FPS Version 6 to Version 7 Differences   (a Frequently Asked Question)

Beginning in January 28 – 29, 2013 the refinements in FPS Version 7 were outlined at a two-day workshop for all FBRI organizations using FPS Version 6. Version 7 software was designed to be more *sensitive to stand structure* than previously. These changes were identified again at the year-end 2013 and year-end 2014 FBRI Annual Meetings.

Many working forest organizations have transitioned to FPS Version 7 and others are anticipating the transition in the near future. However, a number of inventory foresters and consultants have made comparisons of outputs between FPS Versions and have concluded that there is a "bug" or internal "error" in the updated software.

The change observed between Version 6 and Version 7 is a design feature, not a "bug".

Explanation

Let us consider two stands to cruise. The first is an even-aged stand where all trees were established within a few years after a clearcut harvest removal. The stand is now about 16-inches in diameter and recently cruised and compiled in FPS Versions 6 and 7. The height sub-sample is somewhat artificial to provide visual clarity in charts. Only odd-dbh classes were sampled for heights while all even-dbh heights would have to be estimated in the FPS Cruise Compiler as displayed in Figure 1.

Figure 1. FPS Version 6 regression estimation ("*") of total heights.

```
===================================================================
  Stand:          1                          Ht = f(Dbh) Regression
  Species DF..
  ----[? = Not-Fitted]---------------------------------------------
  187|                                                            |
     |                                                            |
  167|                                                            |
     |                                                            |
  148|                                                            |
     |                                                            |
  128|                                                            |
     |                                 1   1 1 * 1 * * * * * * * *|
  108|                           1 2 * 2 * 2 2   2                |
     |                   1 * 3 * 2 1                              |
   89|               * 2 2                                        |
     |         1   2   1                                          |
   69|         2 * 1                                              |
     |       *                                                    |
   49|                                                            |
     |     *                                                      |
   30|                                                            |
     |   *                                                        |
   10|                                                            |
     | *                                                          |
     |...|...|...|...|...|...|...|...|...|...|...|...|...|...|...|
         1   4   6   8  11  13  15  18  20  22  25  27  30  32  34
     Height (feet)          DBH (inches)
           B0 =   156.645  B1 =    -2.395  B2 =     -.600
            F =   462.463  R-SQ =    .935   N =        33
```

Note that the regression coefficients and statistics are included in the Figure. The numbers on the chart represent the number of heights measured in each diameter class.

This cruise compilation results in a stand table displaying structure and volume in Figure 2.

Figure 2. Output from FPS Version 6 Cruise Compiler for Stand #01.

Oregon Cascades Library - 2006 2015-01-17
CRUISE REPORT Std: 1 Msmt Yr: 2014 by Crew

Site Age	Sp..	Dbh	#Trees	Basl Area	Total Ht	%Cr	Tap Cls	....Cubic Volume.... Stem	Merch	Net	Scribner Bdf Merch	Net	Log dib
				** values / acre **									
	DF.. - Douglas-fir												
		5	3.0	0	70	27	35	8	0	0	0	0	0
		6	3.0	1	74	31	34	15	0	0	0	0	0
		7	3.0	1	75	35	33	23	0	0	0	0	0
		8	3.0	1	83	36	32	34	28	26	120	114	6
		9	3.0	1	86	39	32	45	39	37	210	199	7
		10	3.0	2	90	42	31	58	52	50	269	256	7
		11	3.0	2	93	45	30	72	66	63	300	285	8
		12	3.0	2	96	47	29	87	80	76	300	285	9
		13	3.0	3	99	49	29	103	94	90	420	398	9
		14	3.0	3	100	52	28	120	114	109	539	513	10
		15	3.0	4	103	55	27	140	133	127	570	541	10
		16	3.0	4	104	58	26	158	152	144	660	627	11
		17	3.0	5	107	60	25	181	174	165	749	712	11
		18	3.0	5	107	63	24	201	194	184	749	712	12
		19	3.0	6	111	64	23	229	221	210	930	883	12
		20	3.0	7	110	68	23	248	240	228	1049	997	13
		21	3.0	7	112	70	22	275	267	253	1140	1083	13
		22	3.0	8	112	74	21	300	290	276	1289	1225	14
		23	3.0	9	113	76	21	326	316	300	1469	1396	14
		24	3.0	9	114	79	20	356	345	328	1469	1396	15
		25	3.0	10	113	83	20	378	367	349	1620	1538	15
0													
0	DF..	16	63.0	90	108			3366	3181	3022	13860	13167	12

The artificial component is that each dbh class has three trees and the even-dbh classes are being estimated by a regression from the odd-dbh class field measurements of total height.

Now take the exact same cruise details and compile them in FPS Version 7 for comparison.

Instead of regressing a single curved line through all diameters in the stand, the height variability is retained in the output. This is accomplished by using non-parametric regression methods. Non-parametric means that there are no parameters created for an equation. In fact, there is no equation to estimate heights from diameters.

Each height sample tree is tallied by its dbh and dbh/height ratio (a taper class). This sampled population distribution is then the basis to estimate heights for trees which were only tallied by species and dbh class (no height measurement). Figure 3 displays this population distribution.

Figure 3. Estimation of total heights for un-sampled trees in FPS Version 7.

```
========================================================================
 Stand#:         1  Year: 2014  Species: DF..  Height sample tally
 ------------------------------------------------------------------------
              Dbh\  ..... Dbh / (Height - 1.37)  (cm/m) .........
                    0.67  1.00  1.33  1.67  2.00  2.33  2.67  3.00
                    ----------------------------------------------

              Dbh\  ..... Dbh / (Height - 4.5)...(in/ft) .........
          Sp  Size\ 0.08  0.12  0.16  0.20  0.24  0.28  0.32  0.36  Count
          --  ----  ----  ----  ----  ----  ----  ----  ----  ----  -----
     #Obs:DF..   1                                                      0
     #Obs:DF..   2     5     1                                          6
     #Obs:DF..   3           6                                          6
     #Obs:DF..   4           2     4                                    6
     #Obs:DF..   5                 5     1                              6
     #Obs:DF..   6                       5     1                        6
     #Obs:DF..   7                             3                        3
              -----------------------------------------------------------
      DoH:DF..   1
      DoH:DF..   2  0.70  0.88
      DoH:DF..   3        0.98
      DoH:DF..   4        1.12  1.25
      DoH:DF..   5              1.41  1.54
      DoH:DF..   6                    1.67  1.83
      DoH:DF..   7                          1.92
              -----------------------------------------------------------
     %Cnt:DF..   2   83%   17%                                          2
     %Cnt:DF..   3        100%                                          2
     %Cnt:DF..   4         33%   67%                                    2
     %Cnt:DF..   5               83%   17%                              2
     %Cnt:DF..   6                     83%   17%                        2
```

#Obs:DF = Number of measured heights by Dbh Size Class and Dbh/Height ratio class.
DoH:DF = Average Dbh/(Height-4.5) ratio expressed in centimeters dbh per meter of height.
#Cnt:DF = Percentage distribution of height measurements within a Dbh Size Class (horizontal).

Note at the top of the Figure are duplicate horizontal scales, one in cm/m and one in inches/foot. These represent the expected midpoint values for each class while the "DoH:DF" are actuals.

In each horizontal Dbh Size grouping this stand is observed to have two heights with differing distributions. Therefore whatever tally of trees exist in these dbh classes without height measurements will be assigned not a single height as in FPS Version 6, but a distribution of heights according to the observed distribution in Figure 3.

This approach results in the same distribution of diameters at breast height (dbh), but a much broader distribution of heights within those diameters. Now compare Figure 4 results to Figure 2 results from the same cruise.

Note that in Version 6 the cruise compilation resulted in 21 dbh classes with a single averaged height for each diameter class. Volumes are derived from this distribution.

Note that in Version 7 the cruise compilation resulted in 31 dbh classes with multiple heights within some diameter classes. Volumes are derived from this distribution.

Figure 4. Output from FPS Version 7 Cruise Compiler for Stand #01.

Oregon Cascades Library - 2006 FPS 2014 Database
CRUISE REPORT Std: 1 Msmt Yr: 2014 by Crew

Site Age	Sp..	Dbh	#Trees	Basl Area	Total Ht	%Cr	Tap Cls	....Cubic Volume.... Stem	Merch	Net	Scribner Merch	Bdf Net	Log dib
				** values / acre **									
		5	3.0	0	70	0	29	8	0	0	0	0	0
		6	2.5	0	75	0	29	12	0	0	0	0	0
		6	0.5	0	62	0	29	2	0	0	0	0	0
		7	2.0	1	77	0	29	14	0	0	0	0	0
		7	1.0	0	71	0	29	6	0	0	0	0	0
		8	2.5	1	91	0	28	28	22	21	100	95	7
		8	0.5	0	81	0	28	5	3	3	15	14	7
		9	3.0	1	86	0	28	42	35	34	180	171	7
		10	3.0	2	89	0	28	54	48	45	210	199	8
		11	3.0	2	92	0	28	67	62	59	270	256	9
		12	3.0	2	105	0	27	89	80	76	300	285	9
		13	2.0	2	101	0	27	67	61	58	280	266	10
		13	1.0	1	95	0	27	32	29	28	120	114	10
		14	1.0	1	108	0	26	41	39	37	180	171	11
		14	2.0	2	98	0	27	76	70	66	280	266	11
		15	3.0	4	103	0	26	137	130	124	570	541	11
		16	3.0	4	112	0	26	167	160	152	690	655	12
		17	3.0	5	107	0	25	180	173	164	750	712	13
		18	2.5	4	111	0	25	172	166	158	625	593	13
		18	0.5	1	102	0	25	31	30	29	125	118	13
		19	2.0	4	113	0	24	156	150	143	620	589	14
		19	1.0	2	107	0	24	74	71	68	300	285	14
		20	2.5	5	120	0	24	227	220	209	950	902	15
		20	0.5	1	112	0	24	42	41	39	175	166	15
		21	3.0	7	112	0	24	279	271	257	1140	1083	15
		22	3.0	8	113	0	23	307	298	283	1290	1225	16
		23	2.0	6	115	0	23	226	220	209	980	931	17
		23	1.0	3	109	0	23	107	104	99	470	446	17
		24	2.5	8	124	0	22	327	316	300	1450	1377	17
		24	0.5	2	114	0	22	60	58	55	245	232	17
		25	3.0	10	113	0	22	389	378	359	1680	1596	18
0													
0	DF..	16	63.0	90	110			3440	3248	3086	13995	13295	12

Both versions of FPS produce the exact same average dbh, numbers of trees per acre and basal area per acre. However, Version 6 resulted in 13,860 gross Scribner board feet per acre while Version 7 resulted in 13,995 gross Scribner board feet per acre. This is slightly less than a one percent increase in total volume due to the difference in the Cruise Compilers.

This is not significant in this example and could be ignored. However, there is a reason that this occurs and the magnitude of the differences are highly linked to the stand structure found in the cruise.

Next is this same comparison of cruise compilation between Version 6 and Version 7. The difference is that this is an all-aged stand where repeated thinning entries have left a diverse distribution of tree structures. This stand includes small trees with long crowns which established in openings as well as tall trees with small diameters which developed in the original overstory.

Figure 5 provides a view of the FPS Version 6 height regression over diameter.in this all-aged stand.

Figure 5. FPS Version 6 regression estimation ("*") of total heights – Stand #02.

```
=================================================================
Stand:          2                          Ht = f(Dbh) Regression
Species DF..
----[? = Not-Fitted]---------------------------------------------
187|                                                            |
   |                                                            |
167|                                                            |
   |                                                            |
148|                                                            |
   |                                                            |
128|                                                           *|
   |                                   1   1 1     * * * * * *  |
108|                             1 1       1 2 * *              |
   |                     1   1     1 * 1 * 1                    |
 89|                 1       1 * 1 1   1                        |
   |           1   1   * 1 *     1                              |
 69|       1       * 1       1                                  |
   |             * 1     1                                      |
 49|         * 1     1                                          |
   |       1   1   1                                            |
 30|     * 1                                                    |
   |                                                            |
 10|   *                                                        |
   | *                                                          |
   |...|...|...|...|...|...|...|...|...|...|...|...|...|...|...|
       1   4   6   8  11  13  15  18  20  22  25  27  30  32  34
   Height (feet)          DBH (inches)
         B0 =   293.066  B1 =    -3.703  B2 =     -.400
          F =    69.859  R-SQ =    .686   N =       33
```

Note that the regression coefficients and statistics are included in this Figure.

This cruise compilation results in a stand table displaying structure and volume in Figure 6. This all-aged stand has the same number of trees across the same diameters as observed in the even-aged stand. The difference is the variation in observed heights. FPS Version 6 essentially ignores this variation *within* a diameter class and regresses the general height trend *between* classes. The "*" symbols on the chart represent that regression trend. The numbers on the chart represent the number of height measured trees in each diameter class.

Figure 6. Output from FPS Version 6 Cruise Compiler for Stand #02.

```
==============================================================================
 Oregon Cascades Library - 2006                                     2015-01-17
 CRUISE REPORT  Std:         2                           Msmt Yr: 2014 by Crew

===============================================================================
```

Site Age	Sp..	Dbh	#Trees	Basl Area	Total Ht	%Cr	Tap Cls	....Cubic Volume.... Stem	Merch	Net	Scribner Bdf Merch	Net	Log dib
				** values / acre **									
	DF.. - Douglas-fir												
		4	3.0	0	45	33	32	3	0	0	0	0	0
		5	3.0	0	46	40	32	6	0	0	0	0	0
		6	3.0	1	54	41	32	11	0	0	0	0	0
		7	3.0	1	58	45	32	18	0	0	0	0	0
		8	3.0	1	62	49	32	25	20	19	90	85	6
		9	3.0	1	67	50	31	35	27	26	90	85	7
		10	3.0	2	70	53	30	45	40	38	180	170	7
		11	3.0	2	75	55	30	58	53	51	240	228	8
		12	3.0	2	78	57	29	71	66	63	269	256	9
		13	3.0	3	82	59	28	86	81	77	300	285	9
		14	3.0	3	85	62	27	102	97	92	360	341	10
		15	3.0	4	88	64	26	120	113	107	450	427	10
		16	3.0	4	92	65	25	140	131	124	570	541	11
		17	3.0	5	93	68	25	159	153	145	600	570	11
		18	3.0	5	98	69	24	185	178	169	690	655	12
		19	3.0	6	98	73	23	204	196	186	810	769	12
		20	3.0	7	103	73	23	233	225	214	900	854	13
		21	3.0	7	102	77	22	253	245	232	1019	969	13
		22	3.0	8	108	76	21	289	280	266	1289	1225	14
		23	3.0	9	106	81	21	309	299	284	1289	1225	14
		24	3.0	9	111	81	20	347	337	320	1469	1396	15
0													
0	DF..	15	63.0	80	95			2711	2549	2422	10620	10089	12

Now take the exact same cruise details and compile them in FPS Version 7 for comparison.

Instead of regressing a single curved line through all diameters in the stand, the height variability is retained in the output. This is accomplished by using non-parametric regression methods. Non-parametric means that there are no parameters created for an equation. In fact, there is no equation to estimate heights from diameters.

Each height sample tree is tallied by its dbh and dbh/height ratio (a taper class). This sampled population distribution is then the basis to estimate heights for trees which were only tallied by species and dbh class (no height measurement). Figure 7 displays this population distribution.

Figure 7. Estimation of total heights for un-sampled trees in FPS Version 7.

```
=======================================================================
 Stand#:         2  Year: 2014  Species: DF..  Height sample tally
 ------------------------------------------------------------------------
             Dbh\  ..... Dbh / (Height - 1.37)  (cm/m) .........
                   0.67  1.00  1.33  1.67  2.00  2.33  2.67  3.00
                   ----------------------------------------------

             Dbh\  ..... Dbh / (Height - 4.5)...(in/ft) .........
         Sp  Size\ 0.08  0.12  0.16  0.20  0.24  0.28  0.32  0.36  Count
         --  ----  ----  ----  ----  ----  ----  ----  ----  ----  -----
     #Obs:DF..  1     1     1     1     0     0     0     0     0      3
     #Obs:DF..  2     1     2     1     2     0     0     0     0      6
     #Obs:DF..  3     0     2     2     2     0     0     0     0      6
     #Obs:DF..  4     0     0     3     1     2     0     0     0      6
     #Obs:DF..  5     0     0     1     3     2     0     0     0      6
     #Obs:DF..  6     0     0     0     3     3     0     0     0      6
             ----------------------------------------------------------
      DoH:DF..  1  0.54  0.91  1.42
      DoH:DF..  2  0.71  0.97  1.18  1.64
      DoH:DF..  3        1.03  1.33  1.78
      DoH:DF..  4              1.31  1.52  1.85
      DoH:DF..  5              1.40  1.61  1.90
      DoH:DF..  6                    1.75  1.90
             ----------------------------------------------------------
     %Cnt:DF..  2   17%   33%   17%   33%                                2
     %Cnt:DF..  3         33%   33%   33%                                2
     %Cnt:DF..  4               50%   17%   33%                          2
     %Cnt:DF..  5               17%   50%   33%                          2
     %Cnt:DF..  6                     50%   50%                          2
```

#Obs:DF = Number of measured heights by Dbh Size Class and Dbh/Height ratio class.
DoH:DF = Average Dbh/(Height-4.5) ratio expressed in centimeters dbh per meter of height.
#Cnt:DF = Percentage distribution of height measurements within a Dbh Size Class (horizontal).

Note at the top of the Figure are duplicate horizontal scales, one in cm/m and one in inches/foot. These represent the expected midpoint values for each class while the “DoH:DF” are actuals.

In each horizontal Dbh Size grouping this stand is observed to have two or three heights with differing distributions. Therefore whatever tally of trees exist in these dbh classes without height measurements will be assigned not a single height as in FPS Version 6, but a distribution of heights according to the observed distribution in Figure 7.

This approach results in the same distribution of diameters at breast height (dbh), but a much broader distribution of heights within those diameters. Now compare Figure 8 results to Figure 6 results from the same cruise.

Note that in Version 6 the cruise compilation resulted in 21 dbh classes with a single averaged height for each diameter class. Volumes are derived from this distribution.

Note that in Version 7 the cruise compilation resulted in 59 dbh classes with multiple heights within some diameter classes. Volumes are derived from this distribution.

Figure 8. Output from FPS Version 7 Cruise Compiler for Stand #02.

Oregon Cascades Library - 2006 FPS 2014 Database

CRUISE REPORT Std: 2 Msmt Yr: 2014 by Crew

Site Age	Sp..	Dbh	#Trees	Basl Area	Total Ht	%Cr	Tap Cls	....Cubic Volume.... Stem	Merch	Net	Scribner Merch	Bdf Net	Log dib
				** values / acre **									
		4	1.0	0	66	0	29	1	0	0	0	0	0
		4	1.0	0	41	0	30	1	0	0	0	0	0
		4	1.0	0	28	0	29	0	0	0	0	0	0
		5	0.5	0	63	0	29	1	0	0	0	0	0
		5	1.0	0	48	0	29	2	0	0	0	0	0
		5	0.5	0	40	0	29	0	0	0	0	0	0
		5	1.0	0	30	0	27	1	0	0	0	0	0
		6	1.0	0	75	0	29	4	0	0	0	0	0
		6	1.0	0	52	0	29	3	0	0	0	0	0
		6	1.0	0	36	0	27	2	0	0	0	0	0
		7	0.5	0	79	0	28	3	0	0	0	0	0
		7	1.0	0	65	0	29	6	0	0	0	0	0
		7	0.5	0	54	0	28	2	0	0	0	0	0
		7	1.0	0	40	0	26	4	0	0	0	0	0
		8	1.0	0	80	0	28	10	7	7	30	28	7
		8	1.0	0	61	0	28	7	6	5	30	28	7
		8	1.0	0	44	0	25	5	4	4	20	19	7
		9	1.0	0	77	0	28	12	10	10	40	38	7
		9	1.0	0	61	0	27	10	8	8	30	28	7
		9	1.0	0	47	0	25	7	6	6	30	28	7
		10	1.0	1	90	0	28	18	16	15	70	66	8
		10	1.0	1	69	0	27	14	12	11	60	57	8
		10	1.0	1	52	0	24	10	9	8	30	28	8
		11	1.0	1	94	0	28	22	20	19	90	85	9
		11	1.0	1	74	0	27	18	16	15	70	66	9
		11	1.0	1	56	0	24	13	11	11	30	28	9
		12	1.0	1	97	0	27	28	25	24	100	95	9
		12	1.0	1	78	0	27	22	20	19	80	76	9
		12	1.0	1	60	0	24	16	14	13	50	47	9
		13	1.5	1	87	0	27	44	41	39	150	142	10
		13	0.5	0	76	0	26	12	11	11	45	42	10
		13	1.0	1	63	0	24	21	19	18	70	66	10
		14	2.0	2	93	0	26	72	67	64	240	228	11
		14	1.0	1	68	0	24	26	24	23	90	85	11
		15	1.5	2	100	0	26	66	63	60	270	256	11
		15	0.5	1	87	0	25	19	18	17	75	71	11
		15	1.0	1	72	0	24	31	29	28	110	104	11
		16	1.0	1	108	0	26	54	51	49	220	209	12
		16	1.0	1	92	0	25	46	43	41	170	161	12
		16	1.0	1	76	0	24	37	35	34	120	114	12
		17	0.5	1	106	0	25	29	28	27	125	118	13
		17	1.5	2	93	0	25	78	73	69	285	270	13
		17	1.0	2	79	0	23	44	42	40	150	142	13
		18	1.0	2	112	0	25	69	67	64	270	256	13
		18	1.0	2	98	0	25	61	59	56	230	218	13
		18	1.0	2	84	0	23	52	49	47	170	161	13
		19	0.5	1	115	0	24	39	38	36	155	147	14
		19	1.5	3	103	0	24	107	103	98	420	399	14
		19	1.0	2	88	0	23	60	57	54	210	199	14
		20	2.0	4	108	0	24	164	159	151	680	646	15
		20	1.0	2	92	0	23	69	67	63	260	247	15
		21	1.5	4	105	0	23	131	126	120	510	484	15
		21	1.5	4	96	0	23	120	116	110	465	441	15
		22	2.0	5	111	0	23	202	196	186	860	817	16
		22	1.0	3	101	0	23	91	88	84	390	370	16
		23	1.5	4	114	0	23	168	164	155	735	698	17
		23	1.5	4	105	0	22	155	150	143	630	598	17
		24	1.0	3	115	0	22	122	119	113	490	465	17
		24	2.0	6	109	0	22	233	226	215	980	931	17
0													
0	DF..	15	63.0	80	95			2695	2535	2408	10335	9818	11

Both versions of FPS produce the exact same average dbh, numbers of trees per acre and basal area per acre. However, Version 6 resulted in 10,620 gross Scribner board feet per acre while Version 7 resulted in 10,335 gross Scribner board feet per acre. This is slightly less than a three percent decrease in total volume due to the difference in the Cruise Compilers.

This is marginally significant in this example and may be ignored. However, there is a reason that this occurs and the magnitude of the differences are highly linked to the stand structure found in the cruise.

Using traditional Volume/Basal Area Ratios (VBARs) or smooth regression curves of Height over Dbh do not provide a robust characterization of all-aged stand structures. The ability to provide robust estimations of log size mixtures in all-aged stands requires a strong, well-distributed height sample in each cruise. Robust estimation of log mixtures also require a cruise compiler sensitive to these tree size distributions when populating the heights of dbh class tallied trees which were not sampled for height. FPS Version 7 was designed to capture this variation.

Even-aged stands, such as in Figure 1, may be cruised with all heights taken on every third plot. However, when stand structure becomes more characteristic of an all-aged structure, such as in Figure 5, then the cruise should include all heights on two of every three plots, or more. This is only a general guideline pointing toward the importance of height sampling. Any method of picking height sample trees on all plots or systematic selection of height-sample plots may be used. The significance in this topic pertains to fully characterizing (populating) the height by dbh matrix of trees found in each stand with a robust height sample.

The strength of future growth projections of these stands (volumes and log-size mixtures) requires both a Cruise Compiler and a Growth Model each of which embraces this all-aged stand variability and function accordingly. The FPS Version 7 Growth Model built-in design responds directly to the matrix of height by dbh distribution of tree sizes and to the matrix of spatial patterns between even-aged and all-aged stands. (The spatial components of FPS are discussed elsewhere.)

Individual stand input to the FPS Growth Model from the Version 6 Cruise Compiler comes from 21 records in the FPS DBHCLS table for Stand #1 and for Stand #2.

Individual stand input to the FPS Growth Model from the Version 7 Cruise Compiler comes from 31 records in the FPS DBHCLS table for Stand #1 and 59 records for Stand #2. Observe the differences between Figure 6 and Figure 8 which are the input lists to the growth model. Trees which have developed under different past stand histories respond differently in future.

For example, take a sample tree from the cruise which is currently 14-inches in diameter at breast height. If that tree developed to its current size under a heavy overstory canopy, then it would have a very short live crown and be quite tall (perhaps 80 feet). However, that same 14-inch tree could have developed in a large opening where it maintained a full, vigorous crown and may be much shorter (typically 50 feet). The future growth expectation of this tree with or without thinning release is highly determined by its initial Dbh to Height Ratio. Without strong height samples this is not known!

How to Use FPS Version 7 in an Inventory built with Version 6

This is where the forester has installed FPS Version 7 software and has compiled some existing cruised stands. The results are not identical to those from previous compilations using Version 6. The message sent to the Forest Biometrics Research Institute (FBRI) is that there appears to be a "bug" in the new cruise compiler! The FPS Regional Species Library has not changed. Only the software has changed. Therefore, it must be a "bug".

After reading and considering the discussion under the "Explanation" previous 9-page section, the forester now recognizes that this is not a "bug". Instead it is a purposeful "design feature".

When any complete upgrade in the FPS software is released, it should be incorporated into the existing inventory and planning process at a pre-determined point in time. A good time to insert new software is after the annual year-end inventory reporting activities. The FPS Forester's Guidebook describes these year-end activities.

Year-end reporting and software update sequence (example year-end 2014):

1) Copy the VegPoly 2013 GIS layer and name it VegPoly 2014;
2) Insert all harvest depletions and polygon updates into VegPoly 2014 which occurred within the calendar year;
3) Intersect VegPoly 2014 over VegPoly 2013 creating a VegStep temporary layer of polygons and slivers attributed with "Old_ID", "New_ID" and acres of each segment;
4) Link VegStep to the FPS Inventory database and on the menu "Run GIS Updates into FPS", click "Lump / Split Polygons to match GIS Polygons (New_ID)";
5) Select those resulting stands in the updated FPS Inventory which were harvested in 2014 to run a series of harvest depletion reports (this is the inventory depletion as opposed to what was recorded at the scale shack exiting the forest);
6) Deplete the stocking and volume from these selected stands using menu "Deplete stocking (Flag>0)";
7) Flag all stands in the FPS Inventory and select menu "Reserve Residual Inventory (Flag>0)";
8) Use the existing FPS Growth Model to grow all stands from year-end 2013 to year-end 2014.
9) Produce all desired annual growth reports for year-end 2014;
10) Load and only Flag all new cruises occurring in 2014 and after any harvest activities;
11) Run the Cruise Compiler followed by all desired year-end reports identifying the changes in the inventory due to new information (new cruise adjustments);
12) Archive both the FPS and GIS databases for year-end 2014 to match all reports;
13) Begin 2015 with a new Master database (FPS and GIS).

After completing Steps 1 through 10, take the FPS database at that point and convert it to an FPS Version 7 database. Then proceed with the following:

11) Load the FPS Version 7 software onto your computer and set the appropriate Environment Variables;
12) Flag all stands and verify the parameters in the SPECIES, SORTS, HARVEST and CLASS background tables (should be compatible with previous parameters);
13) Run the FPS Re-Merchandizer to populate all missing fields in tables.

14) Run all desired reports documenting adjustments in standing inventory due to software upgrades. This may include locally customized internal reports used in previous years.
15) Now Flag only the new 2014 cruises and run the FPS Cruise Compiler;
16) Produce all desired year-end reports identifying the changes in the inventory due to new information (new cruise adjustments);
17) Archive both the FPS and GIS databases for year-end 2014 to match all reports;
18) Begin 2015 with a new Master database (FPS and GIS).

The importance of this series of steps is their sequence without backing up to previous years. Upgrades in software packages are like incorporating new cruises into an inventory. In this previous example, we had a perfectly good inventory at year-end 2013 using FPS Version 6. We updated that inventory from year-end 2013 using the existing software to produce a perfectly good year-end 2014. Only as the last step at year-end do we introduce the changes in the inventory due to new cruises which occurred during the year. These new cruises will change the statistics for each of the stands included. This is a standard expectation as a result of new field sampling during the year. Adjustments in standing inventory are easily reported and explained.

This is the point when new software upgrades should be incorporated. Only the new cruises should be compiled with the new software. Do not re-compile old cruises and do not re-grow these old cruises to change the year-end 2014 stand statistics.

To re-compile old cruises with new software may create a different set of resulting statistics. To incorporate those differences would imply backing up to adjust year-end 2013 and perhaps years previous to that! This makes no more sense than incorporating a cruise from 2013 which was inadvertently missed and then compiling it in 2014 to adjust the year-end 2013 inventory already reported and archived. When changes occur due to new information (new cruises, new software, and/or new ownership), then only those stands directly affected in the current year-end should be Flagged and invoked.

Transition from Traditional Breast Height Site to 10-meter Site Classification

Since the early 1960s foresters in the west have been using total height at breast height age of 50 years as an index of macro-site capacity. Older site curves were based on total height at 100 years total age. Southern foresters have used total height at 25 years total age. ***Macro-site*** capacity is used here as the sustainable rate of height growth achievable due to local soil, climate and topographic conditions. This definition underlies the goal of traditional site classification.

Micro-site capacity is used here as the rate of *early height growth* achievable due to tree vigor, nutrient additions, and the degree of stress relief from vegetative, insect and disease factors. Management of micro-site factors and magnitudes is within the scope of the practice of silviculture.

Over centuries, foresters have become accustomed to measurements taken at breast height (4.5-feet from ground level) simply because of the ease of access. Age and diameter at breast height may be obtained while standing next to a tree and without requiring a ladder or a saw. Foresters simply like measurements at breast height because they are quick and easy to obtain.

Requirements for precise measurements of Macro-site capacity and Micro-site silvicultural effects have evolved beyond the reliance on breast height age. Simply because measurements at breast height are easily obtained does not make them useful or desirable parameters. Note Figure 9.

In 1966 Dr. Jim King published site index curves and tables for Douglas-fir in the Pacific Northwest. It was Weyerhaeuser Forestry Paper No. 8. Equations and site values from that report have been incorporated into most forestry biometrics (tree-site, soil-site, yield models and annual allowable harvest schedules) throughout the West. All 85 of the sample plots came from western Washington. Only four were based on felled-trees. In 1984 Dr. Bob Monserud published Douglas-fir site curves and equations for Inland Douglas-fir based on felled-tree measurements in Idaho, eastern Washington and eastern Oregon. The published article was Forest Science 30:943-965.

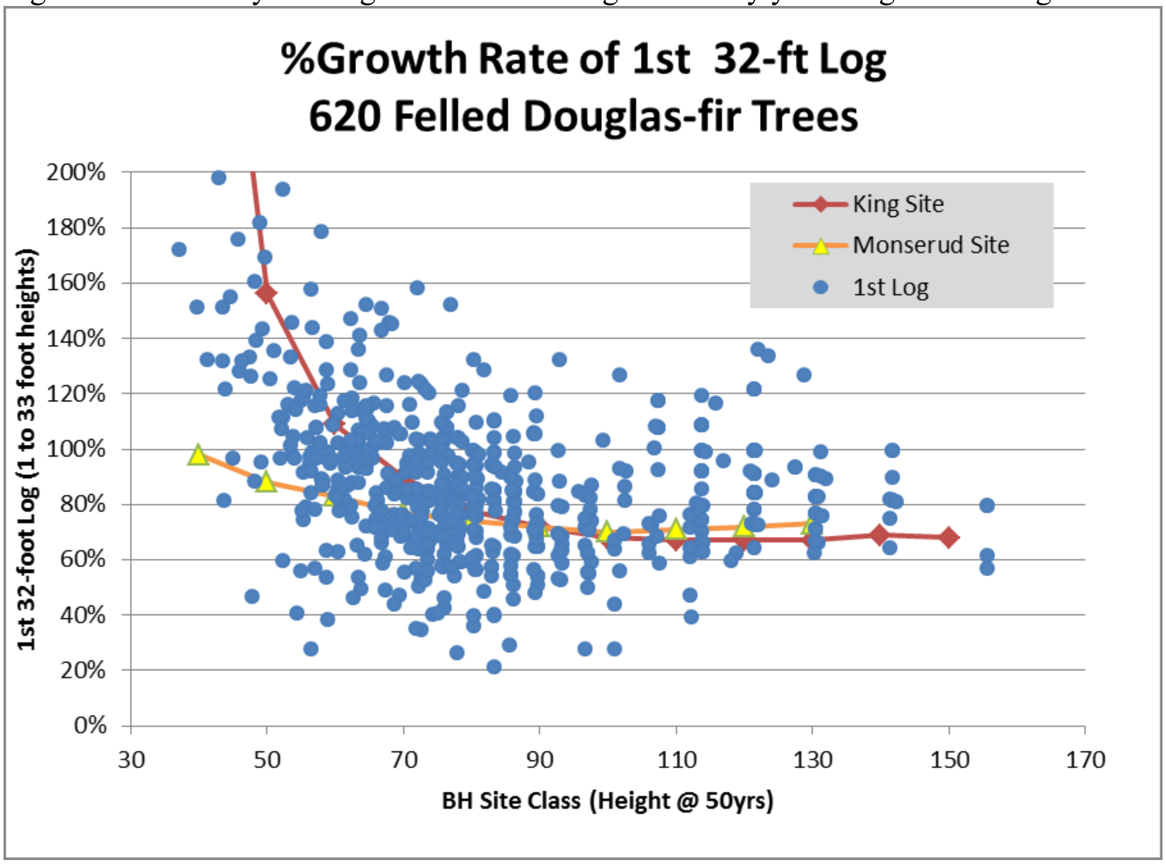
Since both of these published site curves are based on equations, for any given site class there is *only one* height/age profile for the height development of that tree through its life. Least squares regression modeling is common in forestry throughout the world. So these site curves may be considered typical of the technology used to determine *macro-site* growth capacity in the last century (1930 – 2000).

However, in Figure 9, the expectation when charting a sample of 620 felled-tree data is that the height growth observations should follow the published profiles from these two publications and that there should be continuity between publications for the same species and site class. The x-axis displays the traditional breast height site index values. The y-axis displays the rate of height growth in the butt 32-foot log divided by the rate of height growth in the second 32-foot log. This relative growth ratio was computed from each of the published equations and is represented by the solid lines across the chart by author. There is continuity between equations at higher sites. The differences between authors at lower sites is likely due to differences in the specific equations picked rather than effects of the distributions of the independent felled-tree datasets.

The real message in Figure 9 is that trees in different stands with different silvicultural histories do not follow a common height growth pattern, *even for the same macro-site level (Site Index).*

The 620 Douglas-fir felled-trees presented in Figure 9 were all measured by the Forest Biometrics Research Institute throughout Washington, Oregon, California, Idaho and Montana.

Figure 9. Ratios of years to grow the second log divided by years to grow butt log.



After reviewing the source of these felled-tree observations in Figure 9, there is a definite reason for the wide range of variation in height growth of the first log relative to the macro-site where it occurred. Those trees displaying relative growth rates *above* the published curves (lines) are generally from plantations and intensely managed stands (proactive silvicultural regimes).

Those trees displaying relative growth rates *below* the published curves are generally from natural regeneration occurring under overstory canopies and/or minimal silvicultural intervention.

Intensive silvicultural regimes can result in trees achieving a height of 32 feet in much fewer years than predicted from published site curves. Lack of early silvicultural investment and/or overstory competition can result in trees achieving a height of 32 feet only after many more years than predicted from published site curves. For these reasons, relying on a breast-height age and total height to define macro-site is insufficient and likely biased in either positive or negative directions. See Figure 11 for an example of the early silviculture impact on site classification.

FPS Version 7 accommodates these differences **if** the inventory forester conducts regeneration surveys and incorporates the results into the “Origin” regime in the ADMIN table. The Origin regime defines the silvicultural history which actually occurred on each stand. The primary factors to be defined in the Origin regime are: a) Plantation, Natural or Stump-sprout; b) Relative number of years to grow the butt log (percentage basis as in Figure 9); and, c) Relative expected survival of the initial stocking for the same years as item (b) given this regime. These factors are defined within a Regime which has been defined in the SILVICS table and assigned to the Origin regime in the ADMIN table.

If the inventory forester attempts to calculate site index based on breast-height ages and total heights from a cruise, then the parameters assigned to the Origin regime will have a significant influence on the estimated site index produced by the FPS Cruise Compiler. See Figure 11.

Since the release of FPS Version 7 there have been recent inquires about the "bugs" in the Cruise Compiler to compute site index. As with the changes in the height/dbh relationships in the methods of compiling stands, there is a designed difference in the methods to compute site index. It is now essential that the inventory forester have the results of regeneration surveys in local stands where the silviculture has been determined and followed. This information must be used to localize the silvicultural regimes in FPS in order to provide reliable growth and mortality expectations, including estimates of macro-site capacity.

The preferred, un-biased method of determining macro-site is the 10-meter measurement protocol rather than reliance on traditional breast-height methods. Otherwise there may be bias.

Shape of Site Curves (Height / Age Curves)

Just as early silviculture has a significant effect on the growth dynamics in the early years of tree development; the geographic location of each stand within the geographic range of each tree species has an effect on the shape of the height / age curve as those trees mature. The annual rate of height growth in trees over 70 feet tall begins to decline at a rate which depends on the most limiting factor of macro-site. The factors are: a) length of growing season; b) incoming precipitation within the growing season; and, c) soil water-holding and nutrient capacity. For example, an over-dense population of trees on a shallow soil results in a very rapid decline in the rate of height growth in later years.

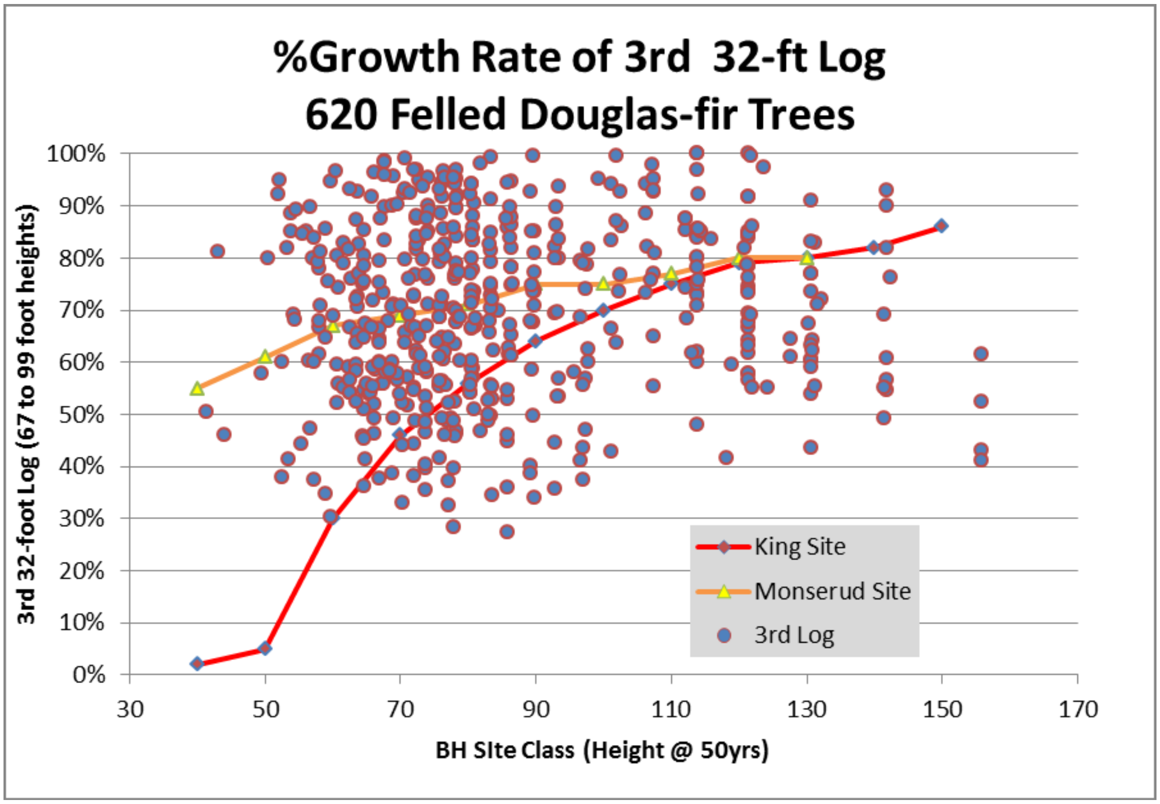
The effects of site curve shape have a major impact on determination of the age of culmination of mean-annual-increment (MAI) and for estimating the highest net-present-value (NPV) under alternative silvicultural investments.

Figure 10 displays 620 Douglas-fir felled-trees where the height growth in the third 32-foot log going up the tree is shown as a ratio to the height growth of the same tree in the second 32-foot log. The number of years to grow the 2nd log has been divided by the number of years to grow the 3rd log. If the growth rate is constant, then the ratio is 1.00 (or 100%). If the growth rate is declining, then the ratio is less than 1.00. Figure 10 shows rates between 30 and 100 percent.

As is readily apparent, existing published height/age equations (site curves) come nowhere close to defining the long-term height growth of trees. This is due to applying a single equation to all sites and a much broader acceptance of unknown variation in previous research (1930 – 2000).

The message here is to participate in the background research of FBRI to quantify the actual components (micro-site, macro-site and shape) based on local felled-tree measurements and quantification of macro-site factors of growing season length, incoming precipitation and soil properties. This is not a trivial undertaking and it requires non-parametric regression methods to extract all trends by species and geographic range. However, while not trivial, it is not difficult. All field sampling designs, collection and office analyses have been researched, developed and documented by FBRI. This results in a localized and updatable GIS SiteGrid layer.

Figure 10. Ratios of years to grow the 3rd log divided by years to grow 2nd log.



To understand and facilitate the transition to the FPS 10-meter site classification methods, the FPS Version 7 Cruise Compiler has an additional output table when the cruise includes trees measured for both height and age. See Figure 11. This table is produced in the "Cruise.Rpt" output file when the Check Box "Stand Tables" has been activated in the Output Reports form on startup of the Cruise Compiler.

The Stand number and measurement year are displayed along with an abbreviated discussion of the %Regen, Site Index, and %Shape components of the local site curve (height / age profile).

Next are the estimated total age and site-height derived from the cruise compilation.

```
Site Tree Total Age:  56    Total Height:  114
```

This is followed by the expected %Regen rate from the Admin table, "Origin" column regime and the %Shape rate from the Admin table, "Site_Shp" column.

```
Pre-specified %Regen: 0.75  %Shape: 0.67
```

These four factors are required to locally determine the site index level displayed in the output as a traditional total height at fifty-years breast height age basis. The site index is displayed.

```
Computes to BH Site Index =  111
```

The table at the bottom of Figure 11 displays the error in site classification if the parameters of %Regen and %Shape are poorly defined. It may be significant depending on the departure in silviculture being practiced on this particular stand relative to the silviculture applied in the original datasets used to build the published site index curves (King and Monserud).

Figure 11. FPS V7 Cruise Compiler Output (text.file)

```
=====================================================
Stand_ID:      1633  Measurement Year: 2011
Traditional breast height age and total height for
determining site index ASSUME even-aged, free-to-grow
natural regeneration.  This is not always the case...
%Regen = ADMIN.ORIGIN SILVICS Regime "PctHT"
%Shape = ADMIN.Site_Shp from SiteGrid analyses.
Both of these parameters must be set by the forester
based on early silviculture regeneration surveys and
local felled-tree site growth measurements.
The following table displays effects on attempting
to estimate Traditional Site Index using BH Age for
pre-specified combinations of %Regen and %Shape.
-----------------------------------------------------
Site Tree Total Age:  56  Total Height:  114
Pre-specified %Regen: 0.75  %Shape: 0.67
  Computes to BH Site Index =  111

The effect of incorrect specifications on BH Site:
%Regen \%Shape   40%   50%   60%   70%   80%   90%
                 .......... Site Index ...........
   30%           211   181   163   151   144   138
   45%           191   161   143   131   124   118
   60%           181   151   133   121   114   108
   75%           176   145   128   115   108   101
   90%           171   141   123   111   104    98
  105%           169   139   120   109   101    95
  120%           166   136   118   106    99    93
  135%           166   135   116   105    98    91
  150%           164   133   115   104    95    90
  165%           164   133   114   103    95    89
  180%           161   131   114   101    94    88
  195%           161   130   113   101    93    88
=====================================================
```

In trees less than 80-feet tall the %Regen parameter is the most significant piece of additional information needed for localizing the early silvicultural effects on site classification and on future growth projections.

Figure 12 provides a lookup table to be used in the field when conducting regeneration surveys. It provides a means to combine the Correct Age, Site, Height parameters (CASH) to derive the appropriate %Regen value. This value is then inserted into the "PctHt" column of the Silvics Regime selected to represent this stand in the Admin, Origin column assigned Regime.

The green bars in Figure 12 highlight the site classes 60, 90, 120 and 150. These are easily identifiable in any stand by observing the rate of height growth in the second 32-foot log. Simply measure (standing or felled) the height difference for a ten-year segment in the second 32-foot log up the tree. *Trees growing in that segment at the rate of 1-foot/year are site 60, 2-feet/year are site 90, 3-feet/year are site 120, and 4-feet/year are site 150.*

The green bars will help the forester to focus on the correct site column in the CASH Card when conducting a regeneration survey. Each unique silvicultural regime will impact %Regen.

Figure 12. The FPS – CASH Card for field regeneration cruising.

FPS - Silvicultural Treatment Response Classification

Site Class			CASH Card (Correct Age, Site, Height)										
25yr	35	40	45	50	55	60	65	70	75	80	85	90	95
50yr	40	50	60	70	80	90	100	110	120	130	140	150	160
10m	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0
%Regen			*Number of Years to Achive 20-ft Height (6m)*										
30%	267.2	133.6	89.1	66.8	53.4	44.5	38.2	33.4	29.7	26.7	24.3	22.3	20.6
45%	166.7	83.4	55.6	41.7	33.3	27.8	23.8	20.8	18.5	16.7	15.2	13.9	12.8
60%	116.7	58.3	38.9	29.2	23.3	19.4	16.7	14.6	13.0	11.7	10.6	9.7	9.0
75%	86.0	43.0	28.7	21.5	17.2	14.3	12.3	10.8	9.6	8.6	7.8	7.2	6.6
90%	69.2	34.6	23.1	17.3	13.8	11.5	9.9	8.6	7.7	6.9	6.3	5.8	5.3
105%	56.1	28.1	18.7	14.0	11.2	9.4	8.0	7.0	6.2	5.6	5.1	4.7	4.3
120%	46.6	23.3	15.5	11.6	9.3	7.8	6.7	5.8	5.2	4.7	4.2	3.9	3.6
135%	39.3	19.7	13.1	9.8	7.9	6.6	5.6	4.9	4.4	3.9	3.6	3.3	3.0
150%	33.6	16.8	11.2	8.4	6.7	5.6	4.8	4.2	3.7	3.4	3.1	2.8	2.6
Site - feet/yr			1.0			2.0			3.0			4.0	

Figure 13. The FPS – CASH Card presented as a Chart.