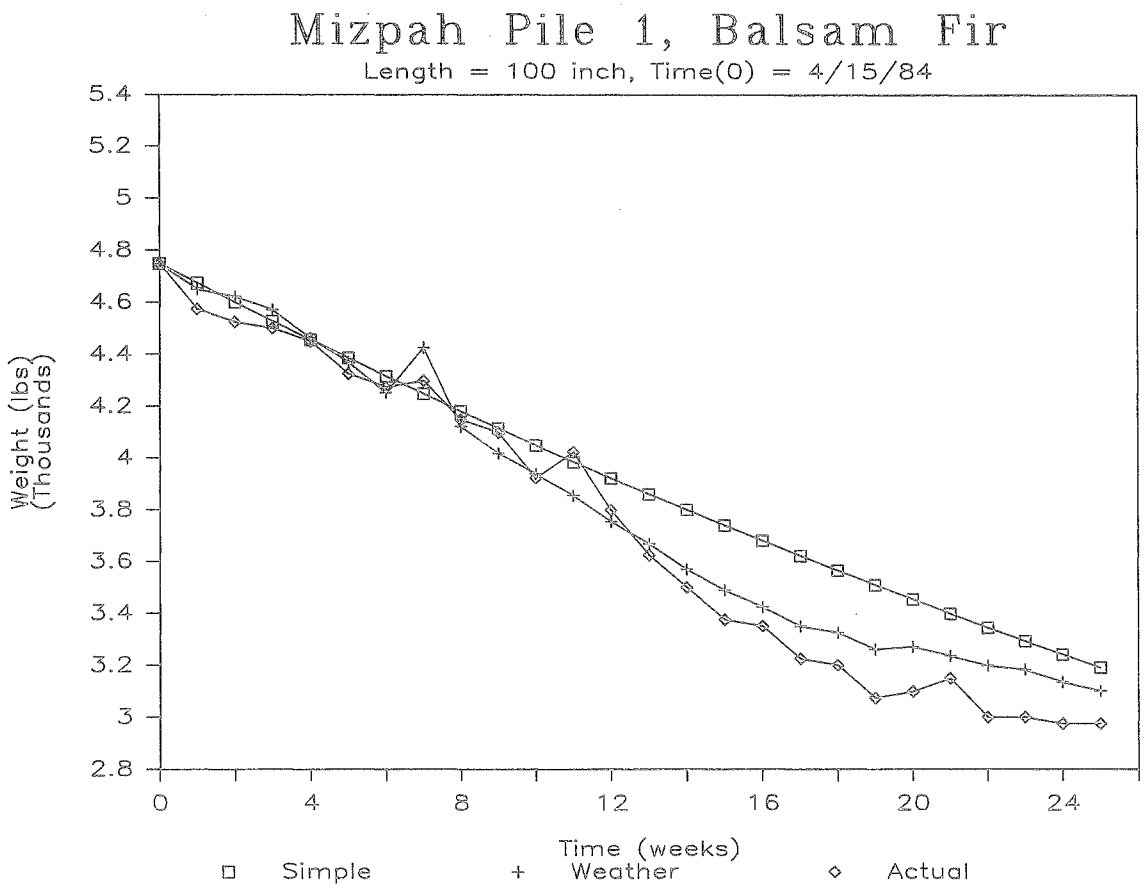

Grand Rapids Pile 1, Aspen
Length = 100 inch, Time(0) = 6/15/83
Weight (lbs) (Thousands)
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Time (weeks)
□ Simple + Weather ◇ Actual

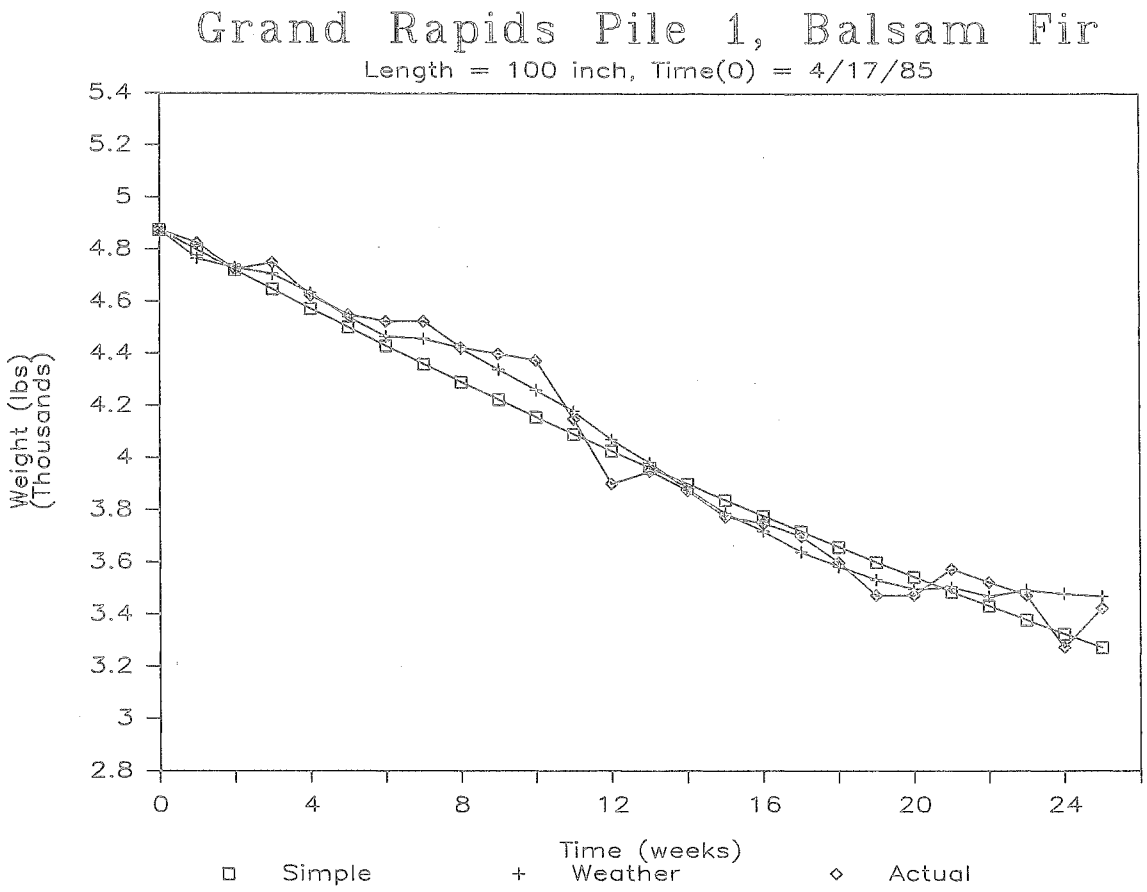

Grand Rapids Pile 2, Aspen
Length = 100 inch, Time(0) = 7/20/83
Weight (lbs) (Thousands)
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Time (weeks)
□ Simple + Weather ◇ Actual


Grand Rapids Pile 3, Aspen
Length = 100 inch, Time(0) = 8/17/83
Weight (lbs) (Thousands)
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
1 2 3 4 5 6 7 8 9 10 11
Time (weeks)
□ Simple + Weather ◇ Actual


Grand Rapids Pile 4, Aspen
Length = 100 inch, Time(0) = 9/21/83
Weight (lbs) (Thousands)
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
0
1
2
3
4
5
6
Time (weeks)
Simple
Weather
Actual


Two Harbors Pile 1, Balsam Fir
Length = 100 inch, Time(0) = 4/21/84
Weight (lbs) (Thousands)
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
0
4
8
12
16
20
24
Time (weeks)
Simple
Weather
Actual


Mizpah Pile 1, Balsam Fir
Length = 100 inch, Time(0) = 4/15/84
Weight (lbs) (Thousands)
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
0
4
8
12
16
20
24
Time (weeks)
Simple
Weather
Actual


Grand Rapids Pile 1, Balsam Fir
Length = 100 inch, Time(0) = 4/17/85
Weight (lbs) (Thousands)
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
0
4
8
12
16
20
24
Time (weeks)
Simple
Weather
Actual