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Westside Cascades (WC) Variant Overview

Forest Vegetation Simulator

Mount Jefferson
(Arnie Browning, BIA)

Westside Cascades (WC) Variant Overview

Forest Vegetation Simulator

Authors and Contributors:

The FVS staff has maintained model documentation for this variant in the form of a variant overview since its release in 1992. The original authors were Dennis Donnelly and Ralph Johnson. In 2008, the previous document was replaced with this updated variant overview. Gary Dixon, Christopher Dixon, Robert Havis, Chad Keyser, Stephanie Rebain, Erin Smith-Mateja, and Don Vandendriesche were involved with this update. Erin Smith-Mateja cross-checked information contained in this variant overview with the FVS source code.

FVS Staff. 2008 (revised June 28, 2021). Westside Cascades (WC) Variant Overview – Forest Vegetation Simulator. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 80p.

Table of Contents

Quick Guide to Default Settings

Parameter or Attribute	**Default Setting**	
Number of Projection Cycles	1 (10 if using FVS GUI)	
Projection Cycle Length	10 years	
Location Code (National Forest)	618 - Willamette	
Plant Association Code	52 (CFS551 ABAM/RHAL/XETE)	
Slope	5 percent	
Aspect	0 (no meaningful aspect)	
Elevation	35 (3500 feet)	
Latitude / Longitude	Latitude	Longitude
All location codes	46	122
Site Species	Plant Association Code specific	
Site Index	Plant Association Code specific	
Maximum Stand Density Index	Plant Association Code specific	
Maximum Basal Area	Based on maximum stand density index for site species	
Volume Equations	National Volume Estimator Library	
Merchantable Cubic Foot Volume Specifications:		
Minimum DBH / Top Diameter	LP	All Other Species
708 – BLM Salem; 709 BLM Eugene; 712 – BLM Coos Bay	7.0 / 5.0 inches	7.0 / 5.0 inches
All other location codes	6.0 / 4.5 inches	7.0 / 4.5 inches
Stump Height	1.0 foot	1.0 foot
Merchantable Board Foot Volume Specifications:		
Minimum DBH / Top Diameter	LP	All Other Species
708 – BLM Salem; 709 BLM Eugene; 712 – BLM Coos Bay	7.0 / 5.0 inches	7.0 / 5.0 inches
All other location codes	6.0 / 4.5 inches	7.0 / 4.5 inches
Stump Height	1.0 foot	1.0 foot
Sampling Design:		
Basal Area Factor	40 BAF	
Small-Tree Fixed Area Plot	1/300th Acre	
Breakpoint DBH	5.0 inches	

1.0 Introduction

The Forest Vegetation Simulator (FVS) is an individual tree, distance independent growth and yield model with linkable modules called extensions, which simulate various insect and pathogen impacts, fire effects, fuel loading, snag dynamics, and development of understory tree vegetation. FVS can simulate a wide variety of forest types, stand structures, and pure or mixed species stands.

New “variants” of the FVS model are created by imbedding new tree growth, mortality, and volume equations for a particular geographic area into the FVS framework. Geographic variants of FVS have been developed for most of the forested lands in the United States.

The Westside Cascades (WC) variant was developed in 1992 and includes the western slopes of the Cascade Mountains from the Canadian border south through Washington and Oregon to the area just north of Interstate 5 from Grants Pass to Medford, Oregon. Data used to build the WC variant came from Forest Service, U.S. Department of Agriculture forest inventories and silviculture stand examinations. In 2013, new small tree growth equations from Gould and Harrington (2012) were embedded in the WC variant.

To fully understand how to use this variant, users should also consult the following publication:

- Essential FVS: A User’s Guide to the Forest Vegetation Simulator (Dixon 2002)

This publication may be downloaded from the Forest Management Service Center (FMSC), Forest Service website. Other FVS publications may be needed if one is using an extension that simulates the effects of fire, insects, or diseases.

2.0 Geographic Range

The WC variant was fit to data representing forest types on the western slopes of the Cascade Mountains from the Canadian border south through Washington and Oregon to the area just north of Interstate 5 from Grants Pass to Medford, Oregon. Data used in initial model development came from USDA Forest Service forest inventories and silviculture stand examinations. Distribution of data samples for species fit from this data are shown in Appendix A.

The WC variant covers inland forest areas of the Pacific Northwest states of Washington and Oregon. The suggested geographic range of use for the WC variant is shown in figure 2.0.1.

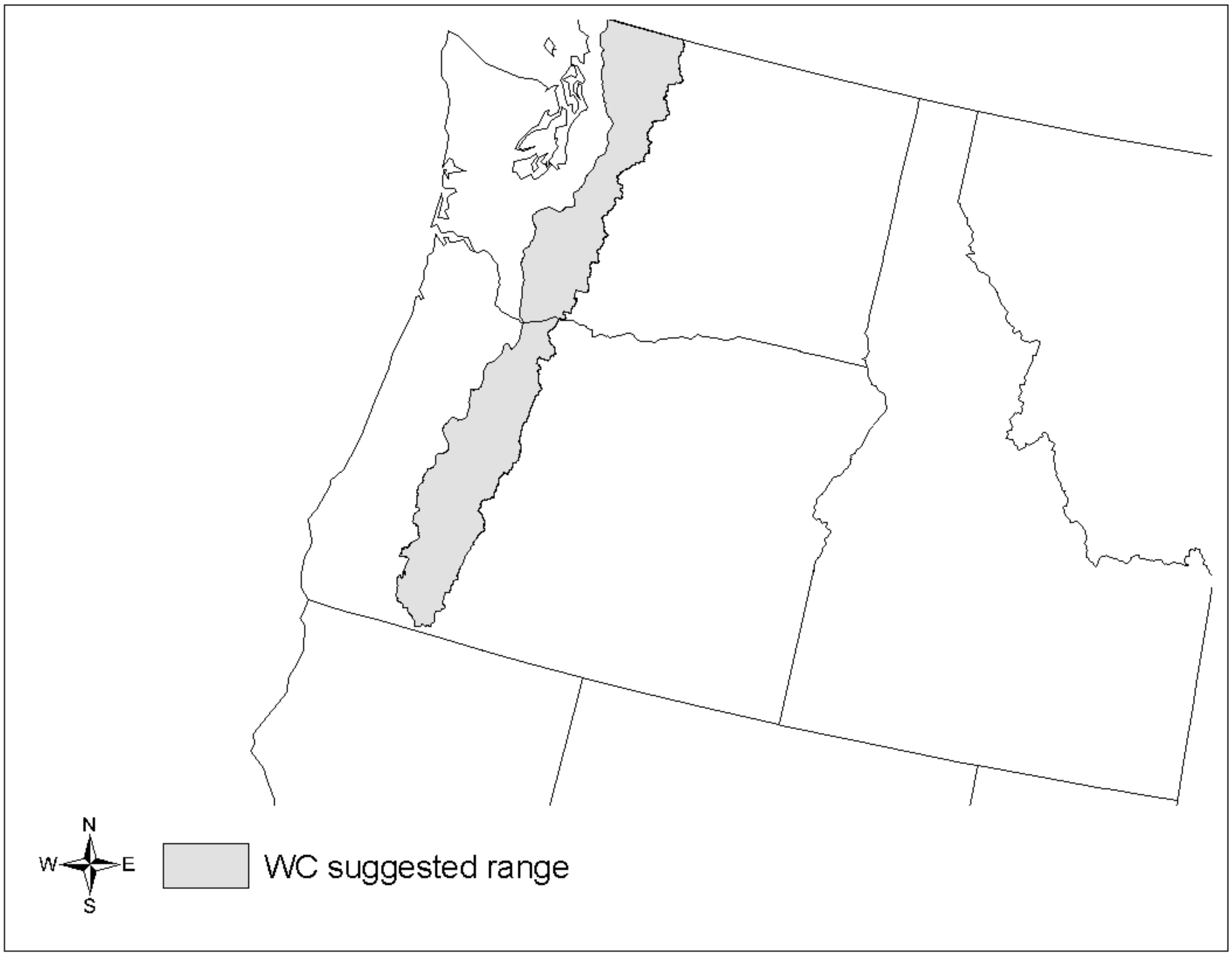

Figure 2.0.1 Suggested geographic range of use for the WC variant.

3.0 Control Variables

FVS users need to specify certain variables used by the PN variant to control a simulation. These are entered in parameter fields on various FVS keywords available in the FVS interface or they are read from an FVS input database using the Database Extension.

3.1 Location Codes

The location code is a 3- or 4-digit code where, in general, the first digit of the code represents the Forest Service Region Number, and the last two digits represent the Forest Number within that region. In some cases, a location code beginning with a "7" or "8" is used to indicate an administrative boundary that doesn't use a Forest Service Region number (for example, other federal agencies, state agencies, or other lands).

If the location code is missing or incorrect in the WC variant, a default forest code of 618 (Willamette National Forest) will be used. Location codes recognized in the WC variant are shown in tables 3.1.1 and 3.1.2.

Table 3.1.1 Location codes used in the WC variant.

Location Code	Location
603	Gifford Pinchot National Forest
605	Mt. Baker - Snoqualmie National Forest
606	Mount Hood National Forest
610	Rogue River National Forest
615	Umpqua National Forest
618	Willamette National Forest
708	BLM Salem ADU
709	BLM Eugene ADU
710	BLM Roseburg ADU
711	BLM Medford ADU
613	Mt. Baker - Snoqualmie National Forest (mapped to 605)

Table 3.1.2 Bureau of Indian Affairs reservation codes used in the WC variant.

Location Code	Location
8124	Sauk-Suiattle Reservation (mapped to 605)
8130	Yakama Nation Reservation (mapped to 603)

3.2 Species Codes

The WC variant recognizes 37 species. You may use FVS species codes, Forest Inventory and Analysis (FIA) species codes, or USDA Natural Resources Conservation Service PLANTS symbols to represent these species in FVS input data. Any valid western species codes identifying species not recognized by the variant will be mapped to the most similar species in the variant. The species mapping crosswalk is available on the variant documentation webpage of the FVS website. Any non-valid species code will default to the “other species” category.

Either the FVS sequence number or species code must be used to specify a species in FVS keywords and Event Monitor functions. FIA codes or PLANTS symbols are only recognized during data input, and may not be used in FVS keywords. Table 3.2.1 shows the complete list of species codes recognized by the WC variant.

Table 3.2.1 Species codes used in the WC variant.

Species Number	Species Code	Common Name	FIA Code	PLANTS Symbol	Scientific Name
1	SF	Pacific silver fir	011	ABAM	*Abies amabilis*
2	WF	white fir	015	ABCO	*Abies concolor*
3	GF	grand fir	017	ABGR	*Abies grandis*
4	AF	subalpine fir	019	ABLA	*Abies lasiocarpa*
5	RF	California red fir / Shasta red fir	020	ABMA	*Abies magnifica*
6					
7	NF	noble fir	022	ABPR	*Abies procera*
8	YC	Alaska cedar / western larch	042	CANO9	*Callitropsis nootkatensis*
9	IC	incense-cedar	081	CADE27	*Libocedrus decurrens*
10	ES	Engelmann / Sitka spruce	093	PIEN	*Picea engelmannii*
11	LP	lodgepole pine	108	PICO	*Pinus contorta*
12	JP	Jeffrey pine	116	PIJE	*Pinus jeffreyi*
13	SP	sugar pine	117	PILA	*Pinus lambertiana*
14	WP	western white pine	119	PIMO3	*Pinus monticola*
15	PP	ponderosa pine	122	PIPO	*Pinus ponderosa*
16	DF	Douglas-fir	202	PSME	*Pseudotsuga menziesii*
17	RW	coast redwood	211	SESE3	*Sequoia sempervirens*
18	RC	western redcedar	242	THPL	*Thuja plicata*
19	WH	western hemlock	263	TSHE	*Tsuga heterophylla*
20	MH	mountain hemlock	264	TSME	*Tsuga mertensiana*
21	BM	bigleaf maple	312	ACMA3	*Acer macrophyllum*
22	RA	red alder	351	ALRU2	*Alnus rubra*
23	WA	white alder / Pacific madrone	352	ALRH2	*Alnus rhombifolia*
24	PB	paper birch	375	BEPA	*Betula papyrifera var. commutata*
25	GC	giant chinquapin / tanoak	431	CHCHC4	*Chrysolepis chrysophylla*
26	AS	quaking aspen	746	POTR5	*Populus tremuloides*

Species Number	Species Code	Common Name	FIA Code	PLANTS Symbol	Scientific Name
27	CW	black cottonwood	747	POBAT	*Populus trichocarpa*
28	WO	Oregon white oak / California black oak	815	QUGA4	*Quercus garryana*
29	WJ	western juniper	064	JUOC	*Juniperus occidentalis*
30	LL	subalpine larch	072	LALY	*Larix lyallii*
31	WB	whitebark pine	101	PIAL	*Pinus albicaulis*
32	KP	knobcone pine	103	PIAT	*Pinus attenuata*
33	PY	Pacific yew	231	TABR2	*Taxus brevifolia*
34	DG	Pacific dogwood	492	CONU4	*Cornus nuttallii*
35	HT	hawthorn species	500	CRATA	*Crataegus spp.*
36	CH	bitter cherry	768	PREM	*Prunus emarginata*
37	WI	willow species	920	SALIX	*Salix spp.*
38					
39	OT	other species	999	2TREE	

3.3 Habitat Type, Plant Association, and Ecological Unit Codes

Plant association codes recognized in the WC variant are shown in Appendix B. If an incorrect plant association code is entered or no code is entered FVS will use the default plant association code, which is 52 (CFS551 ABAM/RHAL/XETE). Plant association codes are used to set default site information such as site species, site indices, and maximum stand density indices as well as predicting snag dynamics in FFE-FVS. The site species, site index and maximum stand density indices can be reset via FVS keywords. Users may enter the plant association code or the plant association FVS sequence number on the STDINFO keyword, when entering stand information from a database, or when using the SETSITE keyword without the PARMS option. If using the PARMS option with the SETSITE keyword, users must use the FVS sequence number for the plant association.

3.4 Site Index

Site index is used in some of the growth equations for the WC variant. Users should always use the same site curves that FVS uses, which are shown in table 3.4.1. If site index is available, a single site index for the whole stand can be entered, a site index for each individual species in the stand can be entered, or a combination of these can be entered.

Table 3.4.1 Site index reference curves for species in the WC variant.

Species Code	Reference	BHA or TTA[1]	Base Age
SF	Hoyer and Herman (1989)	BHA	100
GF, WF	Cochran (1979)	BHA	50
AF, ES	Alexander (1967)	BHA	100
RF	Dolph (1991)	BHA	50
NF	Herman et al. (1978)	BHA	100

Species Code	Reference	BHA or TTA[1]	Base Age
LP	Dahms (1964)	TTA	50
WP, SP	Curtis et al. (1990)	BHA	100
PP, IC, JP	Barrett (1978)	BHA	100
WH	Wiley (1978)	BHA	50
MH	Means et al. (1986)[2]	BHA	100
RA	Harrington and Curtis (1986)	TTA	20
LL	Cochran (1985)	BHA	50
Other[3]	Curtis et al. (1974)	BHA	100
WO	King (1966)	BHA	50

[1] Equation is based on total tree age (TTA) or breast height age (BHA)

[2] The source equation is in metric units; site index values for Mountain hemlock are assumed to be in meters.

[3] Other includes all the following species: Douglas-fir, Alaska cedar, coast redwood, bigleaf maple, white alder, paper birch, giant chinquapin, quaking aspen, black cottonwood, western juniper, whitebark pine, knobcone pine, Pacific yew, Pacific dogwood, hawthorn species, bitter cherry, western redcedar, willow species.

If site index is missing or incorrect, the default site species and site index are determined by plant association codes found in Appendix B. If the plant association code is missing or incorrect, the site species is set to Douglas-fir with a default site index set to 73.

Site indices for species not assigned a site index are determined based on the site index of the site species (height at base age) with an adjustment for the reference age differences between the site species and the target species. For some species that use the Curtis et al. (1974) equation, the site index estimate is adjusted by multiplying the site index estimate by an adjustment factor in table 3.4.2, if the species is not listed as the site species. Similarly, for Oregon white oak, an adjustment is made from the site species using the maximum height equation {3.4.1} from Gould and Harrington (2009).

Table 3.4.2 Site index adjustment factors for hardwood species using Curtis et al equations in the WC variant.

Species	Base Age
BM	0.75
WA	0.65
PB	1.50
GC	0.70
AS	0.75
CW	0.85
WJ	0.23
WB	0.70
PY	0.25
DG	0.60

Species	Base Age
HT	0.25
CH	0.50
WI	0.50

{3.4.1} SI_{wo} = 114.24569[1-exp(-.02659*SI_{site})]^2.25993

where:

SI_{wo}	site index estimate of Oregon white oak
SI_{site}	Site Index of site species

3.5 Maximum Density

Maximum stand density index (SDI) and maximum basal area (BA) are important variables in determining density related mortality and crown ratio change. Maximum basal area is a stand level metric that can be set using the BAMAX or SETSITE keywords. If not set by the user, a default value is calculated from maximum stand SDI each projection cycle. Maximum stand density index can be set for each species using the SDIMAX or SETSITE keywords. If not set by the user, a default value is assigned as discussed below.

The default maximum SDI is set based on a user-specified, or default, plant association code or a user specified basal area maximum. If a user specified basal area maximum is present, the maximum SDI for all species is computed using equation {3.5.1}; otherwise, the SDI maximum for all species is assigned from the SDI maximum associated with the site species for the plant association code shown in Appendix B. SDI maximums were set based on growth basal area (GBA) analysis developed by Hall (1983) or an analysis of Current Vegetation Survey (CVS) plots in USFS Region 6 by Crookston (2008). Some SDI maximums associated with plant associations are unreasonably large, so SDI maximums are capped based on location code, see table 3.5.1. Maximum stand density index at the stand level is a weighted average, by basal area, of the individual species SDI maximums.

{3.5.1} $SDIMAX_i = BAMAX / (0.5454154 * SDIU)$

where:

$SDIMAX_i$	is species-specific SDI maximum
BAMAX	is the user-specified stand basal area maximum
SDIU	is the proportion of theoretical maximum density at which the stand reaches actual maximum density (default 0.85, changed with the SDIMAX keyword)

Table 3.5.1 Stand density index caps by location code in the WC variant.

Location Code	Max SDI
603	950
605	950
606	900
610	850
613	950

Location Code	Max SDI
615	825
618	870
708	885
709	870
710	825
711	850

4.0 Growth Relationships

This chapter describes the functional relationships used to fill in missing tree data and calculate incremental growth. In FVS, trees are grown in either the small tree sub-model or the large tree sub-model depending on the diameter.

4.1 Height-Diameter Relationships

Height-diameter relationships in FVS are primarily used to estimate tree heights missing in the input data, and occasionally to estimate diameter growth on trees smaller than a given threshold diameter. In the WC variant, FVS will dub in heights by one of two methods. By default, the WC variant will use the Curtis-Arney functional form as shown in equation {4.1.1} (Curtis 1967, Arney 1985). If the input data contains at least three measured heights for a species, then FVS can switch to a logistic height-diameter equation {4.1.2} (Wykoff, et.al 1982) or {4.1.3} that may be calibrated to the input data. However, the default in the WC variant is to use equation {4.1.1}.

FVS will not automatically use equations {4.1.2} and {4.1.3} even if you have enough height values in the input data. To override this default, the user must use the NOHTDREG keyword and change field 2 to a 1. Coefficients for equation {4.1.1} are shown in table 4.1.1a and 4.1.1b sorted by species and location code. Coefficients for equations {4.1.2} and {4.1.3} are given in table 4.1.2 by species.

{4.1.1} Curtis-Arney functional form

$DBH \geq 3.0"$: $HT = 4.5 + P_2 * \exp[-P_3 * DBH^{P_4}]$

$DBH < 3.0"$: $HT = [(4.5 + P_2 * \exp[-P_3 * 3.0^{P_4}] - 4.51) * (DBH - 0.3) / 2.7] + 4.51$

{4.1.2} Wykoff functional form

$DBH \geq 5.0"$: $HT = 4.5 + \exp(B_1 + B_2 / (DBH + 1.0))$

{4.1.3} Other functional form

Species: 1-14, 17, 20, 30 or 33

$DBH < 5.0"$: $HT = \exp(H_1 + (H_2 * DBH) + (H_3 * CR) + (H_4 * DBH^2) + H_5)$

Species: 16, 18, 19, 21-29, 31, 32, 34-39

$DBH < 5.0"$: $HT = H_1 + (H_2 * DBH) + (H_3 * CR) + (H_4 * DBH^2) + H_5$

Species: 15

$DBH < 4.0"$: $HT = 8.31485 + 3.03659 * DBH - 0.59200 * CRC$

where:

HT	is tree height
DBH	is tree diameter at breast height
CR	is crown ratio expressed in percent
CRC	is crown ratio code (CRC=6)

B_1 - B_2 are species-specific coefficients shown in table 4.1.1a and 4.1.1b
P_2 - P_4 are species and location specific coefficients shown in table 4.1.2
H_1 - H_5 are species-specific coefficients shown in table 4.1.1a and 4.1.1b

Table 4.1.1a Coefficients for equation {4.1.1} in the WC variant in the 603, 605, 606, and 708 locations.

Species Code	603 – Gifford Pinchot			605 – Mount Baker/Snoqualmine			606 – Mount Hood, 708 – BLM Salem		
	P_2	P_3	P_4	P_2	P_3	P_4	P_2	P_3	P_4
SF	407.996	6.783	-0.523	476.634	6.484	-0.469	223.3492	6.3964	-0.6566
WF	475.170	6.247	-0.481	475.170	6.247	-0.481	475.1698	6.2472	-0.4812
GF	686.483	6.539	-0.374	727.811	5.465	-0.344	432.2186	6.2941	-0.5028
AF	216.400	6.170	-0.602	495.784	6.530	-0.411	290.5142	6.414	-0.472
RF	375.382	6.088	-0.472	375.382	6.088	-0.472	375.382	6.088	-0.472
NF	561.959	6.551	-0.446	2067.859	6.849	-0.259	247.7348	6.183	-0.6335
YC	505.271	6.474	-0.432	181.454	6.579	-0.657	255.4638	5.5577	-0.6054
IC	4691.634	7.467	-0.199	4691.634	7.467	-0.199	4691.634	7.4671	-0.1989
ES	27357.521	8.721	-0.141	211.796	6.702	-0.674	206.3211	9.1227	-0.8281
LP	133.660	4.846	-0.697	121.139	12.662	-1.298	139.7159	4.0091	-0.708
JP	1031.520	7.662	-0.360	1031.520	7.662	-0.360	1031.52	7.6616	-0.3599
SP	702.186	5.703	-0.380	702.186	5.703	-0.380	702.1856	5.7025	-0.3798
WP	3261.831	7.372	-0.252	433.781	6.332	-0.499	1333.818	6.6219	-0.312
PP	1548.415	6.550	-0.270	1181.724	6.698	-0.315	1181.724	6.6981	-0.3151
DF	452.399	5.969	-0.491	536.737	5.580	-0.410	949.1046	5.8482	-0.3251
RW	409.881	6.891	-0.561	409.881	6.891	-0.561	409.8811	6.8908	-0.5611
RC	531.007	5.964	-0.408	422.970	5.734	-0.427	1560.685	6.2328	-0.2541
WH	465.081	6.477	-0.494	319.374	6.396	-0.570	317.8257	6.8287	-0.6034
MH	368.372	6.827	-0.507	547.949	7.137	-0.422	2478.099	7.0762	-0.2456
BM	179.071	3.624	-0.573	293.111	3.734	-0.346	76.517	2.2107	-0.6365
RA	182.305	3.668	-0.474	1089.505	5.200	-0.257	484.4591	4.5713	-0.3643
WA	133.797	6.405	-0.833	133.797	6.405	-0.833	133.7965	6.405	-0.8329
PB	1709.723	5.889	-0.229	1709.723	5.889	-0.229	1709.723	5.8887	-0.2286
GC	10707.391	8.467	-0.186	10707.391	8.467	-0.186	10707.39	8.467	-0.1863
AS	1709.723	5.889	-0.229	1709.723	5.889	-0.229	1709.723	5.8887	-0.2286
CW	178.644	4.585	-0.675	290.333	5.280	-0.585	178.6441	4.5852	-0.6746
WO	55.000	5.500	-0.950	59.421	5.318	-1.037	59.4214	5.3178	-1.0367
WJ	503.662	4.954	-0.209	503.662	4.954	-0.209	503.6619	4.9544	-0.2085
LL	503.662	4.954	-0.209	503.662	4.954	-0.209	503.6619	4.9544	-0.2085
WB	89.554	4.228	-0.644	89.554	4.228	-0.644	73.9147	3.963	-0.8277
KP	34749.474	9.129	-0.142	34749.474	9.129	-0.142	34749.47	9.1287	-0.1417

Species Code	603 – Gifford Pinchot			605 – Mount Baker/Snoqualmine			606 – Mount Hood, 708 – BLM Salem		
	P_2	P_3	P_4	P_2	P_3	P_4	P_2	P_3	P_4
PY	1221.918	5.817	-0.210	175.865	5.089	-0.462	77.2207	3.5181	-0.5894
DG	444.562	3.921	-0.240	444.562	3.921	-0.240	403.3221	4.3271	-0.2422
HT	55.000	5.500	-0.950	55.000	5.500	-0.950	55	5.5	-0.95
CH	73.335	2.655	-1.246	73.335	2.655	-1.246	73.3348	2.6548	-1.246
WI	149.586	2.423	-0.180	149.586	2.423	-0.180	149.5861	2.4231	-0.18
OT	1709.723	5.889	-0.229	1709.723	5.889	-0.229	1709.723	5.8887	-0.2286

Table 4.1.1b Coefficients for equation {4.1.1} in the WC variant in the 610, 711, 615, 710, 618, and 709 locations.

Species Code	610 – Rogue River, 711 – BLM Medford ADU			615 – Umpqua, 710 – BLM Roseburg			618 – Williamette, 709 – BLM Eugene		
	P_2	P_3	P_4	P_2	P_3	P_4	P_2	P_3	P_4
SF	380.251	7.306	-0.576	380.251	7.306	-0.576	237.919	7.795	-0.726
WF	253.925	6.614	-0.591	475.170	6.247	-0.481	475.170	6.247	-0.481
GF	432.219	6.294	-0.503	432.219	6.294	-0.503	432.219	6.294	-0.503
AF	5185.988	8.758	-0.227	133.869	6.780	-0.738	133.869	6.780	-0.738
RF	375.382	6.088	-0.472	375.382	6.088	-0.472	375.382	6.088	-0.472
NF	483.375	7.244	-0.511	483.375	7.244	-0.511	483.375	7.244	-0.511
YC	97.777	8.820	-1.053	97.777	8.820	-1.053	97.777	8.820	-1.053
IC	2245.574	7.199	-0.240	1899.321	6.942	-0.255	4691.634	7.467	-0.199
ES	155.000	9.123	-0.828	206.321	9.123	-0.828	206.321	9.123	-0.828
LP	115.892	5.000	-0.901	127.571	6.346	-0.864	105.445	7.969	-1.092
JP	1000.000	6.550	-0.270	1031.520	7.662	-0.360	1031.520	7.662	-0.360
SP	1631.376	6.479	-0.257	544.372	6.880	-0.464	702.186	5.703	-0.380
WP	1143.625	6.191	-0.310	433.781	6.332	-0.499	514.158	6.300	-0.465
PP	1548.415	6.550	-0.270	1181.724	6.698	-0.315	1181.724	6.698	-0.315
DF	540.941	5.680	-0.404	316.128	5.966	-0.575	439.120	5.818	-0.485
RW	409.881	6.891	-0.561	409.881	6.891	-0.561	409.881	6.891	-0.561
RC	617.762	5.521	-0.351	617.762	5.521	-0.351	1012.127	6.096	-0.308
WH	263.127	6.936	-0.662	608.610	6.088	-0.416	395.498	6.422	-0.532
MH	233.699	6.906	-0.617	393.981	6.393	-0.475	192.961	7.388	-0.723
BM	143.999	3.512	-0.551	106.030	3.882	-0.783	160.217	3.304	-0.530
RA	88.184	2.840	-0.734	88.184	2.840	-0.734	10099.721	7.638	-0.162
WA	123.211	4.125	-0.555	105.129	5.134	-0.789	133.797	6.405	-0.833
PB	1709.723	5.889	-0.229	1709.723	5.889	-0.229	1709.723	5.889	-0.229
GC	83.746	8.332	-1.048	1076.427	6.147	-0.282	10707.391	8.467	-0.186
AS	1709.723	5.889	-0.229	1709.723	5.889	-0.229	1709.723	5.889	-0.229
CW	178.644	4.585	-0.675	178.644	4.585	-0.675	178.644	4.585	-0.675

Species Code	610 – Rogue River, 711 – BLM Medford ADU			615 – Umpqua, 710 – BLM Roseburg			618 – Williamette, 709 – BLM Eugene		
	P_2	P_3	P_4	P_2	P_3	P_4	P_2	P_3	P_4
WO	59.421	5.318	-1.037	55.000	5.500	-0.950	55.000	5.500	-0.950
WJ	503.662	4.954	-0.209	503.662	4.954	-0.209	503.662	4.954	-0.209
LL	503.662	4.954	-0.209	503.662	4.954	-0.209	503.662	4.954	-0.209
WB	89.554	4.228	-0.644	89.554	4.228	-0.644	73.915	3.963	-0.828
KP	4421.458	7.057	-0.194	4421.458	7.057	-0.194	34749.474	9.129	-0.142
PY	127.170	4.898	-0.467	139.073	5.206	-0.541	139.073	5.206	-0.541
DG	403.322	4.327	-0.242	202.975	3.294	-0.323	444.562	3.921	-0.240
HT	55.000	5.500	-0.950	55.000	5.500	-0.950	55.000	5.500	-0.950
CH	73.335	2.655	-1.246	73.335	2.655	-1.246	73.335	2.655	-1.246
WI	149.586	2.423	-0.180	149.586	2.423	-0.180	149.586	2.423	-0.180
OT	1709.723	5.889	-0.229	1709.723	5.889	-0.229	1709.723	5.889	-0.229

Table 4.1.2 Coefficients for equations {4.1.2} and {4.1.3} in the WC variant.

Species Code	Default B_1	B_2	H_1	H_2	H_3	H_4	H_5
SF	5.288	-14.147	1.3134	0.3432	0.0366	0	0
WF	5.308	-13.624	1.4769	0.3579	0	0	0
GF	5.308	-13.624	1.4769	0.3579	0	0	0
AF	5.313	-15.321	1.4261	0.3334	0	0	0
RF	5.313	-15.321	1.3526	0.3335	0.0367	0	0
NF	5.327	-15.450	1.7100	0.2943	0	0	0.1054
YC	5.143	-13.497	1.5907	0.3040	0	0	0
IC	5.188	-13.801	1.5907	0.3040	0	0	0
ES	5.188	-13.801	1.5907	0.3040	0	0	0
LP	4.865	-9.305	0.9717	0.3934	0.0339	0	0.3044
JP	5.333	-17.762	1.0756	0.4369	0	0	0
SP	5.382	-15.866	0.9717	0.3934	0.0339	0	0.3044
WP	5.382	-15.866	0.9717	0.3934	0.0339	0	0.3044
PP	5.333	-17.762	1.0756	0.4369	0	0	0
DF	5.288	-14.147	7.1391	4.2891	-0.7150	0.2750	2.0393
RW	5.188	-13.801	1.5907	0.3040	0	0	0
RC	5.271	-14.996	2.3115	0.2370	-0.0556	0	0.3218
WH	5.298	-13.240	1.3608	0.6151	0	-0.0442	0.0829
MH	5.081	-13.430	1.2278	0.4000	0	0	0
BM	4.700	-6.326	0.0994	4.9767	0	0	0
RA	4.886	-8.792	0.0994	4.9767	0	0	0
WA	5.152	-13.576	0.0994	4.9767	0	0	0
PB	5.152	-13.576	0.0994	4.9767	0	0	0
GC	5.152	-13.576	0.0994	4.9767	0	0	0

Species Code	Default B_1	B_2	H_1	H_2	H_3	H_4	H_5
AS	5.152	-13.576	0.0994	4.9767	0	0	0
CW	5.152	-13.576	0.0994	4.9767	0	0	0
WO	5.152	-13.576	0.0994	4.9767	0	0	0
WJ	5.152	-13.576	0.0994	4.9767	0	0	0
LL	5.188	-13.801	1.5907	0.3040	0	0	0
WB	5.188	-13.801	1.5907	0.3040	0	0	0
KP	5.188	-13.801	1.5907	0.3040	0	0	0
PY	5.188	-13.801	1.5907	0.3040	0	0	0
DG	5.152	-13.576	0.0994	4.9767	0	0	0
HT	5.152	-13.576	0.0994	4.9767	0	0	0
CH	5.152	-13.576	0.0994	4.9767	0	0	0
WI	5.152	-13.576	0.0994	4.9767	0	0	0
OT	5.152	-13.576	0.0994	4.9767	0	0	0

4.2 Bark Ratio Relationships

Bark ratio estimates are used to convert between diameter outside bark and diameter inside bark in various parts of the model. In the WC variant, bark ratio values are determined using estimates from DIB equations. Equations used in the WC variant are shown in {4.2.1} and {4.2.2}. Coefficients (b_1 and b_2) and equation reference for each species are shown in table 4.2.1.

{4.2.1} $DIB = b_1 * (DBH \wedge b_2)$; $BRATIO = DIB / DBH$

{4.2.2} $DIB = b_1 + (b_2 * DBH)$; $BRATIO = DIB / DBH$

where:

BRATIO	is species-specific bark ratio (bounded to $0.80 \leq BRATIO \leq 0.99$)
DBH	is tree diameter at breast height
DIB	is tree diameter inside bark at breast height
b_1, b_2	are species-specific coefficients shown in table 4.2.1

Table 4.2.1 Coefficients and equation reference for bark ratio equations in the WC variant.

Species Code	b_1	b_2	Equation Used	Equation Source
SF	0.904973	1.0	{4.2.1}	Walters et al (1985)
WF	0.904973	1.0	{4.2.1}	Walters et al (1985)
GF	0.904973	1.0	{4.2.1}	Walters et al (1985)
AF	0.904973	1.0	{4.2.1}	Walters et al (1985)
RF	0.904973	1.0	{4.2.1}	Walters et al (1985)
NF	0.904973	1.0	{4.2.1}	Walters et al (1985)
YC	0.837291	1.0	{4.2.1}	Walters et al (1985)
IC	0.837291	1.0	{4.2.1}	Walters et al (1985)
ES	0.90	1.0	{4.2.1}	Wykoff et al (1982)

Species Code	b_1	b_2	Equation Used	Equation Source
LP	0.90	1.0	{4.2.1}	Wykoff et al (1982)
JP	0.859045	1.0	{4.2.1}	Walters et al (1985)
SP	0.859045	1.0	{4.2.1}	Walters et al (1985)
WP	0.859045	1.0	{4.2.1}	Walters et al (1985)
PP	0.809427	1.016866	{4.2.1}	Walters et al (1985)
DF	0.903563	0.989388	{4.2.1}	Walters et al (1985)
RW	0.837291	1.0	{4.2.1}	Walters et al (1985)
RC	0.949670	1.0	{4.2.1}	Wykoff et al (1982)
WH	0.933710	1.0	{4.2.1}	Wykoff et al (1982)
MH	0.949670	1.0	{4.2.1}	Wykoff et al (1982)
BM	0.08360	0.94782	{4.2.2}	Pillsbury and Kirkley (1984)
RA	0.075256	0.949670	{4.2.2}	*Pillsbury and Kirkley (1984)
WA	0.075256	0.949670	{4.2.2}	*Pillsbury and Kirkley (1984)
PB	0.08360	0.94782	{4.2.2}	Pillsbury and Kirkley
GC	0.15565	0.90182	{4.2.2}	Pillsbury and Kirkley
AS	0.075256	0.949670	{4.2.2}	*Pillsbury and Kirkley (1984)
CW	0.075256	0.949670	{4.2.2}	*Pillsbury and Kirkley (1984)
WO	0.8558	1.0213	{4.2.1}	Gould & Harrington (2009)
WJ	0.949670	1.0	{4.2.1}	Wykoff et al (1982)
LL	0.90	1.0	{4.2.1}	Wykoff et al (1982)
WB	0.933290	1.0	{4.2.1}	**Wykoff (1982)
KP	0.933290	1.0	{4.2.1}	**Wykoff (1982)
PY	0.933290	1.0	{4.2.1}	**Wykoff (1982)
DG	0.075256	0.949670	{4.2.2}	*Pillsbury and Kirkley (1984)
HT	0.075256	0.949670	{4.2.2}	*Pillsbury and Kirkley (1984)
CH	0.075256	0.949670	{4.2.2}	*Pillsbury and Kirkley (1984)
WI	0.075256	0.949670	{4.2.2}	*Pillsbury and Kirkley (1984)
OT	0.90	1.0	{4.2.1}	Wykoff et al (1982)

* Equation was developed from averaging 5 hardwood species from Pillsbury and Kirkley (1984)
** Equation was developed from averaging 5 conifer species from Wykoff (1982)

4.3 Crown Ratio Relationships

Crown ratio equations are used for three purposes in FVS: (1) to estimate tree crown ratios missing from the input data for both live and dead trees; (2) to estimate change in crown ratio from cycle to cycle for live trees; and (3) to estimate initial crown ratios for regenerating trees established during a simulation.

4.3.1 Crown Ratio Dubbing

In the WC variant, crown ratios missing in the input data for live and dead trees are predicted using different equations depending on tree size. Live trees less than 1.0” in diameter and dead trees of all sizes use equations {4.3.1.1} and {4.3.1.2} to compute crown ratio. Equation coefficients are found in table 4.3.1.1.

{4.3.1.1} $X = R_1 + R_2 * HT + R_3 * BA + N(0,SD)$

{4.3.1.2} $CR = ((X - 1) * 10 + 1) / 100$

where:

CR	is crown ratio expressed as a proportion (bounded to $0.05 \leq CR \leq 0.95$)
HT	is tree height
BA	is total stand basal area
N(0,SD)	is a random increment from a normal distribution with a mean of 0 and a standard deviation of SD
$R_1 - R_3$	are species-specific coefficients shown in table 4.3.1.1

Table 4.3.1.1 Coefficients for the crown ratio equation {4.3.1.1} in the WC variant.

Species Code	R_1	R_2	R_3	SD
SF	8.042774	0.007198	-0.016163	1.3167
WF	8.042774	0.007198	-0.016163	1.3167
GF	8.042774	0.007198	-0.016163	1.3167
AF	8.042774	0.007198	-0.016163	1.3167
RF	8.042774	0.007198	-0.016163	1.3167
NF	8.042774	0.007198	-0.016163	1.3167
YC	7.558538	-0.015637	-0.009064	1.9658
IC	7.558538	-0.015637	-0.009064	1.9658
ES	8.042774	0.007198	-0.016163	1.3167
LP	6.489813	-0.029815	-0.009276	2.0426
JP	6.489813	-0.029815	-0.009276	2.0426
SP	6.489813	-0.029815	-0.009276	2.0426
WP	6.489813	-0.029815	-0.009276	2.0426
PP	8.477025	-0.018033	-0.018140	1.3756
DF	8.477025	-0.018033	-0.018140	1.3756
RW	7.558538	-0.015637	-0.009064	1.9658
RC	7.558538	-0.015637	-0.009064	1.9658
WH	7.558538	-0.015637	-0.009064	1.9658
MH	5.000000	0.000000	0.000000	0.5
BM	5.000000	0.000000	0.000000	0.5
RA	5.000000	0.000000	0.000000	0.5
WA	5.000000	0.000000	0.000000	0.5
PB	5.000000	0.000000	0.000000	0.5
GC	5.000000	0.000000	0.000000	0.5
AS	5.000000	0.000000	0.000000	0.5
CW	5.000000	0.000000	0.000000	0.5

Species Code	R_1	R_2	R_3	SD
WO	5.000000	0.000000	0.000000	0.5
WJ	9.000000	0.000000	0.000000	0.5
LL	6.489813	-0.029815	-0.009276	2.0426
WB	6.489813	-0.029815	-0.009276	2.0426
KP	6.489813	-0.029815	-0.009276	2.0426
PY	6.489813	-0.029815	-0.009276	2.0426
DG	5.000000	0.000000	0.000000	0.5
HT	5.000000	0.000000	0.000000	0.5
CH	5.000000	0.000000	0.000000	0.5
WI	5.000000	0.000000	0.000000	0.5
OT	5.000000	0.000000	0.000000	0.5

A Weibull-based crown model developed by Dixon (1985) as described in Dixon (2002) is used to predict crown ratio for all live trees 1.0” in diameter or larger. To estimate crown ratio using this methodology, the average stand crown ratio is estimated from stand density index using equation {4.3.1.3}. Weibull parameters are then estimated from the average stand crown ratio using equations in equation set {4.3.1.4}. Individual tree crown ratio is then set from the Weibull distribution, equation {4.3.1.5} based on a tree’s relative position in the diameter distribution and multiplied by a scale factor, shown in equation {4.3.1.6}, which accounts for stand density. Crowns estimated from the Weibull distribution are bounded to be between the 5 and 95 percentile points of the specified Weibull distribution. Species equation index number is shown in table 4.3.1.2 with equation coefficients for each index shown in table 4.3.1.2.

{4.3.1.3} $ACR = d_0 + d_1 * RELSDI * 100.0$

$RELSDI = SDI_{stand} / SDI_{max}$

{4.3.1.4} Weibull parameters A, B, and C are estimated from average crown ratio

$A = a_0$
$B = b_0 + b_1 * ACR \quad (B \geq 3)$
$C = c_0 + c_1 * ACR \quad (C \geq 2)$

{4.3.1.5} $Y = 1-\exp(-((X-A)/B)^C)$

{4.3.1.6} $SCALE = 1 – (0.00167 * (CCF – 100))$

where:

ACR	is predicted average stand crown ratio for the species
SDI_{stand}	is stand density index of the stand
SDI_{max}	is maximum stand density index
A, B, C	are parameters of the Weibull crown ratio distribution
X	is a tree’s crown ratio expressed as a percent / 10
Y	is a trees rank in the diameter distribution (1 = smallest; ITRN = largest) divided by the total number of trees (ITRN) multiplied by *SCALE*

SCALE is a density dependent scaling factor (bounded to 0.3 ≤ *SCALE* ≤ 1.0)
CCF is stand crown competition factor
a_0, $b_{0\text{-}1}$, $c_{0\text{-}1}$, and $d_{0\text{-}1}$ are species index-specific coefficients shown in table 4.3.1.3

Table 4.3.1.2 Species index number used in assigning Weibull parameters in the WC variant.

Species Code	Species Index Number
SF	1
WF	2
GF	2
AF	3
RF	3
NF	4
YC	15
IC	11
ES	11
LP	16
JP	6
SP	5
WP	5
PP	6
DF	7
RW	11
RC	8
WH	9
MH	10

Species Code	Species Index Number
BM	12
RA	13
WA	14
PB	14
GC	14
AS	14
CW	14
WO	14
WJ	14
LL	11
WB	11
KP	11
PY	11
DG	14
HT	14
CH	14
WI	14
OT	14

Table 4.3.1.3 Coefficients for the Weibull parameter equations {4.3.1.3} and {4.3.1.4} in the WC variant.

Species Index	a_0	b_0	b_1	c_0	c_1	d_0	d_1
1	0.0	-0.173100	1.080573	1.062168	0.445799	5.614200	-0.016547
2	0.0	0.130939	1.093406	1.355139	0.350472	5.212394	-0.011623
3	1.0	-0.981113	1.092273	1.326047	0.318386	4.860467	-0.006173
4	0.0	-0.135807	1.147712	3.017494	0.000000	5.568864	-0.021293
5	0.0	0.019948	1.108738	2.621230	0.186734	4.279655	-0.002484
6	0.0	-0.036696	1.132792	2.876094	0.000000	5.073273	-0.020988
7	0.0	-0.082379	1.137459	2.914892	0.000000	5.067560	-0.010484
8	0.0	0.179839	1.084924	0.122967	0.567784	5.570928	-0.012043
9	0.0	0.490848	1.014138	3.164558	0.000000	5.488532	-0.007173
10	0.0	0.162672	1.073404	3.288501	0.000000	6.484942	-0.023248
11	0.0	0.196054	1.073909	0.345647	0.620145	5.417431	-0.011608

Species Index	a_0	b_0	b_1	c_0	c_1	d_0	d_1
12	1.0	-0.818809	1.054176	-2.366108	1.202413	4.420000	-0.010660
13	1.0	-1.112738	1.123138	2.533158	0.000000	4.120478	-0.006357
14	0.0	-0.238295	1.180163	3.044134	0.000000	4.625125	-0.016042
15	1.0	-0.811424	1.056190	-3.831124	1.401938	5.200550	-0.014890
16	0.0	-0.131210	1.159760	2.598238	0.000000	4.890318	-0.018837

4.3.2 Crown Ratio Change

Crown ratio change is estimated after growth, mortality and regeneration are estimated during a projection cycle. Crown ratio change is the difference between the crown ratio at the beginning of the cycle and the predicted crown ratio at the end of the cycle. Crown ratio predicted at the end of the projection cycle is estimated for live tree records using the Weibull distribution, equations {4.3.1.3}-{4.3.1.6}. Crown change is checked to make sure it doesn't exceed the change possible if all height growth produces new crown. Crown change is further bounded to 1% per year for the length of the cycle to avoid drastic changes in crown ratio. Equations {4.3.1.1} – {4.3.1.2} are not used when estimating crown ratio change.

4.3.3 Crown Ratio for Newly Established Trees

Crown ratios for newly established trees during regeneration are estimated using equation {4.3.3.1}. A random component is added in equation {4.3.3.1} to ensure that not all newly established trees are assigned exactly the same crown ratio.

{4.3.3.1} $CR = 0.89722 - 0.0000461 * PCCF + RAN$

where:

CR	is crown ratio expressed as a proportion (bounded to $0.2 \leq CR \leq 0.9$)
PCCF	is crown competition factor on the inventory point where the tree is established
RAN	is a small random component

4.4 Crown Width Relationships

The WC variant calculates the maximum crown width for each individual tree, based on individual tree and stand attributes. Crown width for each tree is reported in the tree list output table and used for percent canopy cover (*PCC*) calculations in the model.

Crown width is calculated using equations {4.4.1} – {4.4.6}, and coefficients for these equations are shown in table 4.4.1. The minimum diameter and bounds for certain data values are given in table 4.4.2. Equation numbers in table 4.4.1 are given with the first three digits representing the FIA species code, and the last two digits representing the equation source.

{4.4.1} Bechtold (2004); Equation 02

$DBH \geq MinD$: $CW = a_1 + (a_2 * DBH) + (a_3 * DBH^2) + (a_4 * CR\%) + (a_5 * BA) + (a_6 * HI)$

$DBH < MinD$: $CW = [a_1 + (a_2 * MinD) + (a_3 * MinD^2) + (a_4 * CR\%) + (a_5 * BA) + (a_6 * HI)] * (DBH / MinD)$

{4.4.2} Crookston (2003); Equation 03 (used only for Mountain Hemlock)

$HT < 5.0$: $CW = [0.8 * HT * \mathrm{MAX}(0.5, CR * 0.01)] * [1 - (HT - 5) * 0.1] * a_1 * DBH^{a_2} * HT^{a_3} * CL^{a_4} * (HT-5) * 0.1$

$5.0 \leq HT < 15.0$: $CW = 0.8 * HT * \mathrm{MAX}(0.5, CR * 0.01)$

$HT \geq 15.0$: $CW = a_1 * (DBH^{a_2}) * (HT^{a_3}) * (CL^{a_4})$

{4.4.3} Crookston (2003); Equation 03

$DBH \geq MinD$: $CW = [a_1 * \exp[a_2 + (a_3 * \ln(CL)) + (a_4 * \ln(DBH)) + (a_5 * \ln(HT)) + (a_6 * \ln(BA))]]$

$DBH < MinD$: $CW = [a_1 * \exp[a_2 + (a_3 * \ln(CL)) + (a_4 * \ln(MinD)) + (a_5 * \ln(HT)) + (a_6 * \ln(BA))]] * (DBH / MinD)$

{4.4.4} Crookston (2005); Equation 04

$DBH \geq MinD$: $CW = a_1 * DBH^{a_2}$

$DBH < MinD$: $CW = [a_1 * MinD^{a_2}] * (DBH / MinD)$

{4.4.5} Crookston (2005); Equation 05

$DBH \geq MinD$: $CW = (a_1 * BF) * DBH^{a_2} * HT^{a_3} * CL^{a_4} * (BA + 1.0)^{a_5} * (\exp(EL)^{a_6}$

$DBH < MinD$: $CW = [(a_1 * BF) * MinD^{a_2} * HT^{a_3} * CL^{a_4} * (BA + 1.0)^{a_5} * (\exp(EL)^{a_6}] * (DBH / MinD)$

{4.4.6} Donnelly (1996); Equation 06

$DBH \geq MinD$: $CW = a_1 * DBH^{a_2}$

$DBH < MinD$: $CW = [a_1 * MinD^{a_2}] * (DBH / MinD)$

where:

BF	is a species-specific coefficient based on forest code shown in table 4.4.3
CW	is tree maximum crown width
CL	is tree crown length
CR%	is crown ratio expressed as a percent
DBH	is tree diameter at breast height
HT	is tree height
BA	is total stand basal area
EL	is stand elevation in hundreds of feet
MinD	is the minimum diameter
HI	is the Hopkins Index $HI = (ELEVATION - 5449) / 100) * 1.0 + (LATITUDE - 42.16) * 4.0 + (-116.39 - LONGITUDE) * 1.25$
$a_1 – a_6$	are species-specific coefficients shown in table 4.4.1

Table 4.4.1 Coefficients for crown width equations {4.4.1}-{4.4.6} in the WC variant.

Species Code	Equation Number*	a_1	a_2	a_3	a_4	a_5	a_6
SF	1105	4.4799	0.45976	-0.1043	0.11866	0.06762	-0.0072
WF	1505	5.0312	0.5368	-0.1896	0.16199	0.04385	-0.0065
GF	1703	1.0303	1.14079	0.20904	0.38787	0	0
AF	1905	5.8827	0.51479	-0.215	0.17916	0.03277	-0.0083
RF	2006	3.1146	0.578	0	0	0	0
NF	2206	3.0614	0.6276	0	0	0	0
YC	4205	3.3756	0.45445	-0.1152	0.22547	0.08756	-0.0089
IC	8105	5.0446	0.47419	-0.1392	0.1423	0.04838	-0.0062
ES	9305	6.7575	0.55048	-0.252	0.19002	0	-0.0031
LP	10805	6.6941	0.8198	-0.3699	0.17722	-0.012	-0.0088
JP	11605	4.0217	0.66815	-0.1135	0.09689	-0.636	0
SP	11705	3.593	0.63503	-0.2277	0.17827	0.04267	-0.0029
WP	11905	5.3822	0.57896	-0.1958	0.14875	0	-0.0069
PP	12205	4.7762	0.74126	-0.2873	0.17137	-0.006	-0.0021
DF	20205	6.0227	0.54361	-0.2067	0.20395	-0.0064	-0.0038
RW	21104	3.7023	0.52618	0	0	0	0
RC	24205	6.2382	0.29517	-0.1067	0.23219	0.05341	-0.0079
WH	26305	6.0384	0.51581	-0.2135	0.17468	0.06143	-0.0057
MH	26403	6.90396	0.55645	-0.2851	0.2043	0	0
BM	31206	7.5183	0.4461	0	0	0	0
RA	35106	7.0806	0.4771	0	0	0	0
WA	31206	7.5183	0.4461	0	0	0	0
PB	37506	5.898	0.4841	0	0	0	0
GC	63102	3.115	0.7966	0	0.0745	-0.0053	0.0523
AS	74605	4.7961	0.64167	-0.187	0.18581	0	0
CW	74705	4.4327	0.41505	-0.2326	0.41477	0	0
WO	81505	2.4857	0.70862	0	0.10168	0	0
WJ	6405	5.1486	0.73636	-0.4693	0.39114	-0.0543	0
LL	7204	2.2586	0.68532	0	0	0	0
WB	10105	2.2354	0.6668	-0.1166	0.16927	0	0
KP	10305	4.0069	0.84628	-0.2904	0.13143	0	-0.0084
PY	23104	6.1297	0.45424	0	0	0	0
DG	35106	7.0806	0.4771	0	0	0	0
HT	35106	7.0806	0.4771	0	0	0	0

Species Code	Equation Number*	a_1	a_2	a_3	a_4	a_5	a_6
CH	35106	7.0806	0.4771	0	0	0	0
WI	31206	7.5183	0.4461	0	0	0	0
OT	12205	4.7762	0.74126	-0.2873	0.17137	-0.006	-0.0021

*Equation number is a combination of the species FIA code (###) and source (##).

Table 4.4.2 *MinD* values and data bounds for equations {4.4.1}-{4.4.6} in the WC variant.

Species Code	Equation Number*	*MinD*	*EL* min	*EL* max	*HI* min	*HI* max	CW max
SF	01105	1.0	4	72	n/a	n/a	33
WF	01505	1.0	2	75	n/a	n/a	35
GF	01703	1.0	n/a	n/a	n/a	n/a	40
AF	01905	1.0	10	85	n/a	n/a	30
RF	02006	1.0	n/a	n/a	n/a	n/a	65
NF	02206	1.0	n/a	n/a	n/a	n/a	40
YC	04205	1.0	16	62	n/a	n/a	59
IC	08105	1.0	5	62	n/a	n/a	78
ES	09305	1.0	1	85	n/a	n/a	40
LP	10805	1.0	1	79	n/a	n/a	40
JP	11605	1.0	n/a	n/a	n/a	n/a	39
SP	11705	1.0	5	75	n/a	n/a	56
WP	11905	1.0	10	75	n/a	n/a	35
PP	12205	1.0	13	75	n/a	n/a	50
DF	20205	1.0	1	75	n/a	n/a	80
RW	21104	1.0	n/a	n/a	n/a	n/a	39
RC	24205	1.0	1	72	n/a	n/a	45
WH	26305	1.0	1	72	n/a	n/a	54
MH	26403	n/a	n/a	n/a	n/a	n/a	45
BM	31206	1.0	n/a	n/a	n/a	n/a	30
RA	35106	1.0	n/a	n/a	n/a	n/a	35
WA	31206	1.0	n/a	n/a	n/a	n/a	30
PB	37506	1.0	n/a	n/a	n/a	n/a	25
GC	63102	5.0	n/a	n/a	-55	15	41
AS	74605	1.0	n/a	n/a	n/a	n/a	45
CW	74705	1.0	n/a	n/a	n/a	n/a	56
WO	81505	1.0	n/a	n/a	n/a	n/a	39
WJ	06405	1.0	n/a	n/a	n/a	n/a	36
LL	07204	1.0	n/a	n/a	n/a	n/a	33
WB	10105	1.0	n/a	n/a	n/a	n/a	40
KP	10305	1.0	12	49	n/a	n/a	46
PY	23104	1.0	n/a	n/a	n/a	n/a	30

Species Code	Equation Number*	*MinD*	*EL* min	*EL* max	*HI* min	*HI* max	CW max
DG	35106	1.0	n/a	n/a	n/a	n/a	35
HT	35106	1.0	n/a	n/a	n/a	n/a	35
CH	35106	1.0	n/a	n/a	n/a	n/a	35
WI	31206	1.0	n/a	n/a	n/a	n/a	30
OT	12205	1.0	13	75	n/a	n/a	50

Table 4.4.3 BF values for equation {4.4.5} in the WC variant.

	Location Code					
Species Code	**603**	**605**	**606, 708**	**610, 710, 711**	**613**	**618, 709**
SF	1.032		1.296		1.032	
WF			1.130		1.130	
GF			1.086			0.972
AF	0.906	0.886	1.038	0.886		0.936
NF	1.123	1.075	1.301		1.043	
YC			1.493		1.295	1.127
IC				0.903		
ES		0.949		0.949	1.325	0.857
LP			0.944	0.944	1.050	0.903
JP						
SP				1.048	1.097	1.097
WP	1.128	1.081	1.081	1.081	1.128	1.081
PP				0.918	1.035	1.070
DF		1.019			1.055	
RC	0.920	0.973	1.115		1.049	
WH	1.028		1.260		1.106	1.087
MH	1.077		1.106	0.900		
RA				0.810		

*Any *BF* values not listed in Table 4.4.3 are assumed to be *BF* = 1.0

4.5 Crown Competition Factor

The WC variant uses crown competition factor (*CCF*) as a predictor variable in some growth relationships. Crown competition factor (Krajicek and others 1961) is a relative measurement of stand density that is based on tree diameters. Individual tree CCF_t values estimate the percentage of an acre that would be covered by the tree's crown if the tree were open-grown. Stand *CCF* is the summation of individual tree (CCF_t) values. A stand *CCF* value of 100 theoretically indicates that tree crowns will just touch in an unthinned, evenly spaced stand.

Crown competition factor for an individual tree is calculated using equation set {4.5.1}. For Douglas-fir and ponderosa pine greater than 1.0 inch DBH, the coefficients were derived from Paine and Hann

(1982). All others use the Inland Empire variant coefficients (Wykoff, et.al 1982). All species coefficients are shown in table 4.5.1.

{4.5.1} CCF Equations

$DBH \geq 1.0$”: $CCF_t = R_1 + (R_2 * DBH) + (R_3 * DBH^2)$

$DBH < 1.0$”: $CCF_t = (R_1 + R_2 + R_3) * DBH$

where:

CCF_t	is crown competition factor for an individual tree
DBH	is tree diameter at breast height
$R_1 - R_3$	are species-specific coefficients shown in table 4.5.1

Table 4.5.1 Coefficients for *CCF* equation set {4.5.1} in the WC variant.

Species Code	Model Coefficients		
	R_1	R_2	R_3
SF	0.10142	0.0432725	0.00461575
WF	0.0690403	0.0224682	0.00182799
GF	0.0690403	0.0224682	0.00182799
AF	0.0245276	0.0114741	0.0013419
RF	0.0172	0.00876	0.00112
NF	0.0245276	0.0114741	0.0013419
YC	0.0194415	0.0142461	0.00260979
IC	0.0194415	0.0142461	0.00260979
ES	0.0288484	0.0173091	0.00259636
LP	0.0220871	0.0252424	0.0072121
JP	0.0219	0.0168	0.00325
SP	0.0219	0.0168	0.00325
WP	0.0387616	0.0268821	0.00466086
PP	0.0219	0.0168	0.00325
DF	0.0387616	0.0268821	0.00466086
RW	0.0387616	0.0268821	0.00466086
RC	0.0288484	0.0237999	0.00490874
WH	0.037577	0.0232893	0.00360853
MH	0.037577	0.0232893	0.00360853
BM	0.0160051	0.0166659	0.00433848
RA	0.115394	0.0441381	0.0042207
WA	0.115394	0.0441381	0.0042207
PB	0.0170887	0.0213617	0.00667579
GC	0.0160051	0.0166659	0.00433848
AS	0.0170887	0.0213617	0.00667579
CW	0.000450757	0.0029209	0.00473186
WO	0.0170887	0.0213617	0.00667579
WJ	0.0318054	0.0215065	0.00363562
LL	0.0219	0.0168	0.00325

Species Code	Model Coefficients		
	R_1	R_2	R_3
WB	0.01925	0.01676	0.00365
KP	0.01925	0.01676	0.00365
PY	0.0318054	0.0215065	0.00363562
DG	0.0160051	0.0166659	0.00433848
HT	0.0170887	0.0213617	0.00667579
CH	0.0160051	0.0166659	0.00433848
WI	0.0160051	0.0166659	0.00433848
OT	0.0220871	0.0252424	0.0072121

4.6 Small Tree Growth Relationships

Trees are considered "small trees" for FVS modeling purposes when they are smaller than some threshold diameter. The threshold diameter is set to 3.0" for all species in the WC variant.

The small tree model is diameter-growth driven, meaning diameter growth is estimated first, then height growth is estimated from diameter growth. These relationships are discussed in the following sections and were developed by Gould and Harrington (2012).

4.6.1 Small Tree Height Growth

As stated previously, for trees being projected with the small tree equations, diameter growth is predicted first, and then height growth. Five year height increment is calculated using a height-diameter ratio equation {4.6.1.1}.

{4.6.1.1} Small Tree Height Growth

$H5 = D5/a_1$

where:

D5 is 5-yr diameter increment (in)
H5 is 5-yr height increment (ft)
a_1 is a species-specific coefficient from table 4.6.1.1

For trees that have not yet reached breast height, the *D5* value in equation {4.6.2.1} is temporarily calculated to calculate *H5* using equation {4.6.2.2}. If the new height is less than 4.5 feet, than *D5* value remains at 0. If the new height is greater than 4.5 feet then the trees diameter is calculated using equation 4.6.2.2

Table 4.6.1.1 Coefficient (a_1) and equation reference for small-tree height increment equations {4.6.1.1} and equation {4.6.2.2} in the WC variant.

SpeciesNumber	Species Code	a_1
1	SF	0.2474
2	WF	0.2175

SpeciesNumber	Species Code	a_1
3	GF	0.1797
4	AF	0.2056
5	RF	0.2168
7	NF	0.2822
8	YC	0.2168
9	IC	0.2815
10	ES	0.1704
11	LP	0.1682
12	JP	0.2168
13	SP	0.2168
14	WP	0.2168
15	PP	0.2369
16	DF	0.1635
17	RW	0.1727
18	RC	0.1829
19	WH	0.1727
20	MH	0.3029
21	BM	0.2168
22	RA	0.2168
23	WA	0.2168
24	PB	0.2168
25	GC	0.2168
26	AS	0.2168
27	CW	0.2168
28	WO	0.2168
29	WJ	0.2168
30	LL	0.2168
31	WB	0.2168
32	KP	0.1682
33	PY	0.2168
34	DG	0.2168
35	HT	0.2168
36	CH	0.2168
37	WI	0.2168
39	OT	0.1635

For all species, a small random error is then added to the height growth estimate. The estimated height growth is then adjusted to account for cycle length, user defined small-tree height growth adjustments, and adjustments due to small tree height increment calibration from input data.

Height growth estimates from the small-tree model are weighted with the height growth estimates from the large tree model over a range of diameters (X_{min} and X_{max}) in order to smooth the transition between the two models. For example, the closer a tree's *DBH* value is to the minimum diameter (X_{min}), the more the growth estimate will be weighted towards the small-tree growth model. The closer a tree's *DBH* value is to the maximum diameter (X_{max}), the more the growth estimate will be weighted towards the large-tree growth model. If a tree's *DBH* value falls outside of the range given by X_{min} and X_{max}, then the model will use only the small-tree or large-tree growth model in the growth estimate. The weight applied to the growth estimate is calculated using equation {4.6.1.2}, and applied as shown in equation {4.6.1.3}. The range of diameters for each species is shown in table 4.6.1.2.

{4.6.1.2}

$DBH \leq X_{\mathrm{min}}$: $XWT = 0$
$X_{\mathrm{min}} < DBH < X_{\mathrm{max}}$: $XWT = (DBH - X_{\mathrm{min}}) / (X_{\mathrm{max}} - X_{\mathrm{min}})$
$DBH \geq X_{\mathrm{max}}$: $XWT = 1$

{4.6.1.3} Estimated growth = $[(1 - XWT) * STGE] + [XWT * LTGE]$

where:

XWT	is the weight applied to the growth estimates
DBH	is tree diameter at breast height
Xmax	is the maximum *DBH* is the diameter range
X_{min}	is the minimum *DBH* in the diameter range
STGE	is the growth estimate obtained using the small-tree growth model
LTGE	is the growth estimate obtained using the large-tree growth model

Table 4.6.1.2 Diameter bounds by species in the WC variant.

Species Code	X_{min}	X_{max}
SF	2.0	4.0
WF	2.0	4.0
GF	2.0	4.0
AF	2.0	4.0
RF	2.0	4.0
NF	2.0	4.0
YC	2.0	4.0
IC	2.0	4.0
ES	2.0	4.0
LP	1.0	3.0
JP	2.0	4.0
SP	2.0	4.0
WP	2.0	4.0
PP	2.0	4.0
DF	2.0	4.0
RW	2.0	4.0
RC	2.0	4.0

Species Code	X_{min}	X_{max}
RA	2.0	4.0
WA	2.0	4.0
PB	2.0	4.0
GC	2.0	4.0
AS	2.0	4.0
CW	2.0	4.0
WO	2.0	4.0
WJ	2.0	4.0
LL	2.0	4.0
WB	2.0	4.0
KP	2.0	4.0
PY	2.0	4.0
DG	2.0	4.0
HT	2.0	4.0
CH	2.0	4.0
WI	2.0	4.0
OT	2.0	4.0

Species Code	X_{min}	X_{max}
WH	2.0	4.0
MH	2.0	4.0
BM	2.0	4.0

Species Code	X_{min}	X_{max}

4.6.2 Small Tree Diameter Growth

The small-tree diameter model predicts 5-year diameter increment growth for small trees. Diameter growth is estimated using equations {4.6.2.1} and coefficients for these equations are shown in table 4.6.2.1. In the case that height is initially less than 4.5 feet, but after height growth is calculated a tree grows to be greater than 4.5 feet, a height-diameter equation {4.6.2.2} is used to calculate an initial diameter for the tree.

{4.6.2.1} Small Tree Diameter Growth

$HT < 4.5$: $D5 = 0$
$HT > 4.5$: $D5 = DMAX / (1 + \exp(c_0 + c_1*PTBA + c_2*PTBA2 + c_3*PTBAL + c_4*PTBAL2 + c_5*OPEN + c_6*CR + c_7*RELHT + c_8*RELHT2 + c_9*SI))$

where:

$OPEN = 1/(1 + \exp(-3.1 + 0.18*PTBA))$

{4.6.2.2} Small tree Height – Diameter Equation

$DBH = (HT – 4.5) * a_1$

where:

HT	is tree height
DBH	is tree diameter at breast height
D5	is 5-yr diameter increment (in)
DMAX	is maximum diameter increment for the species (in).
OPEN	is an adjustment for open grown conditions
PTBA	is basal area (sq. ft. /ac.) on the inventory point where the tree is located
PTBA2	is the transformation of *PTBA*: log(*PTBA* + 2.71)
PTBAL	is basal area of trees larger than the subject tree (ft2/acre) on the inventory point Where the tree is located
PTBAL2	is the transformation of PTBAL: log(*PTBAL* + 2.71)
CR	is crown ratio expressed as a proportion
RELHT	is tree height / height of 40 largest trees/acre, measured at the stand level (proportion, bound between 0 and 1.5)
RELHT2	is *RELHT*^0.5
SI	is species site index, if species is Douglas-fir the values are transformed using the following equation: SI= 5.21486+0.66486*SI
c_0-c_9	are species-specific coefficients in table 4.6.2.1
a_1	are species-specific coefficients in table 4.6.1.1

Table 4.6.2.1 Coefficients ($c_0 – c_9$) and equation reference for small-tree diameter increment equations {4.6.2.1} in the WC variant.

Species Code	*DMAX*	Model Coefficients									
		c_0	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9
SF	1.7035	2.9445	0	0	0.0068	0	0	-0.1895	0	-1.4049	-0.0168
WF	1.4964	1.7536	0	0.2928	0.0009	0	-0.0446	-2.0349	0	-1.3839	-0.0033
GF	1.6389	2.3571	0.0052	0	0.0006	0	-0.4269	-1.2219	0	0	-0.0170
AF	1.1961	2.5839	0	0.0410	0.0020	0	-0.0152	-2.2060	0	-0.5915	-0.0009
RF	1.5146	2.4743	0	0	0.0032	0	-0.8934	-2.2709	0	-1.0690	0
NF	2.9394	0.3376	0	0	0.0101	0	0	0	0	0	-0.0043
YC	1.5400	-2.0216	0.0063	0	0	0.7175	0	0	0	0	0
IC	1.6825	0.5996	0	0	0.0080	0	0	0	-1.0479	0	0
ES	1.8853	0.0452	0.0080	0	0.0071	0	0	0	0	0	0
LP	1.6535	1.7400	0	0.3718	0.0027	0	-0.1712	-2.1359	0	-0.7266	-0.0074
JP	1.7985	1.8451	0	0	0.0167	0	-1.4737	0	0	-0.4103	-0.0112
SP	2.4740	3.8085	0	0	0.0023	0	-0.4265	-2.0913	0	-1.3932	-0.0093
WP	2.4740	3.8085	0	0	0.0023	0	-0.4265	-2.0913	0	-1.3932	-0.0093
PP	1.7985	1.8451	0	0	0.0167	0	-1.4737	0	0	-0.4103	-0.0112
DF	5.3730	2.4473	0	0	0.0098	0	-0.4290	-0.1710	0	-0.1879	-0.0110
RW	2.8489	2.9527	0	0	0.0066	0	0	-0.4734	0	-0.7394	-0.0207
RC	2.7899	1.6815	0	0	0.0068	0	0	0	0	-0.6049	-0.0121
WH	3.4187	2.9527	0	0	0.0066	0	0	-0.4734	0	-0.7394	-0.0207
MH	1.3834	2.6762	0.0024	0	0.0006	0	-0.4309	-1.6205	0	-0.5930	-0.0051
BM	3.0939	-1.2421	0.0124	0	0	0.4161	0	0	0	0	0
RA	3.0939	1.4593	0	0	0.0085	0	-0.6000	0	0	-1.2280	0
WA	2.0110	-1.1900	0.0158	0	0	0.6600	0	0	0	0	0
PB	2.1657	-1.2421	0.0124	0	0	0.7813	0	0	0	0	0
GC	3.0939	-1.2421	0.0124	0	0	0.6382	0	0	0	0	0
AS	2.4751	-1.2421	0.0124	0	0	0.6013	0	0	0	0	0
CW	3.7127	-1.2421	0.0124	0	0	0.6013	0	0	0	0	0
WO	0.9861	-2.1910	0	0	0	0.7191	-3.1321	0	0	0	0
WJ	1.2192	0.3755	0.0120	0	0	0	0	0	0	0	0
LL	0.6234	1.0527	0	0.3580	0.0019	0	0	-0.6008	0	-0.7451	-0.0101
WB	0.8070	2.4949	0	0	0.0049	0	-0.2085	-1.7001	0	-0.7952	-0.0177
KP	0.5859	-0.8085	0	0.5001	0	0	0	0	0	0	-0.0081
PY	0.8601	1.5156	0	0	0.0012	0	0	-0.5478	0	-0.6123	0
DG	1.0032	-3.8345	0	0	0	1.0701	0	0	0	0	0
HT	1.8903	3.5521	0	0	0.0002	0	0	-0.5932	0	-0.5029	-0.0038
CH	2.1657	-1.2421	0.0124	0	0	0.7312	0	0	0	0	0
WI	2.1657	-1.2421	0.0124	0	0	0.6598	0	0	0	0	0
OT	5.3730	2.4473	0	0	0.0098	0	-0.3575	-0.1710	0	-0.1879	-0.0110

4.7 Large Tree Growth Relationships

Trees are considered "large trees" for FVS modeling purposes when they are equal to, or larger than, some threshold diameter. This threshold diameter is set to 3.0" for all species in the WC variant.

The large-tree model is driven by diameter growth meaning diameter growth is estimated first, and then height growth is estimated from diameter growth and other variables. These relationships are discussed in the following sections.

4.7.1 Large Tree Diameter Growth

The large tree diameter growth model used in most FVS variants is described in section 7.2.1 in Dixon (2002). For most variants, instead of predicting diameter increment directly, the natural log of the periodic change in squared inside-bark diameter (ln(*DDS*)) is predicted (Dixon 2002; Wykoff 1990; Stage 1973; and Cole and Stage 1972). For variants predicting diameter increment directly, diameter increment is converted to the *DDS* scale to keep the FVS system consistent across all variants.

The WC variant predicts diameter growth using equation {4.7.1.1} for all species except red alder. Coefficients for this equation are shown in tables 4.7.1.1 – 4.7.1.4. Diameter growth for red alder in the WC variant is shown later in this section.

In the WC variant, each species is mapped into a species index as shown in table 4.7.1.1. The coefficients for each species for equation 4.7.1.1 will depend on the species index of the subject species.

{4.7.1.1} $\ln(DDS) = b_1 + (b_2 * EL) + (b_3 * EL^2) + (b_4 * \ln(SI)) + (b_5 * \sin(ASP) * SL) + (b_6 * \cos(ASP) * SL) + (b_7 * SL) + (b_8 * SL^2) + (b_9 * \ln(DBH)) + (b_{10} * CR) + (b_{11} * CR^2) + (b_{12} * DBH^2) + (b_{13} * BAL / (\ln(DBH + 1.0))) + (b_{14} * PCCF) + (b_{15} * RELHT) + (b_{16} * \ln(BA)) + (b_{17} * BAL) + (b_{18} * BA)$

where:

DDS	is the square of the diameter growth increment
EL	is stand elevation in hundreds of feet (if species index 14, $EL \leq 30$)
SI	is species site index in feet (if species index 10, $SI = SI * 3.281$ or if species index =18, $SI = SI_{King}$)
ASP	is stand aspect
SL	is stand slope
DBH	is tree diameter at breast height
BAL	is total basal area in trees larger than the subject tree
CR	is crown ratio expressed as a proportion
PCCF	is crown competition factor on the inventory point where the tree is established
RELHT	is tree height divided by average height of the 40 largest diameter trees in the stand bounded to $RELHT \leq 1.5$)
BA	is total stand basal area
b_1	is a location-specific coefficient shown in table 4.7.1.3
b_2- b_{18}	are species-specific coefficients shown in table 4.7.1.4

Table 4.7.1.1 Mapped species index for each species for large-tree diameter growth in the WC variant.

Species Code	Species Index
SF	1
WF	2
GF	2
AF	3

Species Code	Species Index
BM	12
RA	13
WA	14
PB	14

Species Code	Species Index
RF	17
NF	4
YC	15
IC	11
ES	11
LP	16
JP	6
SP	5
WP	5
PP	6
DF	7
RW	11
RC	8
WH	9
MH	10

Species Code	Species Index
GC	14
AS	14
CW	14
WO	18
WJ	14
LL	11
WB	11
KP	11
PY	11
DG	14
HT	14
CH	14
WI	14
OT	14

Table 4.7.1.2 Coefficients (b_2-b_{18}) for species with a species index 1-9 for equation {4.7.1.1} in the WC variant.

	Species Index								
Coefficient	1	2	3	4	5	6	7	8	9
b_2	-0.048852	-0.003051	-0.003773	-0.069045	-0.023376	-0.003784	-0.037591	-0.050081	-0.040067
b_3	0.000478	0	0	0.000608	0	0.0000666	0.000549	0.00066	0.000395
b_4	0.534255	0.318254	0.349888	0.684939	0.40401	1.011504	1.020863	0.139734	0.380416
b_5	0	0	0.02216	-0.207659	0	0	-0.038992	0	0
b_6	0	0	-0.782418	-0.374512	0	0	-0.080943	0	0
b_7	0.245548	0	0.319956	0.400223	0	0	0.077787	0	0.421486
b_8	0	0	0	0	0	0	-0.215778	0	-0.69361
b_9	0.527758	0.905119	0.993986	0.904253	0.84469	0.73875	0.534138	0.843013	0.722462
b_{10}	2.982807	1.754811	1.522401	4.123101	1.59725	3.454857	1.636854	2.878032	2.160348
b_{11}	-1.331331	0	0	-2.68934	0	-1.773805	-0.045578	-1.631418	-0.834196
b_{12}	-0.0001983	-0.0003137	-0.0002621	-0.0003996	-0.0000596	-0.0004708	-0.0001039	-0.0000644	-0.0001546
b_{13}	-0.011247	-0.005355	-0.002979	-0.006368	-0.003726	-0.013091	-0.009363	-0.003923	-0.004065
b_{14}	0	0	0	-0.000471	-0.000257	-0.000593	0	-0.000552	0
b_{15}	0	-0.000661	0	0	0	0	0	0	-0.000358
b_{16}	-0.03073	0	0	0	0	-0.131185	0	0	0
b_{17}	0.002839	0	0	0	0	0	0	0	0
b_{18}	0	0	-0.000137	0	0	0	-0.000215	0	0

*If location code is 610 (Rogue River) or 711 (BLM Medford ADU), β_{12} = 0 for species index 1

Table 4.7.1.2 (continued) Coefficients (b_2- b_{18}) for species with a species index 10-17 for equation {4.7.1.1} in the WC variant.

	Species Index							
Coefficient	10	11	12	14	15	16	17	18

Coefficient	Species Index							
	10	11	12	14	15	16	17	18
b_2	-0.003809	0	-0.012111	-0.075986	0	-0.005414	0.323546	0
b_3	0	0	0	0.001193	0	0	-0.00313	0
b_4	0.20804	0.252853	1.965888	0.227307	0.244694	0.391327	0.375175	0.14995
b_5	-0.12613	0	0	-0.86398	0.679903	0.37886	0.202507	0
b_6	-0.104495	0	0	0.085958	-0.023186	0.207853	-0.93587	0
b_7	0.411602	0	0	0	0	-0.06644	0	0
b_8	0	0	0	0	0	0	0	0
b_9	0.857131	0.879338	1.024186	0.889596	0.81688	0.478504	0.949631	1.66609
b_{10}	1.505513	1.970052	0.459387	1.732535	2.471226	1.905011	1.826879	0
b_{11}	0	0	0	0	0	0	0	0
b_{12}	-0.0002214	-0.0001323	-0.0001737	0	-0.0002536	0	-0.0003552	-0.00154
b_{13}	-0.004101	-0.004215	-0.010222	-0.001265	-0.00595	-0.004706	-0.00535	0
b_{14}	-0.000201	0	-0.000757	0	0	0	0	0
b_{15}	0	0	0	0	0	0	0	0
b_{16}	0	0	0	0	0	0	0	0
b_{17}	0	0	0	0	0	0	0	-0.00326
b_{18}	0	-0.000173	0	-0.000981	-0.000147	-0.000114	0.00004	-0.002040

Table 4.7.1.3 b_1 values by location class for species that have a species index 1 – 9 for equation {4.7.1.1} in the WC variant.

Location Class	Species Index								
	1	2	3	4	5	6	7	8	9
1	-0.619069	-0.64392	-1.888949	-1.401865	-0.58957	-2.922255	-2.750874	0.412763	-0.29831
2	-0.479015	0	-1.27618	-1.127977	-0.909553	0	-2.787499	0.645645	-0.147675
3	-0.291244	0	0	0	0	0	-2.672664	0	-0.006413
4	0	0	0	0	0	0	-2.533437	0	0
5	-0.420228	0	0	0	0	0	-2.693964	0	0
6	-0.746419	0	0	0	0	0	-2.718852	0	0

Table 4.7.1.3 (continued) b1 values by location class for species that have a species index 10 – 17 for equation {4.7.1.1} in the WC variant.

Location Class	Species Index							
	10	11	12	14	15	16	17	18
1	-1.052161	-1.310067	-7.753469	-0.107648	-1.277664	-0.524624	-9.211184	-1.33299
2	-0.793945	-1.432659	-8.279266	-0.098335	-1.178041	-0.803095	-9.800653	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0

Table 4.7.1.4 Location class by species index and location code in the WC variant.

Location Code	Species Index															
	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18
603-Gifford Pinchot	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
605-Mt. Baker - Snoqualmie	2	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1

Location Code	Species Index																
	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18
606-Mt. Hood,708-BLM Salem	3	1	1	2	1	1	3	2	2	2	1	1	1	1	1	1	1
610-Rogue River,711-BLM Medford	4	1	2	2	1	1	4	1	3	2	1	1	1	1	2	1	1
615-Umpqua,710-BLM Roseburg	5	1	1	2	1	1	5	1	2	1	1	1	1	1	2	2	1
618-Willamette,709-BLM Eugene	6	1	1	2	2	1	6	1	1	1	2	2	2	2	2	1	1

Large-tree diameter growth for red alder is predicted using equation set {4.7.1.2}. Diameter growth is predicted based on tree diameter and stand basal area. While not shown here, this diameter growth estimate is eventually converted to the *DDS* scale.

{4.7.1.2} Used for red alder

$DBH \leq 18.0”: DG = CON – (0.166496 * DBH) + (0.004618 * DBH^2)$
$DBH > 18.0”: DG = CON – (CON / 10) * (DBH – 18)$
$CON = (3.2505 – 0.00303 * BA)$

where:

DG	is potential diameter growth
DBH	is tree diameter at breast height
BA	is stand basal area

For all trees, diameter growth is checked to make sure diameter growth is between zero and a maximum allowed value, set by equation {4.7.1.3}. If diameter growth exceeds the estimate in equation {4.7.1.3}, diameter growth is set to the maximum growth allowed.

{4.7.1.3} $DGMax = (7.92 * \exp(-0.03*DBH))$

where:

DGMax	is maximum diameter growth allowed
DBH	is tree diameter at breast height

4.7.2 Large Tree Height Growth

For all species except white oak, height growth equations used in the WC variant are based on site index curves shown in section 3.4. Species differences in height growth are accounted for by entering the appropriate curve with the species specific site index value (see section 3.4).

In the WC variant, each species is mapped into a species index as shown in table 4.7.2.1. The coefficients and equations used for each species will depend on the species index of the subject species.

Table 4.7.2.1 Mapped species index for each species for height growth in the WC variant.

Species Code	Species Index
SF	1
WF	2
GF	2
AF	3

Species Code	Species Index
BM	6
RA	12
WA	6
PB	6

Species Code	Species Index
RF	4
NF	5
YC	6
IC	7
ES	3
LP	8
JP	7
SP	9
WP	9
PP	7
DF	6
RW	6
RC	6
WH	10
MH	11

Species Code	Species Index
GC	6
AS	6
CW	6
WO	
WJ	6
LL	13
WB	6
KP	6
PY	6
DG	6
HT	6
CH	6
WI	6
OT	6

Using a species site index and tree height at the beginning of the projection cycle, an estimated tree age is computed using the site index curves. Also, maximum species heights are computed using equations {4.7.2.1 – 4.7.2.2}.

{4.7.2.1} $HTMAX = a_0 + a_1 * DBH$

{4.7.2.2} $HTMAX2 = a_0 + a_1 * (DBH + (DG/BARK))$

where:

HTMAX	is maximum expected tree height in feet at the start of the projection cycle
HTMAX2	is maximum expected tree height in feet 10-years in the future
DBH	is tree diameter at the start of the projection cycle
DG	is estimated 10-year inside-bark diameter growth
BARK	is tree bark ratio
$a_0 – a_1$	are species-specific coefficients shown in table 4.7.2.2

Table 4.7.2.2 Coefficients for equations {4.7.2.1} and {4.7.2.2} and maximum age in the WC variant.

Species Code	a_0	a_1	Maximum Age
SF	43.9957174	4.3396271	200
WF	43.9957174	4.3396271	200
GF	43.9957174	4.3396271	200
AF	39.6317079	4.3149844	200
RF	39.6317079	4.3149844	200
NF	39.6317079	4.3149844	200
YC	62.7139427	3.2412923	200

Species Code	a_0	a_1	Maximum Age
IC	62.7139427	3.2412923	200
ES	39.6317079	4.3149844	200
LP	65.7622908	2.3475244	200
JP	18.6043842	5.5324838	200
SP	18.6043842	5.5324838	200
WP	18.6043842	5.5324838	200
PP	18.6043842	5.5324838	200
DF	16.2223589	6.3657425	200
RW	16.2223589	6.3657425	200
RC	62.7139427	3.2412923	200
WH	51.9732476	4.0156013	200
MH	51.9732476	4.0156013	200
BM	59.3370816	3.9033821	200
RA	59.3370816	3.9033821	200
WA	59.3370816	3.9033821	200
PB	59.3370816	3.9033821	200
GC	59.3370816	3.9033821	200
AS	59.3370816	3.9033821	200
CW	59.3370816	3.9033821	200
WO	59.3370816	3.9033821	200
WJ	62.7139427	3.2412923	200
LL	62.7139427	3.2412923	200
WB	62.7139427	3.2412923	200
KP	62.7139427	3.2412923	200
PY	62.7139427	3.2412923	200
DG	59.3370816	3.9033821	200
HT	59.3370816	3.9033821	200
CH	59.3370816	3.9033821	200
WI	59.3370816	3.9033821	200
OT	16.2223589	6.3657425	200

For all species, if tree height at the beginning of the projection cycle is greater than the maximum species height (*HTMAX*), then tree height at the beginning of the projection cycle is compared to the estimated tree height at the end of the projection cycle (HTMAX2). If beginning of the cycle height is less than HTMAX2, height growth is computed using equation {4.7.2.3}; if beginning of the cycle height is greater than or equal to HTMAX2, height growth is set using equation {4.7.2.3} or {4.7.2.4} whichever is larger.

If tree height at the beginning of the projection cycle is less than or equal to the maximum species height (*HTMAX*), then height growth is obtained by estimating a tree's potential height growth and adjusting the estimate using a height growth modifier based on the tree's crown ratio and height relative to other trees in the stand, equation {4.7.2.5}.

{4.7.2.3} $HTG = 0.1$

{4.7.2.4} $HTG = 0.5 * DG$

{4.7.2.5} $HTG = POTHTG * HTGMOD$

where:

HTG	is estimated 10-year tree height growth (bounded $0.1 \leq HTG$)
DG	is species estimated 10-year diameter growth
POTHTG	is potential height growth
HTGMOD	is a weighted height growth modifier

If estimated tree age at the beginning of the projection cycle is greater than or equal to the species maximum age, potential height growth is calculated using equation {4.7.2.6}.

{4.7.2.6} $POTHTG = 0.1$

where:

POTHTG is estimated potential 10-year tree height growth (bounded $0.1 \leq HTG$)

When estimated tree age at the beginning of the projection cycle is less than the species maximum age, then potential height growth is obtained by subtracting estimated current height from an estimated future height. In all cases, potential height growth is then adjusted according to the tree's crown ratio and height relative to other trees in the stand.

For all species except Oregon white oak, estimated current height (ECH) and estimated future height (H10) are both obtained using the equations shown below. Estimated current height is obtained using estimated tree age at the start of the projection cycle and site index. Estimated future height is obtained using estimated tree age at the start of the projection cycle plus 10-years and site index.

{4.7.2.7} Used for species index 1: Pacific silver fir

$$H = ([1 - \exp((-1 * (b_0 + b_1 * SM45)) * A)]^{\wedge}b_2 / [1 - \exp((-1 * (b_0 + b_1 * SM45)) * 100)]^{\wedge}b_2) * SM45 + 4.5$$

$$SM45 = SI - 4.5$$

{4.7.2.8} Used for species index 2: white fir, grand fir

$$H = \exp[b_0 + b_1 * \ln(A) + b_2 * (\ln(A))^{\wedge}4 + b_3 * (\ln(A))^{\wedge}9 + b_4 * (\ln(A))^{\wedge}11 + b_5 * (\ln(A))^{\wedge}18] + b_{12} * \exp[b_6 + b_7 * \ln(A) + b_8 * (\ln(A))^{\wedge}2 + b_9 * (\ln(A))^{\wedge}7 + b_{10} * (\ln(A))^{\wedge}16 + b_{11} * (\ln(A))^{\wedge}24] + (SI - 4.5) * \exp[b_6 + b_7 * \ln(A) + b_8 * (\ln(A))^{\wedge}2 + b_9 * (\ln(A))^{\wedge}7 + b_{10} * (\ln(A))^{\wedge}16 + b_{11} * (\ln(A))^{\wedge}24] + 4.5$$

{4.7.2.9} Used for species index 3: subalpine fir, Engelmann spruce

$H = 4.5 + [(b_0 * SI\text{^}b_1) * \{1 - \exp(-b_2 * A)) \text{^} (b_3 * SI\text{^}b_4)]$

{4.7.2.10} Used for species index 4: California red fir / Shasta red fir

$H = [(SI - 4.5) * (1 - \exp(-X * A\text{^}b_1))] / [1 - \exp(-Y * 50\text{^}b_1)] + 4.5$
$X = (SI * TERM) + (b_4 * TERM\text{^}2) + b_5$
$TERM = A * b_2 * \exp(A * b_3)$
$Y = (SI * TERM2) + (b_4 * TERM2\text{^}2) + b_5$
$TERM2 = 50 * b_2 * \exp(50 * b_3)$

{4.7.2.11} Used for species index 5: noble fir

$H = 4.5 + [(SI - 4.5) / (X_1 * (1 / A)\text{^}2 + X_2 * (1 / A) + 1 - (X_1 * 0.0001) - (X_2 * 0.01))]$
$X_1 = b_0 + (b_1 * (SI - 4.5)) - (b_2 * (SI - 4.5)\text{^}2)$
$X_2 = b_3 + (b_4 * 1 / (SI - 4.5)) - (b_5 * (SI - 4.5)\text{^}{-2})$

{4.7.2.12} Used for species index 6: Alaska cedar / western larch, Douglas-fir, coast redwood, western redcedar, bigleaf maple, white alder / Pacific madrone, paper birch, giant chinquapin / tanoak, quaking aspen, black cottonwood, western juniper, whitebark pine, knobcone pine, Pacific yew, Pacific dogwood, hawthorn species, bitter cherry, willow species, other species

$H = [(SI - 4.5) / [b_0 + (b_1 / (SI - 4.5)) + [b_2 + (b_3 / (SI - 4.5))] * A\text{^}{-1.4}] + 4.5$

{4.7.2.13} Used for species index 7: incense-cedar, Jeffrey pine, ponderosa pine

$H = [b_0 * (1 - \exp(b_1 * A))\text{^}b_2] - [(b_3 + b_4 * (1 - \exp(b_5 * A))\text{^}b_6) * b_7] + [(b_3 + b_4 * (1 - \exp(b_5 * A))\text{^}b_6) * (\mathrm{SI} - 4.5)] + 4.5$

{4.7.2.14} Used for species index 8: lodgepole pine

$H = SI * [b_0 + (b_1 * A) + (b_2 * A\text{^}2)]$

{4.7.2.15} Used for species index 9: sugar pine, western white pine

$H = ([1 - \exp(-\exp(b_0 + (b_1 * \ln(A)) + (b_2 / \mathrm{SI})))] / [1 - \exp(-\exp(b_0 + (b_1 * \ln(100)) + (b_2 / SI)))]) * (SI - 4.5) + 4.5$

{4.7.2.16} Used for species index 10: western hemlock

$H = [A\text{^}2 / (b_0 + (b_1 * Z) + ((b_2 + (b_3 * Z)) * A) + ((b_4 + (b_5 * Z)) * A\text{^}2))] + 4.5$
$Z = 2500 / (SI - 4.5)$

{4.7.2.17} Used for species index 11: mountain hemlock

$H = [(b_0 + b_1 * SI) * (1 - \exp(b_2 * SI\text{^}0.5 * A))\text{^}(b_4 + b_5/SI) + 1.37] * 3.281$

{4.7.2.18} Used for species index 12: red alder

$H = SI + (b_0 + (b_1 * SI)) * (1 - \exp(b_2 + (b_3 * \mathrm{SI}) * A))\text{^}b_4 - (b_0 + (b_1 * SI)) * (1 - \exp(b_2 + (b_3 * SI) * 20))\text{^}b_4$

{4.7.2.19} Used for species index 13: subalpine larch

$H = 4.5 + [(b_1 * A) + (b_2 * A\text{^}2) + (b_3 * A\text{^}3) + (b_4 * A\text{^}4)] + [(SI - 4.5) * (b_5 + (b_6 * A) + (b_7 * A\text{^}2) + (b_8 * A\text{^}3))] - [b_9 * (b_{10} + (b_{11} * A) + (b_{12} * A\text{^}2) + (b_{13} * A\text{^}3))]$

where:

H	is estimated height of the tree
SI	is species site index
A	is estimated tree age
$b_0 - b_{13}$	are species-specific coefficients shown in table 4.7.2.3

Table 4.7.2.3 Coefficients (b_0-b_{13}) for height-growth equations in the WC variant.

	Species Index							
Coefficient	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
b_0	0.0071839	-0.30935	2.7578	0	-564.38	0.6192	128.89522	-0.0968
b_1	0.0000571	1.2383	0.83312	1.51744	22.25	-5.3394	-0.016959	0.02679
b_2	1.39005	0.001762	0.015701	1.42E-06	0.04995	240.29	1.23114	-9.31E-05
b_3	0	-5.40E-06	22.71944	-0.044085	6.8	3368.9	-0.7864	0
b_4	0	2.05E-07	-0.63557	-3.05E+06	2843.21	0	2.49717	0
b_5	0	-4.04E-13	0	5.72E-04	34735.54	0	-0.004504	0
b_6	0	-6.2056	0	0	0	0	0.33022	0
b_7	0	2.097	0	0	0	0	100.43	0
b_8	0	-0.09411	0	0	0	0	0	0
b_9	0	-4.38E-05	0	0	0	0	0	0
b_{10}	0	2.01E-11	0	0	0	0	0	0
b_{11}	0	-2.05E-17	0	0	0	0	0	0
b_{12}	0	-84.93	0	0	0	0	0	0
b_{13}	0	0	0	0	0	0	0	0

Table 4.7.2.2 (continued) Coefficients (b_0- b_{13}) for height-growth equations in the WC variant.

Coefficient	Species Index				
	9	10	11	12	13
b_0	-4.62536	-1.7307	22.8741	59.5864	0
b_1	1.346399	0.1394	0.950234	0.7953	1.46897
b_2	-135.3545	-0.0616	-0.002065	0.00194	0.0092466
b_3	0	0.0137	0	-0.00074	-2.40E-04
b_4	0	0.00192	1.365566	0.9198	1.11E-06
b_5	0	0.00007	2.045963	0	-0.12528
b_6	0	0	0	0	0.039636
b_7	0	0	0	0	-4.28E-04
b_8	0	0	0	0	1.70E-06
b_9	0	0	0	0	73.57
b_{10}	0	0	0	0	-0.12528
b_{11}	0	0	0	0	0.039636
b_{12}	0	0	0	0	-4.28E-04
b_{13}	0	0	0	0	1.70E-06

For all species except Oregon white oak, potential height growth is estimated using equation {4.7.2.20}.

{4.7.2.20} *POTHTG = H10 – ECH*

where:

POTHTG is potential height growth
H10 is estimated height of the tree in ten years
ECH is estimated height of the tree at the beginning of the cycle

For Oregon white oak, potential 10-year height growth is calculated using equation {4.7.2.21}.

{4.7.2.21} *POTHTG* = [4.5+{(114.24569(1-exp(-.02659**SIKing*))^2.25993)-18.602 / ln(2.71**BA*)}*{1-exp(-.13743**DBH2*)}^1.38994] – [4.5+{(114.24569(1-exp(-.02659**SIKing*))^2.25993)-18.602 / ln(2.71**BA*)}*{1-exp(-.13743**DBH1*)}^1.38994]

where:

POTHTG is potential 10-year height growth
BA is stand basal area
SIking is Site Index based on King (1966)
DBH1 is diameter of the tree at the beginning of the cycle
DBH2 is estimated diameter of the tree at the end of the cycle

For all species, modifiers are applied to the height growth based upon a tree's crown ratio (equation {4.7.2.22}), and relative height and shade tolerance (equation {4.7.2.23}). Equation {4.7.2.24} uses the Generalized Chapman – Richard's function (Donnelly et. al, 1992) to calculate a height-growth modifier. Final height growth is calculated using equation {4.7.2.5} as a product of the modifier and potential height growth. The final height growth is then adjusted to the length of the cycle.

{4.7.2.22} $HGMDCR = (100 * (CR / 100)^3) * \exp(-5 * (CR / 100))$ bounded $HGMDCR \leq 1.0$

{4.7.2.23} $HGMDRH = [1 + ((1 / b_1)^{(b_2 - 1)} – 1) * \exp(-1 * (b_3 / (1 – b_4)) * RELHT^{(1 – b_4)})]^{(-1 / (b_2 - 1))}$

{4.7.2.24} $HTGMOD = (0.25 * HGMDCR) + (0.75 * HGMDRH)$ bounded $0.0 \leq HTGMOD \leq 2.0$

*if $HTGMOD \leq 0.0$, then $HTGMOD = 0.1$

where:

POTHTG	is potential height growth
H10	is estimated height of the tree in ten years
HT	is height of the tree at the beginning of the cycle
BA	is stand basal area
SIking	is Site Index based on King (1966)
DBH1	is diameter of the tree at the beginning of the cycle
DBH2	is estimated diameter of the tree at the end of the cycle
HGMDCR	is a height growth modifier based on crown ratio
HGMDRH	is a height growth modifier based on relative height and shade tolerance
HTGMOD	is a weighted height growth modifier
CR	is crown ratio expressed as a percent
RELHT	is tree height divided by average height of the 40 largest diameter trees in the stand
$b_1 – b_4$	are species-specific coefficients shown in table 4.7.2.4

Table 4.7.2.4 Coefficients ($b_1 – b_4$) for equation 4.7.2.23 in the WC variant.

Species Code	Coefficients			
	b_1	b_2	b_3	b_4
SF	0.15	1.1	16	-1.2
WF	0.15	1.1	16	-1.2
GF	0.15	1.1	16	-1.2
AF	0.2	1.1	20	-1.1
RF	0.15	1.1	16	-1.2
NF	0.1	1.1	15	-1.45
YC	0.15	1.1	16	-1.2
IC	0.2	1.1	20	-1.1
ES	0.15	1.1	16	-1.2
LP	0.01	1.1	12	-1.6
JP	0.05	1.1	13	-1.6
SP	0.1	1.1	15	-1.45
WP	0.15	1.1	15	-1.45
PP	0.05	1.1	13	-1.6
DF	0.1	1.1	15	-1.45
RW	0.2	1.1	20	-1.1
RC	0.2	1.1	20	-1.1
WH	0.2	1.1	20	-1.1
MH	0.2	1.1	20	-1.1

Species Code	Coefficients			
	b_1	b_2	b_3	b_4
BM	0.2	1.1	20	-1.1
RA	0.05	1.1	13	-1.6
WA	0.05	1.1	13	-1.6
PB	0.05	1.1	13	-1.6
GC	0.1	1.1	15	-1.45
AS	0.01	1.1	12	-1.6
CW	0.01	1.1	12	-1.6
WO	0.1	1.1	15	-1.45
WJ	0.05	1.1	13	-1.6
LL	0.01	1.1	12	-1.6
WB	0.1	1.1	15	0.1
KP	0.01	1.1	12	-1.6
PY	0.2	1.1	20	-1.1
DG	0.2	1.1	20	-1.1
HT	0.01	1.1	12	-1.6
CH	0.05	1.1	13	-1.6
WI	0.01	1.1	12	-1.6
OT	0.1	1.1	15	-1.45

One check is done after computing height growth to limit the maximum height for a given diameter. This check is to make sure that current height plus height growth does not exceed the maximum height for the given diameter. The maximum height for a given diameter is calculated using equation {4.7.2.25}. Species-specific coefficients for this equation are shown in Table 4.7.2.2.

{4.7.2.25} $HT_{max} = a_0 + a_1 * DBH$

where:

HT_{max}	is the maximum height for a given diameter
DBH	is tree diameter at breast height
a_0, a_1	are species-specific coefficients shown in table 4.7.2.2

5.0 Mortality Model

All species in the WC variant use individual tree mortality equations. The large tree equations except for Oregon white oak, were developed by Hann et al 2003 and Hann and Hanus 2001. The small tree equations were developed by Gould and Harrington 2013.

The annual mortality rate estimates, *RA*, predicts individual tree mortality based on trees size, stand density and other tree and stand attributes. The equations used to calculate the annual mortality rate is shown in equations 5.0.1, 5.0.2 and 5.0.3.

{5.0.1} Hann Mortality Equations:

DBH ≥ 3.0”: RA=1-[((1-(1/(1+exp(-Z))))$^{0.2}$)*CRADJ]

group 1 species: $Z=d_0 + d_1*DBH^{.5} + d_3*CR^{0.25} + d_4*(XSITE1+4.5) + d_5*BAL$

group 2 species: $Z= d_0 + d_1*DBH + d_4*(XSITE1+4.5)+ d_5*(BAL/DBH)$

group 3 species: $Z= d_0 + d_1*DBH + d_2*DBH^2+ d_3*CR + d_4*(XSITE2+4.5) + d_5*BAL$

group 4 species: $Z= d_0 + d_1*DBH + d_2*DBH^2+ d_3*CR +*(XSITE1+4.5) + d_5*BAL$

{5.0.2} Gould and Harrington (2009) Mortality Equation for Oregon white oak

DBH ≥ 3.0”: RA = 1 – [1/(1+exp(-6.6707 + 0.5105*ln(5+BA) - 1.3183*RELHT)))]*RADJ

{5.0.3} Gould and Harrington (2013) Mortality for small trees

DBH < 3”: *RA* = 1- [1/(1 + exp(-4.4384 + 0.0053 * PBAL* MCLASS / (DBHA + 1)$^{0.5}$ + -0.6001 * RELHT$^{0.5}$]

HT < 4.5: DBHA = DBH+HT* a_1

HT ≥ 4.5: DBHA = DBH+4.5* a_1

where:

RA	is the estimated annual mortality rate
DBH	is tree diameter at breast height
BA	is total stand basal area
BAL	is total basal area in trees larger
RELHT	is tree height divided by average height of the 40 largest diameter trees in the stand
CR	is crown ratio
CRADJ	crown adjustment =1.0-exp(-(25.0*CR)^2)
XSITE1	=5.21486+0.66486*Douglas-fir site index
XSITE2	Western hemlock site index
PBAL	is basal area of trees larger than the subject tree on the inventory point
MCLASS	Mortality class based on shade tolerance table 5.0.1
HT	is tree height
d_{0-5}	are species-specific coefficients shown in table 5.0.1
a_i	is a species-specific coefficient from table 4.6.1.1

Table 5.0.1 values used in the individual tree mortality equation {5.0.1, 5.0.3} in the WC variant.

Species Code	Coefficients							
	group	d_0	d_1	d_2	d_3	d_4	d_5	MCLASS
SF	2	-7.60159	-0.20052	0	0	0.044133	0.000638	1
WF	2	-7.60159	-0.20052	0	0	0.044133	0.000638	1.5
GF	2	-7.60159	-0.20052	0	0	0.044133	0.000638	1.5
AF	2	-7.60159	-0.20052	0	0	0.044133	0.000638	1.5
RF	2	-7.60159	-0.20052	0	0	0.044133	0.000638	1.5

Species Code	Coefficients							
	group	d_0	d_1	d_2	d_3	d_4	d_5	MCLASS
NF	2	-7.60159	-0.20052	0	0	0.044133	0.000638	2.25
YC	4	-1.92269	-0.13608	0.00248	-3.17812	0	0.004684	1.5
IC	4	-1.92269	-0.13608	0.00248	-3.17812	0	0.004684	2.25
ES	2	-7.60159	-0.20052	0	0	0.044133	0.000638	1.5
LP	4	-1.05	-0.19436	0.003803	-3.5573	0.003972	0.005574	3.375
JP	4	-1.05	-0.19436	0.003803	-3.5573	0.003972	0.005574	3.375
SP	4	-1.05	-0.19436	0.003803	-3.5573	0.003972	0.005574	2.25
WP	4	-1.05	-0.19436	0.003803	-3.5573	0.003972	0.005574	2.25
PP	4	-1.05	-0.19436	0.003803	-3.5573	0.003972	0.005574	3.375
DF	1	-4.13142	-1.13736	0	-0.82331	0.030775	0.00991	2.25
RW	1	-4.13142	-1.13736	0	-0.82331	0.030775	0.00991	1
RC	3	-0.76161	-0.52937	0	-4.74019	0.011959	0.007564	1
WH	3	-0.76161	-0.52937	0	-4.74019	0.011959	0.007564	1
MH	3	-0.76161	-0.52937	0	-4.74019	0.011959	0.007564	1
BM	4	-2.97682	0	0	-6.22325	0	0	1
RA	4	-2	-0.5	0.015	-3	0.015	0.01	3.375
WA	4	-2	-0.5	0.015	-3	0.015	0.01	2.25
PB	4	-2	-0.5	0.015	-3	0.015	0.01	3.375
GC	4	-4.13175	-0.0577	0	0	0.004861	0.009981	2.25
AS	4	-2	-0.5	0.015	-3	0.015	0.01	5.062
CW	4	-2	-0.5	0.015	-3	0.015	0.01	5.062
WO	5	0	0	0	0	0	0	5.062
WJ	4	-1.05	-0.19436	0.003803	-3.5573	0.003972	0.005574	5.062
LL	4	-1.05	-0.19436	0.003803	-3.5573	0.003972	0.005574	3.375
WB	4	-1.05	-0.19436	0.003803	-3.5573	0.003972	0.005574	3.375
KP	4	-1.05	-0.19436	0.003803	-3.5573	0.003972	0.005574	5.062
PY	4	-4.07278	-0.17643	0	-1.72945	0	0.012526	1
DG	4	-3.02035	0	0	-8.46788	0.013966	0.009462	1
HT	4	-3.02035	0	0	-8.46788	0.013966	0.009462	2.25
CH	4	-3.02035	0	0	-8.46788	0.013966	0.009462	2.25
WI	4	-2	-0.5	0.015	-3	0.015	0.01	5.062
--	1	-4.13142	-1.13736	0	-0.82331	0.030775	0.00991	1
OT	1	-4.13412	-1.13736	0	-0.82331	0.030775	0.00991	5.062

The annual mortality rates are adjusted for the length of cycle using a compound interest formula (Hamilton 1976), and then applied to each tree record. After the rate is applied to each tree, if the stand density is above the maximum stand density index (or a basal area of 550ft^2/acre) the stand will reapply the mortality rate to each tree record again until the stand is below the maximum density.

{5.0.4} $RT = 1 - (1 - RA)^{Y}$

where:

RT is the mortality rate applied to an individual tree record for the growth period
RA is the annual mortality rate for the tree record
Y is length of the current projection cycle in years

6.0 Regeneration

The WC variant contains a partial establishment model which may be used to input regeneration and ingrowth into simulations. A more detailed description of how the partial establishment model works can be found in section 5.4.5 of the Essential FVS Guide (Dixon 2002).

The regeneration model is used to simulate stand establishment from bare ground, or to bring seedlings and sprouts into a simulation with existing trees. Sprouts are automatically added to the simulation following harvest or burning of known sprouting species (see table 6.0.1 for sprouting species).

Table 6.0.1 Regeneration parameters by species in the WC variant.

Species Code	Sprouting Species	Minimum Bud Width (in)	Minimum Tree Height (ft)	Maximum Tree Height (ft)
SF	No	0.3	1.0	20.0
WF	No	0.3	1.5	20.0
GF	No	0.3	1.5	20.0
AF	No	0.3	1.0	20.0
RF	No	0.3	1.0	20.0
NF	No	0.3	1.0	20.0
YC	No	0.2	1.0	20.0
IC	No	0.2	1.0	20.0
ES	No	0.3	1.0	20.0
LP	No	0.4	1.4	20.0
JP	No	0.4	1.0	20.0
SP	No	0.4	1.0	20.0
WP	No	0.4	1.0	20.0
PP	No	0.5	1.3	20.0
DF	No	0.3	1.5	20.0
RW	Yes	0.2	1.0	20.0
RC	No	0.2	1.0	20.0
WH	No	0.2	1.0	20.0
MH	No	0.2	1.0	20.0
BM	Yes	0.2	1.0	20.0
RA	Yes	0.2	1.0	50.0
WA	Yes	0.2	1.0	20.0
PB	Yes	0.2	1.0	20.0
GC	Yes	0.2	1.0	20.0
AS	Yes	0.2	1.0	20.0
CW	Yes	0.2	1.0	20.0
WO	Yes	0.2	1.0	20.0
WJ	No	0.2	1.0	20.0
LL	No	0.3	1.5	20.0

Species Code	Sprouting Species	Minimum Bud Width (in)	Minimum Tree Height (ft)	Maximum Tree Height (ft)
WB	No	0.4	1.0	20.0
KP	No	0.4	1.0	20.0
PY	Yes	0.2	1.0	20.0
DG	Yes	0.2	1.0	20.0
HT	Yes	0.2	1.0	20.0
CH	Yes	0.2	1.0	20.0
WI	Yes	0.2	1.0	20.0
OT	No	0.2	1.0	20.0

The number of sprout records created for each sprouting species is found in table 6.0.2. For more prolific stump sprouting hardwood species, logic rule {6.0.1} is used to determine the number of sprout records, with logic rule {6.0.2} being used for root suckering species. The trees-per-acre represented by each sprout record is determined using the general sprouting probability equation {6.0.3}. See table 6.0.2 for species-specific sprouting probabilities, number of sprout records created, and reference information.

Users wanting to modify or turn off automatic sprouting can do so with the SPROUT or NOSPROUT keywords, respectively. Sprouts are not subject to maximum and minimum tree heights found in table 6.0.1 and do not need to be grown to the end of the cycle because estimated heights and diameters are end of cycle values.

{6.0.1} For stump sprouting hardwood species

$DSTMP_i \le 5$: $NUMSPRC = 1$
$5 < DSTMP_i \le 10$: $NUMSPRC = \mathrm{NINT}(0.2 * DSTMP_i)$
$DSTMP_i > 10$: $NUMSPRC = 2$

{6.0.2} For root suckering hardwood species

$DSTMP_i \le 5$: $NUMSPRC = 1$
$5 < DSTMP_i \le 10$: $NUMSPRC = \mathrm{NINT}(-1.0 + 0.4 * DSTMP_i)$
$DSTMP_i > 10$: $NUMSPRC = 3$

{6.0.3} $TPA_s = TPA_i * PS$

{6.0.4} $PS = ((93.2669 - 0.4303 * DSTMP_i)/100)$

{6.0.5} $PS = ((99.9 - 3.8462 * DSTMP_i)/100)$

{6.0.6} $PS = (TPA_i / (ASTPAR * 2)) * ((ASBAR / 198) * (40100.45 - 3574.02 * RSHAG\text{^}2 + 554.02 * RSHAG\text{^}3 - 3.5208 * RSHAG\text{^}5 + 0.011797 * RSHAG\text{^}7))$

where:

$DSTMP_i$ is the diameter at breast height of the parent tree
$NUMSPRC$ is the number of sprout tree records
NINT rounds the value to the nearest integer
TPA_s is the trees per acre represented by each sprout record

TPA_i	is the trees per acre removed/killed represented by the parent tree
PS	is a sprouting probability (see table 6.0.2)
ASBAR	is the aspen basal area removed
ASTPAR	is the aspen trees per acre removed
RSHAG	is the age of the sprouts at the end of the cycle in which they were created

Table 6.0.2 Sprouting algorithm parameters for sprouting species in the WC variant.

Species Code	Sprouting Probability	Number of Sprout Records	Source
RW	{6.0.4}	{6.0.2}	Neal 1967 Boe 1975 Griffith 1992
BM	0.9	{6.0.2}	Roy 1955 Tappenier et al. 1996 Ag. Handbook 654
RA	{6.0.5}	{6.0.2}	Harrington 1984 Uchytil 1989
WA	0.9	{6.0.2}	See red alder (RA)
PB	0.7	1	Hutnik and Cunningham 1965 Bjorkbom 1972
GC	0.9	{6.0.2}	Harrington et al. 1992 Wilkinson et al. 1997 Fryer 2008
AS	{6.0.6}	2	Keyser 2001
CW	0.9	{6.0.2}	Gom and Rood 2000 Steinberg 2001
WO	0.9	{6.0.1}	Roy 1955 Gucker 2007
PY	0.4	1	Minore 1996 Ag. Handbook 654
DG	0.9	[A]	Gucker 2005
HT	No info available--default to 0.7	1	n/a
CH	0.9	{6.0.2}	Mueggler 1965 Leedge and Hickey 1971 Morgan and Neuenschwander 1988
WI	0.9	1	Ag. Handbook 654

Regeneration of seedlings must be specified by the user with the partial establishment model by using the PLANT or NATURAL keywords. Height of the seedlings is estimated in two steps. First, the height is estimated when a tree is 5 years old (or the end of the cycle – whichever comes first) by using the small-tree height growth equations found in section 4.6.1. Users may override this value by entering a height in field 6 of the PLANT or NATURAL keyword; however the height entered in field 6 is not subject to minimum height restrictions and seedlings as small as 0.05 feet may be established. The second step also uses the equations in section 4.6.1, which grow the trees in height from the point five years after establishment to the end of the cycle.

Seedlings and sprouts are passed to the main FVS model at the end of the growth cycle in which regeneration is established. Unless noted above, seedlings being passed are subject to minimum and maximum height constraints and a minimum budwidth constraint shown in table 6.0.1. After seedling height is estimated, diameter growth is estimated using equations described in section 4.6.2. Crown ratios on newly established trees are estimated as described in section 4.3.1.

Regenerated trees and sprouts can be identified in the treelist output file with tree identification numbers beginning with the letters “ES”.

7.0 Volume

Volume is calculated for three merchantability standards: total stem cubic feet, merchantable stem cubic feet, and merchantable stem board feet (Scribner). Volume estimation is based on methods contained in the National Volume Estimator Library maintained by the Forest Products Measurements group in the Forest Management Service Center (Volume Estimator Library Equations 2009). The default volume merchantability standards and equation numbers for the WC variant are shown in tables 7.0.1-7.0.4.

Table 7.0.1 Volume merchantability standards for the WC variant.

Merchantable Cubic Foot Volume Specifications:		
Minimum DBH / Top Diameter	LP	All Other Species
708 – BLM Salem; 709 BLM Eugene; 712 – BLM Coos Bay	7.0 / 5.0 inches	7.0 / 5.0 inches
All other location codes	6.0 / 4.5 inches	7.0 / 4.5 inches
Stump Height	1.0 foot	1.0 foot
Merchantable Board Foot Volume Specifications:		
Minimum DBH / Top Diameter	LP	All Other Species
708 – BLM Salem; 709 BLM Eugene; 712 – BLM Coos Bay	7.0 / 5.0 inches	7.0 / 5.0 inches
All other location codes	6.0 / 4.5 inches	7.0 / 4.5 inches
Stump Height	1.0 foot	1.0 foot

Table 7.0.2 Volume equation defaults for each species, at specific location codes, with model name.

Common Name	Location Code	Equation Number	Reference
Pacific silver fir	603, 606	I12FW2W017	Flewelling's 2-Point Profile Model
Pacific silver fir	605, 610, 615, 618	616BEHW011	Behre's Hyperbola
Pacific silver fir	708, 709, 710, 711	B00BEHW011	Behre's Hyperbola
white fir	603, 605, 606, 618	616BEHW015	Behre's Hyperbola
white fir	610	I00FW2W093	Flewelling's 2-Point Profile Model
white fir	615	I00FW2W017	Flewelling's 2-Point Profile Model
white fir	708, 709, 710, 711	B00BEHW015	Behre's Hyperbola
grand fir	606	I13FW2W017	Flewelling's 2-Point Profile Model
grand fir	603, 605, 610, 615, 618	616BEHW017	Behre's Hyperbola
grand fir	708, 709, 710, 711	B00BEHW017	Behre's Hyperbola
subalpine fir	603	I00FW2W108	Flewelling's 2-Point Profile

Common Name	Location Code	Equation Number	Reference
			Model
subalpine fir	605, 606, 610, 615, 618	616BEHW019	Behre's Hyperbola
subalpine fir	708, 709, 710, 711	B00BEHW015	Behre's Hyperbola
California red fir / Shasta red fir	615	I00FW2W012	Flewelling's 2-Point Profile Model
California red fir / Shasta red fir	603, 605, 606, 610, 618	616BEHW020	Behre's Hyperbola
California red fir / Shasta red fir	708, 709, 710, 711	B00BEHW021	Behre's Hyperbola
noble fir	606	I13FW2W017	Flewelling's 2-Point Profile Model
noble fir	618	I00FW2W108	Flewelling's 2-Point Profile Model
noble fir	603, 605, 610, 615	616BEHW022	Behre's Hyperbola
noble fir	708, 709, 710, 711	B00BEHW022	Behre's Hyperbola
Alaska cedar / western larch	All Region 6	616BEHW042	Behre's Hyperbola
Alaska cedar / western larch	708, 709, 710, 711	B00BEHW042	Behre's Hyperbola
incense-cedar	615	I00FW2W073	Flewelling's 2-Point Profile Model
incense-cedar	603, 605, 606, 610, 618	616BEHW081	Behre's Hyperbola
incense-cedar	708, 709, 710, 711	B00BEHW081	Behre's Hyperbola
Engelmann / Sitka spruce	606	I11FW2W093	Flewelling's 2-Point Profile Model
Engelmann / Sitka spruce	615	I00FW2W093	Flewelling's 2-Point Profile Model
Engelmann / Sitka spruce	603, 605, 610, 618	616BEHW093	Behre's Hyperbola
Engelmann / Sitka spruce	708, 709, 710, 711	B00BEHW093	Behre's Hyperbola
lodgepole pine	606	I11FW2W108	Flewelling's 2-Point Profile Model
lodgepole pine	615	I00FW2W108	Flewelling's 2-Point Profile Model
lodgepole pine	603, 605, 606, 610, 618	616BEHW108	Behre's Hyperbola
lodgepole pine	708, 709, 710, 711	B00BEHW108	Behre's Hyperbola
Jeffrey pine	All Region 6	616BEHW116	Behre's Hyperbola
Jeffrey pine	708, 709, 710, 711	B00BEHW116	Behre's Hyperbola
sugar pine	All Region 6	616BEHW117	Behre's Hyperbola
sugar pine	708, 709, 710, 711	B00BEHW117	Behre's Hyperbola
western white pine	All Region 6	616BEHW119	Behre's Hyperbola

Common Name	Location Code	Equation Number	Reference
western white pine	708, 709, 710, 711	B00BEHW119	Behre's Hyperbola
ponderosa pine	606	I12FW2W122	Flewelling's 2-Point Profile Model
ponderosa pine	610, 615	I00FW2W073	Flewelling's 2-Point Profile Model
ponderosa pine	603, 605, 618	616BEHW122	Behre's Hyperbola
ponderosa pine	708, 709, 710, 711	B00BEHW122	Behre's Hyperbola
Douglas-fir	603	F03FW2W202	Flewelling's 2-Point Profile Model
Douglas-fir	605	F08FW2W202	Flewelling's 2-Point Profile Model
Douglas-fir	606	F03FW2W202	Flewelling's 2-Point Profile Model
Douglas-fir	610	F06FW2W202	Flewelling's 2-Point Profile Model
Douglas-fir	615	F00FW2W202	Flewelling's 2-Point Profile Model
Douglas-fir	618	F05FW2W202	Flewelling's 2-Point Profile Model
Douglas-fir	708, 709, 710, 711	B01BEHW202	Behre's Hyperbola
coast redwood	All Region 6	616BEHW211	Behre's Hyperbola
coast redwood	708, 709, 710, 711	B00BEHW211	Behre's Hyperbola
western redcedar	615	I00FW2W012	Flewelling's 2-Point Profile Model
western redcedar	603, 605, 606, 610, 618	616BEHW242	Behre's Hyperbola
western redcedar	708, 709, 710, 711	B00BEHW242	Behre's Hyperbola
western hemlock	603	F00FW2W263	Flewelling's 2-Point Profile Model
western hemlock	605, 618	F03FW2W263	Flewelling's 2-Point Profile Model
western hemlock	610	616BEHW263	Behre's Hyperbola
western hemlock	606, 615	I11FW2W260	Flewelling's 2-Point Profile Model
western hemlock	708, 709, 710, 711	B00BEHW260	Behre's Hyperbola
mountain hemlock	615	I00FW2W242	Flewelling's 2-Point Profile Model
mountain hemlock	603, 605, 606, 610, 618	616BEHW264	Behre's Hyperbola
mountain hemlock	708, 709, 710, 711	B00BEHW260	Behre's Hyperbola

Common Name	Location Code	Equation Number	Reference
bigleaf maple	All Region 6	616BEHW312	Behre's Hyperbola
bigleaf maple	708, 709, 710, 711	B00BEHW312	Behre's Hyperbola
red alder	All Region 6	616BEHW351	Behre's Hyperbola
red alder	708, 709, 710, 711	B00BEHW351	Behre's Hyperbola
white alder / Pacific madrone	All Region 6	616BEHW352	Behre's Hyperbola
white alder / Pacific madrone	708, 709, 710, 711	B00BEHW361	Behre's Hyperbola
paper birch	All Region 6	616BEHW375	Behre's Hyperbola
paper birch	708, 709, 710, 711	B00BEHW999	Behre's Hyperbola
giant chinquapin / tanoak	All Region 6	616BEHW431	Behre's Hyperbola
giant chinquapin / tanoak	708, 709, 710, 711	B00BEHW431	Behre's Hyperbola
quaking aspen	All Region 6	616BEHW746	Behre's Hyperbola
quaking aspen	708, 709, 710, 711	B00BEHW999	Behre's Hyperbola
black cottonwood	All Region 6	616BEHW747	Behre's Hyperbola
black cottonwood	708, 709, 710, 711	B00BEHW747	Behre's Hyperbola
Oregon white oak / California black oak	All Region 6	616BEHW815	Behre's Hyperbola
Oregon white oak / California black oak	708, 709, 710, 711	B00BEHW800	Behre's Hyperbola
western juniper	All Region 6	616BEHW064	Behre's Hyperbola
western juniper	708, 709, 710, 711	B00BEHW242	Behre's Hyperbola
subalpine larch	All Region 6	616BEHW072	Behre's Hyperbola
subalpine larch	708, 709, 710, 711	B00BEHW073	Behre's Hyperbola
whitebark pine	All Region 6	616BEHW101	Behre's Hyperbola
whitebark pine	708, 709, 710, 711	B00BEHW119	Behre's Hyperbola
knobcone pine	All Region 6	616BEHW103	Behre's Hyperbola
knobcone pine	708, 709, 710, 711	B00BEHW108	Behre's Hyperbola
Pacific yew	All Region 6	616BEHW231	Behre's Hyperbola
Pacific yew	708, 709, 710, 711	B00BEHW231	Behre's Hyperbola
Pacific dogwood	All Region 6	616BEHW492	Behre's Hyperbola
Pacific dogwood	708, 709, 710, 711	B00BEHW999	Behre's Hyperbola
hawthorn species	All Region 6	616BEHW500	Behre's Hyperbola
hawthorn species	708, 709, 710, 711	B00BEHW999	Behre's Hyperbola
bitter cherry	All Region 6	616BEHW768	Behre's Hyperbola
bitter cherry	708, 709, 710, 711	B00BEHW999	Behre's Hyperbola
willow species	All Region 6	616BEHW920	Behre's Hyperbola
willow species	708, 709, 710, 711	B00BEHW999	Behre's Hyperbola
other species	All Region 6	616BEHW999	Behre's Hyperbola
other species	708, 709, 710, 711	B00BEHW999	Behre's Hyperbola

Table 7.0.3 Citations by Volume Model

Model Name	Citation
Behre's Hyperbola	USFS-R6 Sale Preparation and Valuation Section of Diameter and Volume Procedures - R6 Timber Cruise System. 1978.
Flewelling 2-Point Profile Model	Unpublished. Based on work presented by Flewelling and Raynes. 1993. Variable-shape stem-profile predictions for western hemlock. Canadian Journal of Forest Research Vol 23. Part I and Part II.

Table 7.0.4 Species-specific default form class values for the WC variant.

		Form Class				
Species Code	**Behre's Hyperbola Equation Number**	**0<DBH<11**	**11<=DBH<21**	**21<=DBH<31**	**31<=DBH<41**	**DBH>=41**
Gifford Pinchot NF (603)						
SF*	616BEHW011	97	97	93	92	92
WF	616BEHW015	95	95	91	90	90
GF	616BEHW017	93	93	89	88	88
AF*	616BEHW019	98	98	90	89	89
RF	616BEHW020	87	87	82	80	79
NF	616BEHW022	95	95	90	88	88
YC	616BEHW042	93	93	86	86	84
IC	616BEHW081	81	81	72	71	70
ES	616BEHW093	90	90	86	85	85
LP	616BEHW108	96	96	91	91	90
JP	616BEHW116	92	92	82	80	79
SP	616BEHW117	79	79	76	76	75
WP	616BEHW119	93	93	89	88	88
PP	616BEHW122	89	89	82	80	80
DF*	616BEHW202	90	90	87	86	86
RW	616BEHW211	82	82	79	78	78
RC	616BEHW242	79	79	76	74	74
WH*	616BEHW263	95	95	91	91	90
MH	616BEHW260	96	96	90	89	88
BM	616BEHW312	84	84	82	81	80
RA	616BEHW351	84	84	80	78	78
WA	616BEHW352	82	82	78	76	76
PB	616BEHW375	79	79	76	74	74
GC	616BEHW431	87	87	81	79	79
AS	616BEHW746	85	85	81	80	79
CW	616BEHW747	82	82	80	79	79
WO	616BEHW815	95	95	95	95	95

		Form Class				
Species Code	**Behre's Hyperbola Equation Number**	**0<DBH<11**	**11<=DBH<21**	**21<=DBH<31**	**31<=DBH<41**	**DBH>=41**
WJ	616BEHW064	81	81	81	81	74
LL	616BEHW072	92	92	92	92	92
WB	616BEHW101	96	96	96	96	96
KP	616BEHW103	96	96	89	87	86
PY	616BEHW231	81	81	74	70	70
DG	616BEHW492	91	91	84	82	82
HT	616BEHW500	95	95	95	95	95
CH	616BEHW768	86	86	86	84	84
WI	616BEHW920	92	92	92	92	92
OT	616BEHW999	84	84	80	79	78
Mt. Baker - Snoqualmie (605)						
SF	616BEHW011	97	97	92	91	91
WF	616BEHW015	95	95	91	90	90
GF	616BEHW017	86	86	83	82	82
AF	616BEHW019	97	97	97	95	95
RF	616BEHW020	87	87	82	80	79
NF	616BEHW022	88	88	84	82	82
YC	616BEHW042	92	92	85	85	83
IC	616BEHW081	81	81	72	71	70
ES	616BEHW093	90	90	86	85	85
LP	616BEHW108	96	96	91	91	90
JP	616BEHW116	92	92	82	80	79
SP	616BEHW117	79	79	76	76	75
WP	616BEHW119	95	95	91	90	90
PP	616BEHW122	89	89	82	80	80
DF*	616BEHW202	82	82	80	79	78
RW	616BEHW211	82	82	79	78	78
RC	616BEHW242	85	85	81	79	79
WH*	616BEHW263	96	96	93	92	91
MH	616BEHW260	98	98	95	94	93
BM	616BEHW312	84	84	82	81	80
RA	616BEHW351	84	84	80	78	78
WA	616BEHW352	82	82	78	76	76
PB	616BEHW375	79	79	76	74	74
GC	616BEHW431	87	87	81	79	79
AS	616BEHW746	85	85	81	80	79

		Form Class				
Species Code	**Behre's Hyperbola Equation Number**	**0<DBH<11**	**11<=DBH<21**	**21<=DBH<31**	**31<=DBH<41**	**DBH>=41**
CW	616BEHW747	82	82	80	79	79
WO	616BEHW815	95	95	95	95	95
WJ	616BEHW064	81	81	81	81	74
LL	616BEHW072	92	92	92	92	92
WB	616BEHW101	96	96	96	96	96
KP	616BEHW103	96	96	89	87	86
PY	616BEHW231	76	76	69	65	65
DG	616BEHW492	86	86	79	78	78
HT	616BEHW500	95	95	95	95	95
CH	616BEHW768	86	86	86	84	84
WI	616BEHW920	92	92	92	92	92
OT	616BEHW999	84	84	80	79	78
Mount Hood (606)						
SF*	616BEHW011	98	98	93	92	92
WF	616BEHW015	97	97	94	92	92
GF*	616BEHW017	84	84	81	80	79
AF	616BEHW019	98	98	95	93	93
RF	616BEHW020	87	87	82	80	79
NF*	616BEHW022	88	88	84	82	82
YC	616BEHW042	92	92	85	85	83
IC	616BEHW081	92	92	82	80	79
ES*	616BEHW093	87	87	83	82	81
LP*	616BEHW108	89	89	84	84	83
JP	616BEHW116	92	92	82	80	79
SP	616BEHW117	79	79	76	76	75
WP	616BEHW119	93	93	89	88	88
PP*	616BEHW122	92	92	85	84	83
DF*	616BEHW202	83	83	81	80	79
RW	616BEHW211	82	82	79	78	78
RC	616BEHW242	85	85	81	79	79
WH*	616BEHW263	86	86	83	82	82
MH	616BEHW260	84	84	79	78	77
BM	616BEHW312	84	84	82	81	80
RA	616BEHW351	84	84	80	78	78
WA	616BEHW352	82	82	78	76	76
PB	616BEHW375	79	79	76	74	74

		Form Class				
Species Code	**Behre's Hyperbola Equation Number**	**0<DBH<11**	**11<=DBH<21**	**21<=DBH<31**	**31<=DBH<41**	**DBH>=41**
GC	616BEHW431	87	87	81	79	79
AS	616BEHW746	85	85	81	80	79
CW	616BEHW747	82	82	80	79	79
WO	616BEHW815	95	95	95	95	95
WJ	616BEHW064	81	81	81	81	74
LL	616BEHW072	92	92	92	92	92
WB	616BEHW101	96	96	96	96	96
KP	616BEHW103	96	96	89	87	86
PY	616BEHW231	81	81	74	70	70
DG	616BEHW492	86	86	79	78	78
HT	616BEHW500	95	95	95	95	95
CH	616BEHW768	86	86	86	84	84
WI	616BEHW920	92	92	92	92	92
OT	616BEHW999	84	84	80	79	78
Rogue River (610)						
SF	616BEHW011	86	86	81	80	80
WF*	616BEHW015	86	86	83	82	82
GF	616BEHW017	86	86	83	82	82
AF	616BEHW019	94	94	87	85	85
RF	616BEHW020	90	90	84	82	81
NF	616BEHW022	87	87	82	81	80
YC	616BEHW042	85	85	78	78	76
IC	616BEHW081	85	85	75	74	73
ES	616BEHW093	86	86	82	81	80
LP	616BEHW108	82	82	78	78	76
JP	616BEHW116	93	93	83	81	80
SP	616BEHW117	84	84	81	81	80
WP	616BEHW119	85	85	82	81	80
PP*	616BEHW122	89	89	82	80	80
DF*	616BEHW202	84	84	82	81	80
RW	616BEHW211	76	76	74	73	73
RC	616BEHW242	79	79	76	74	74
WH	616BEHW263	82	82	79	78	77
MH	616BEHW260	83	83	78	77	76
BM	616BEHW312	81	81	80	79	78
RA	616BEHW351	81	81	78	76	76

		Form Class				
Species Code	**Behre's Hyperbola Equation Number**	**0<DBH<11**	**11<=DBH<21**	**21<=DBH<31**	**31<=DBH<41**	**DBH>=41**
WA	616BEHW352	84	84	80	79	79
PB	616BEHW375	79	79	76	74	74
GC	616BEHW431	84	84	78	76	76
AS	616BEHW746	81	81	78	77	76
CW	616BEHW747	80	80	78	77	77
WO	616BEHW815	89	89	89	89	89
WJ	616BEHW064	95	95	95	95	86
LL	616BEHW072	95	95	95	95	86
WB	616BEHW101	92	92	92	92	87
KP	616BEHW103	82	82	76	74	73
PY	616BEHW231	98	98	88	84	84
DG	616BEHW492	85	85	78	76	76
HT	616BEHW500	95	95	95	95	95
CH	616BEHW768	79	79	79	77	77
WI	616BEHW920	98	98	98	98	98
OT	616BEHW999	79	79	76	74	74
Umpqua (615)						
SF	616BEHW011	94	94	89	88	87
WF*	616BEHW015	92	92	88	87	87
GF	616BEHW017	92	92	88	87	87
AF	616BEHW019	97	97	97	95	95
RF*	616BEHW020	97	97	91	89	88
NF	616BEHW022	94	94	89	87	87
YC	616BEHW042	76	76	70	70	69
IC*	616BEHW081	76	76	68	66	66
ES*	616BEHW093	97	97	93	91	91
LP*	616BEHW108	96	96	91	91	90
JP	616BEHW116	94	94	84	82	81
SP	616BEHW117	82	82	79	79	78
WP	616BEHW119	86	86	83	82	82
PP*	616BEHW122	90	90	83	81	81
DF*	616BEHW202	84	84	82	81	80
RW	616BEHW211	82	82	79	78	78
RC*	616BEHW242	79	79	76	74	74
WH*	616BEHW263	96	96	93	92	91
MH*	616BEHW260	90	90	84	83	82

		Form Class				
Species Code	**Behre's Hyperbola Equation Number**	**0<DBH<11**	**11<=DBH<21**	**21<=DBH<31**	**31<=DBH<41**	**DBH>=41**
BM	616BEHW312	85	85	83	82	81
RA	616BEHW351	85	85	81	79	79
WA	616BEHW352	82	82	78	76	76
PB	616BEHW375	79	79	76	74	74
GC	616BEHW431	87	87	81	79	79
AS	616BEHW746	85	85	81	80	79
CW	616BEHW747	83	83	81	80	80
WO	616BEHW815	95	95	95	95	95
WJ	616BEHW064	92	92	92	92	92
LL	616BEHW072	92	92	92	92	92
WB	616BEHW101	96	96	96	96	96
KP	616BEHW103	96	96	89	87	86
PY	616BEHW231	95	95	86	82	82
DG	616BEHW492	92	92	85	83	83
HT	616BEHW500	95	95	95	95	95
CH	616BEHW768	87	87	87	85	85
WI	616BEHW920	92	92	92	92	92
OT	616BEHW999	79	79	76	74	74
Willamette (618)						
SF	616BEHW011	78	78	74	73	73
WF	616BEHW015	95	95	91	90	90
GF	616BEHW017	76	76	73	72	72
AF	616BEHW019	81	81	75	73	73
RF	616BEHW020	87	87	82	80	79
NF*	616BEHW022	78	78	74	73	72
YC	616BEHW042	69	69	63	63	62
IC	616BEHW081	69	69	61	60	59
ES	616BEHW093	79	79	76	74	74
LP	616BEHW108	82	82	78	78	76
JP	616BEHW116	92	92	82	80	79
SP	616BEHW117	76	76	74	73	73
WP	616BEHW119	78	78	74	73	73
PP	616BEHW122	82	82	76	74	74
DF*	616BEHW202	71	71	69	68	68
RW	616BEHW211	82	82	79	78	78
RC	616BEHW242	63	63	60	59	59

		Form Class				
Species Code	Behre's Hyperbola Equation Number	0<DBH<11	11<=DBH<21	21<=DBH<31	31<=DBH<41	DBH>=41
WH*	616BEHW263	75	75	72	72	71
MH	616BEHW260	77	77	72	71	71
BM	616BEHW312	75	75	73	72	71
RA	616BEHW351	77	77	73	72	71
WA	616BEHW352	82	82	78	76	76
PB	616BEHW375	79	79	76	74	74
GC	616BEHW431	87	87	81	79	79
AS	616BEHW746	85	85	81	80	79
CW	616BEHW747	75	75	73	73	72
WO	616BEHW815	95	95	95	95	95
WJ	616BEHW064	81	81	81	81	74
LL	616BEHW072	92	92	92	92	92
WB	616BEHW101	96	96	96	96	96
KP	616BEHW103	96	96	89	87	86
PY	616BEHW231	76	76	69	65	65
DG	616BEHW492	86	86	79	78	78
HT	616BEHW500	95	95	95	95	95
CH	616BEHW768	86	86	86	84	84
WI	616BEHW920	92	92	92	92	92
OT	616BEHW999	84	84	80	79	78

***Species whose default volume equation at this location code is not Behre's Hyperbola (see Table 7.0.2).**

BLM Locations:		708	709	710	711
SF	B00BEHW011	84	82	82	74
WF	B00BEHW015	86	78	76	78
GF	B00BEHW017	84	82	80	77
AF	B00BEHW015	82	78	82	75
RF	B00BEHW021	75	78	76	78
	B00BEHW999	80	78	76	70
NF	B00BEHW022	84	78	76	75
YC	B00BEHW042	73	78	70	67
IC	B00BEHW081	73	70	66	66
ES	B00BEHW093	77	78	76	74
LP	B00BEHW108	68	78	80	68
JP	B00BEHW116	75	78	80	70
SP	B00BEHW117	75	72	80	76

BLM Locations:		708	709	710	711
WP	B00BEHW119	76	78	80	76
PP	B00BEHW122	82	70	80	80
DF	B02BEHW202	80	78	72	76
RW	B00BEHW211	75	78	76	70
RC	B00BEHW242	76	72	72	70
WH	B00BEHW260	88	80	82	78
MH	B00BEHW260	72	78	76	70
BM	B00BEHW312	84	78	82	72
RA	B00BEHW351	88	80	82	72
WA	B00BEHW361	70	78	76	72
PB	B00BEHW999	70	78	76	70
GC	B00BEHW431	75	80	76	72
AS	B00BEHW999	75	78	76	72
CW	B00BEHW747	74	82	76	72
WO	B00BEHW800	70	78	76	66
WJ	B00BEHW242	60	78	76	70
LL	B00BEHW073	75	78	76	70
WB	B00BEHW119	82	78	80	73
KP	B00BEHW108	82	78	80	68
PY	B00BEHW231	60	78	76	72
DG	B00BEHW999	70	78	76	69
HT	B00BEHW999	70	78	76	70
CH	B00BEHW999	75	78	76	68
WI	B00BEHW999	75	78	76	72
	B00BEHW999	74	78	76	70
OT	B00BEHW999	74	78	76	70

8.0 Fire and Fuels Extension (FFE-FVS)

The Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS) (Reinhardt and Crookston 2003) integrates FVS with models of fire behavior, fire effects, and fuel and snag dynamics. This allows users to simulate various management scenarios and compare their effect on potential fire hazard, surface fuel loading, snag levels, and stored carbon over time. Users can also simulate prescribed burns and wildfires and get estimates of the associated fire effects such as tree mortality, fuel consumption, and smoke production, as well as see their effect on future stand characteristics. FFE-FVS, like FVS, is run on individual stands, but it can be used to provide estimates of stand characteristics such as canopy base height and canopy bulk density when needed for landscape-level fire models.

For more information on FFE-FVS and how it is calibrated for the WC variant, refer to the updated FFE-FVS model documentation (Rebain, comp. 2010) available on the FVS website.

9.0 Insect and Disease Extensions

FVS Insect and Pathogen models for dwarf mistletoe and western root disease have been developed for the WC variant through the participation and contribution of various organizations led by Forest Health Protection. These models are currently maintained by the Forest Management Service Center and regional Forest Health Protection specialists. Additional details regarding each model may be found in chapter 8 of the Essential FVS Users Guide (Dixon 2002).

10.0 Literature Cited

Alexander, R.R., Tackle, D., and Dahms, W.G. 1967. Site Indices for Engelmann Spruce. Res. Pap. RM-32. Forest Service, Rocky Mountain Research Station.

Arney, J. D. 1985. A modeling strategy for the growth projection of managed stands. Canadian Journal of Forest Research. 15(3):511-518.

Barrett, James W. 1978. Height growth and site index curves for managed, even-aged stands of ponderosa pine in the Pacific Northwest. Res. Pap. PNW-232. Portland, OR: Forest Service, Pacific Northwest Forest and Range Experiment Station. 14 p.

Bechtold, William A. 2004. Largest-crown-diameter Prediction Models for 53 Species in the Western United States. WJAF. Forest Service. 19(4): pp 241-245.

Boe, Kenneth N. 1975. Natural seedlings and sprouts after regeneration cuttings in old-growth redwood. PSW-111. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 17 p.

Bjorkbom, John C. 1972. Stand changes in the first 10 years after seedbed preparation for paper birch. USDA Forest Service, Research Paper NE-238. Northeastern Forest Experiment Station, Upper Darby, PA. 10 p.

Burns, R. M., & Honkala, B. H. 1990. Silvics of North America: 1. Conifers; 2. Hardwoods Agriculture Handbook 654. US Department of Agriculture, Forest Service, Washington, DC.

Cochran, P.H. 1979. Site index and height growth curves for managed, even-aged stands of white or grand fir east of the Cascades in Oregon and Washington. Res. Pap. PNW-251. Portland, OR: Forest Service, Pacific Northwest Forest and Range Experiment Station. 16 p.

Cochran, P.H. 1979. Site index and height growth curves for managed, even-aged stands of white or grand fir east of the Cascades in Oregon and Washington. Res. Pap. PNW-252. Portland, OR: Forest Service, Pacific Northwest Forest and Range Experiment Station. 13 p.

Cochran, P. H. 1985. Site index, height growth, normal yields, and stocking levels for larch in Oregon and Washington. Res. Note PNW-424. Portland, OR: Forest Service, Pacific Northwest Forest and Range Experiment Station. 13 p.

Cole, D. M.; Stage, A. R. 1972. Estimating future diameters of lodgepole pine. Res. Pap. INT-131. Ogden, UT: U. S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 20p.

Crookston, Nicholas L. 2003. Internal document on file. Data provided from Region 1. Moscow, ID: Forest Service.

Crookston, Nicholas L. 2005. Draft: Allometric Crown Width Equations for 34 Northwest United States Tree Species Estimated Using Generalized Linear Mixed Effects Models.

Crookston, Nicholas L. 2008. Internal Report.

Curtis, Robert O. 1967. Height-diameter and height-diameter-age equations for second-growth Douglas-fir. Forest Science 13(4):365-375.

Curtis, Robert O.; Herman, Francis R.; DeMars, Donald J. 1974. Height growth and site index for Douglas-fir in high-elevation forests of the Oregon-Washington Cascades. Forest Science 20(4):307-316.

Curtis, Robert O.; Diaz, Nancy M.; Clendenen, Gary W. 1990. Height growth and site index curves for western white pine in the Cascade Range of Washington and Oregon. Res. Pap. PNW-423. Portland, OR: Forest Service, Pacific Northwest Forest and Range Experiment Station. 14 p.

Dahms, Walter. 1964. Gross and net yield tables for lodgepole pine. Res. Pap. PNW-8. Portland, OR: Pacific Northwest Forest and Range Experiment Station. 14 p.

Dixon, G. E. 1985. Crown ratio modeling using stand density index and the Weibull distribution. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 13p.

Dixon, Gary E. comp. 2002 (revised frequently). Essential FVS: A user's guide to the Forest Vegetation Simulator. Internal Rep. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Forest Management Service Center.

Dolph, K. Leroy. 1991. Polymorphic site index curves for red fir in California and southern Oregon. Res. Paper PSW-206. Berkeley, CA: Forest Service, Pacific Southwest Forest and Range Experiment Station. 18p.

Donnelly, Dennis M., Betters, David R., Turner, Matthew T., and Gaines, Robert E. 1992. Thinning even-aged forest stands: Behavior of singular path solutions in optimal control analyses. Res. Pap. RM-307. Fort Collins, CO: Forest Service. Rocky Mountain Forest and Range Experiment Station. 12 p.

Donnelly, Dennis. 1996. Internal document on file. Data provided from Region 6. Fort Collins, CO: Forest Service.

Unpublished. Based on work presented by Flewelling and Raynes. 1993. Variable-shape stem-profile predictions for western hemlock. Canadian Journal of Forest Research Vol 23. Part I and Part II.

Fryer, Janet L. 2008. Lithocarpus densiflorus. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer).

Gom, L. A., & Rood, S. B. (2000). Fire induces clonal sprouting of riparian cottonwoods. Canadian Journal of Botany, 77(11), 1604-1616.

Gould, Peter and Harrington, Constance. 2009. Draft - Revising the Pacific Northwest Coast Variant of the Forest Vegetation Simulator (FVS-PN) for Oregon White Oak. USDA Forest Service, Pacific Northwest Research Station. 25 p.

Gould, Peter J.; Harrington, Constance A. 2013. Making the little things count: modeling the development of understory trees in complex stands. In: Anderson, Paul D.; Ronnenberg, Kathryn L., eds. Density management for the 21st century: west side story. Gen. Tech. Rep. PNW-GTR-880. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacifi c Northwest Research Station: 59–70.Hall, Frederick C. 1983. Growth basal area: a field method for appraising forest site productivity for stockability. Can. J. For. Res. 13:70-77.

Griffith, Randy Scott. 1992. Sequoia sempervirens. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer).

Gucker, Corey L. 2005. Cornus nuttallii. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer).

Gucker, Corey L. 2007. Quercus garryana. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer).

Hall, Frederick C. 1983. Growth basal area: a field method for appraising forest site productivity for stockability. Can. J. For. Res. 13:70-77.

Hamilton, D. A., Jr. 1986. A logistic model of mortality in thinned and unthinned mixed conifer stands of northern Idaho. Forest Science 32(4): 989-1000.

Harrington, Constance A. 1984. Factors influencing initial sprouting of red alder. Canadian Journal of Forest Research. 14: 357-361.

Harrington, Constance A.; Curtis, Robert O. 1986. Height growth and site index curves for red alder. Res. Pap. PNW-358. Portland, OR: Forest Service, Pacific Northwest Forest and Range Experiment Station. 14 p.

Harrington, T. B., Tappeiner, I. I., John, C., & Warbington, R. 1992. Predicting crown sizes and diameter distributions of tanoak, Pacific madrone, and giant chinkapin sprout clumps. Western Journal of Applied Forestry, 7(4), 103-108.

Herman, Francis R.; Curtis, Robert O.; DeMars, Donald J. 1978. Height growth and site index estimates for noble fir in high-elevation forests of the Oregon-Washington Cascades. Res. Pap. PNW-243. Portland, OR: Forest Service, Pacific Northwest Forest and Range Experiment Station. 15 p.

Hoyer, Gerald E.; Herman, Francis R. 1989. Height-age and site index curves for Pacific silver fir in the Pacific Northwest. Res. Pap. PNW-418. Portland, OR: Forest Service, Pacific Northwest Forest and Range Experiment Station. 33 p.

Hutnik, Russell J., and Frank E. Cunningham. 1965. Paper birch (Betula papyrifera Marsh.). In Silvics of forest trees of the United States. p. 93-98. H. A. Fowells, comp. U.S. Department of Agriculture, Agriculture Handbook 271. Washington, DC.

Keyser, C.E. 2001. Quaking Aspen Sprouting in Western FVS Variants: A New Approach. Unpublished Manuscript.

Krajicek, J.; Brinkman, K.; Gingrich, S. 1961. Crown competition – a measure of density. Forest Science. 7(1):35-42

Leedge, T. A., & Hickey, W. O. 1971. Sprouting of northern Idaho shrubs after prescribed burning. The Journal of Wildlife Management, 508-515.

Means, J.F., M.H. Campbell, and G.P. Johnson. 1986. Preliminary height growth and site index curves for mountain hemlock. FIR Report, Vol 10, No.1. Corvallis, OR: Oregon State University.

Minore, D., & Weatherly, H. G. (1996). Stump sprouting of Pacific yew. General Technical Report. PNW-GTR-378. Portland, Or.: U.S. Dept. of Agriculture, Pacific Northwest Research Station.

Morgan, P., & Neuenschwander, L. F. 1988. Shrub response to high and low severity burns following clearcutting in northern Idaho. Western Journal of Applied Forestry, 3(1), 5-9.

Mueggler, W. F. 1965. Ecology of seral shrub communities in the cedar-hemlock zone of northern Idaho. Ecological Monographs, 165-185.

Neal, Robert L., Jr. 1967. Sprouting of old-growth redwood stumps--first year after logging. USDA Forest Service, Research Note PSW-137. Pacific Southwest Forest and Range Experiment Station, Berkeley, CA. 8 p.

Paine, D.P., and Hann, D.W. 1982. Maximum Crown Width Equations for Southwestern Oregon Tree Species. Res. Pap. 46. Corvallis, OR: Oregon State University, Forest Research Laboratory. 20 p.

Pillsbury, Norman H.; Kirkley, Michael L. 1984. Equations for total, wood, and saw-log volume for thirteen California hardwoods. Res. Note PNW-414. Portland, OR: Forest Service, Pacific Northwest Forest and Range Experiment Station. 52 p.

Rebain, Stephanie A. comp. 2010 (revised frequently). The Fire and Fuels Extension to the Forest Vegetation Simulator: Updated Model Documentation. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 379 p.

Reinhardt, Elizabeth; Crookston, Nicholas L. (Technical Editors). 2003. The Fire and Fuels Extension to the Forest Vegetation Simulator. Gen. Tech. Rep. RMRS-GTR-116. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 209 p.

Roy, D. F. 1955. Hardwood sprout measurements in northwestern California. Forest Research Notes. California Forest and Range Experiment Station, (95).

Stage, A. R. 1973. Prognosis Model for stand development. Res. Paper INT-137. Ogden, UT: U. S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 32p.

Steinberg, Peter D. 2001. Populus balsamifera subsp. trichocarpa. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer).

Tappeiner, I. I., John, C., Zasada, J., Huffman, D., & Maxwell, B. D. 1996. Effects of cutting time, stump height, parent tree characteristics, and harvest variables on development of bigleaf maple sprout clumps. Western Journal of Applied Forestry, 11(4), 120-124.

Uchytil, Ronald J. 1989. Alnus rubra. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory.

USFS-R6 Sale Preparation and Valuation Section of Diameter and Volume Procedures - R6 Timber Cruise System. 1978.

-----. 2009(revised frequently). Volume Estimator Library Equations. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center.

Walters, David K., Hann, David W., Clyde, Merlise A. 1985. Equations and tables predicting gross total stem volumes in cubic feet for six major conifers of southwest Oregon. Res. Bull. No. 50. Corvallis, OR: Forest Research Laboratory, College of Forestry, Oregon State University. 36p.

Wiley, Kenneth N. 1978. Site index tables for western hemlock in the Pacific Northwest. For. Pap. No. 17. Centralia, WA: Weyerhaeuser Forestry Research Center. 28 p.

Wilkinson, W. H., McDonald, P. M., & Morgan, P. 1997. Tanoak sprout development after cutting and burning in a shade environment. Western Journal of Applied Forestry, 12(1), 21-26.

Wykoff, W. R. 1990. A basal area increment model for individual conifers in the northern Rocky Mountains. For. Science 36(4): 1077-1104.

Wykoff, William R., Crookston, Nicholas L., and Stage, Albert R. 1982. User's guide to the Stand Prognosis Model. Gen. Tech. Rep. INT-133. Ogden, UT: Forest Service, Intermountain Forest and Range Experiment Station. 112p.

11.0 Appendices

11.1 Appendix A: Distribution of Data Samples

Data used to develop the WC variant come from the following sources, listed along with each principal reference governing their collection.

Gifford Pinchot National Forest

1981 Inventory (USDA Forest Service 1981)

Mt. Baker-Snoqualmie National Forest

1976 Inventory (USDA Forest Service 1976)
1987 Managed Stand Survey (USDA Forest Service 1987)

Mt. Hood National Forest

1970 Inventory (USDA Forest Service 1968)
1971 Inventory (USDA Forest Service 1971)
1986 Inventory (USDA Forest Service 1986)
1987 Managed Stand Survey (USDA Forest Service 1987)

Rogue River National Forest

1980 Inventory (USDA Forest Service 1980)

Umpqua National Forest

1968, 1969 Inventories (USDA Forest Service 1968)
1980 Inventory (USDA Forest Service 1980)

Willamette National Forest

1971 Inventory (USDA Forest Service 1971)
1981 Inventory (USDA Forest Service 1981)
1987 Managed Stand Survey (USDA Forest Service 1987)

The following tables contain distribution information of data used to fit species relationships in this variant’s geographic region (information from original variant overview).

Table 11.1.1 Species codes and names used in the WC variant.

Common Name	FIA Code	Scientific Name	Number of Observations	Comments (see below)
Pacific silver fir	011	*Abies amabilis*	3878	*
white fir	015	*Abies concolor*	1044	
grand fir	017	*Abies grandis*	504	*
subalpine fir	019	*Abies lasiocarpa*	227	*
California red fir	020	*Abies magnifica*	44	* A
Shasta red fir	021	*Abies magnifica var. shastensis*	515	* a
noble fir	022	*Abies procera*	1555	*
Alaska cedar	042	*Callitropsis nootkatensis*	112	* B
western larch	073	*Laryx Occidentalis*	74	* b
incense cedar	081	*Libocedrus decurrens*	296	
Engelmann spruce	093	*Picea engelmannii*	209	* C
lodgepole pine	108	*Pinus contorta*	2	* c
Sitka spruce	108	*Picea sitchensis*	898	*
Jeffrey pine	116	*Pinus jeffreyi*	0	
sugar pine	117	*Pinus lambertiana*	240	
western white pine	119	*Pinus monticola*	414	*
ponderosa pine	122	*Pinus ponderosa*	432	*
Douglas-fir	202	*Pseudotsuga menziesii*	17250	*
coast redwood	211	*Sequoia sempervirens*	0	
western redcedar	242	*Thuja plicata*	1354	*
western hemlock	263	*Tsuga heterophylla*	5008	*
mountain hemlock	264	*Tsuga mertensiana*	3019	*
bigleaf maple	312	*Acer macrophyllum*	89	*
red alder	351	*Alnus rubra*	125	*
white alder	352	*Alnus rhombifolia*	2	D
Pacific madrone	361	*Arbutus menziesii*	70	d
paper birch	375	*Betula papyrifera var. commutata*	0	
giant chinquapin	431	*Castanopsis chrysophylla*	62	E
Tanoak	631	*Lithocarpus densiflorus*	1	e
quaking aspen	746	*Populus tremuloides*	0	
black cottonwood	747	*Populus trichocarpa*	8	
Oregon white	815	*Quercus garryana*	12	F

Common Name	FIA Code	Scientific Name	Number of Observations	Comments (see below)
oak				
California black oak	818	*Quercus kelloggi*	4	f
juniper	064	*Juniperus occidentalis*	0	
subalpine larch	072	*Larix lyallii*	0	
whitebark pine	101	*Pinus albicaulis*	2	
knobcone pine	103	*Pinus attenuata*	0	
Pacific yew	231	*Taxus brevifolia*	5	
Pacific dogwood	492	*Cornus nuttallii*	0	
hawthorn	500	*Crataegus spp.*	0	
bitter cherry	768	*Prunus emarginata*	0	
willow	920	*Salix spp.*	0	
other species	999			

A “*” marks a species whose large tree growth relationships were fitted specifically for either the WC or PN variant.

Pairs of letters, for example “A” and “a” indicate two species of the same variety that are combined into one code in the variant. The capital letter marks which species of the two the variant assumes.

Table 11.1.2 Distribution of samples by National Forest (expressed in percent of total observations for each species).

	National Forest					
Species	Gifford Pinchot	Mt. Baker/ Snoqualmie	Mount Hood	Rogue River	Umpqua	Willamette
Pacific silver fir	12	24	33	0	4	28
grand fir	4	0	35	28	21	11
subalpine fir	28	12	18	1	23	19
California red fir/ Shasta red fir	-	-	-	75	25	0
noble fir	4	3	32	2	17	43
Engelmann spruce	4	1	13	17	36	29
Alaska cedar	7	46	19	-	-	28
lodgepole pine	5	-	30	8	44	13
ponderosa pine	2	-	67	14	15	2
western white pine	2	0	9	11	46	33
Douglas-fir	9	5	20	4	23	40
western redcedar	8	24	28	-	3	37
western hemlock	8	24	31	1	6	30
mountain hemlock	3	7	16	3	22	49
Pacific madrone	8	23	7	-	9	54
red alder	11	23	52	-	6	7

Species	National Forest					
	Gifford Pinchot	Mt. Baker/ Snoqualmie	Mount Hood	Rogue River	Umpqua	Willamette
miscellaneous hardwood	3	4	35	3	48	7

Table 11.1.3 Distribution of samples for DBH (expressed in percent of total observations for each species).

Species	DBH Range									
	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	90+
Pacific silver fir	29	39	21	9	3	0	-	-	-	-
grand fir	25	39	22	12	2	0	-	0	0	-
subalpine fir	30	46	21	3	1	-	-	-	-	-
California red fir/ Shasta red fir	19	24	25	18	10	4	1	-	-	-
noble fir	15	33	27	17	7	1	0	-	-	-
Engelmann spruce	17	21	22	17	10	3	1	1	-	-
Alaska cedar	21	30	21	17	8	2	1	-	-	-
lodgepole pine	52	48	0	0	-	-	-	-	-	-
ponderosa pine	16	20	29	25	10	1	0	-	-	-
western white pine	11	24	31	18	10	6	1	1	-	-
Douglas-fir	11	26	24	18	12	7	2	1	0	0
western redcedar	15	25	21	15	9	6	5	3	1	1
western hemlock	20	33	25	14	6	2	0	0	-	-
mountain hemlock	20	41	29	8	1	0	0	-	-	-
Pacific madrone	48	44	7	1	-	-	-	-	-	-
red alder	28	63	9	-	-	-	-	-	-	-
miscellaneous hardwood	51	33	8	7	-	-	-	-	0	-

Table 11.1.4 Distribution of samples by diameter growth (expressed in percent for each species).

Species	Diameter Growth (inches/10 years)								
	<1.0	1.1-2.0	2.1-3.0	3.1-4.0	4.1-5.0	5.1-6.0	6.1-7.0	7.1-8.0	8.0+
Pacific silver fir	75	20	4	1	0	-	0	-	-
grand fir	51	34	11	3	1	0	-	-	0
subalpine fir	77	20	2	0	-	-	-	-	-
California red fir/ Shasta red fir	53	36	9	2	1	-	-	-	-
noble fir	51	34	10	3	2	1	0	-	0
Engelmann spruce	73	22	3	1	0	-	0	-	-
Alaska cedar	80	15	3	-	1	-	-	-	-

lodgepole pine	83	15	2	0	0	-	-	-	-
ponderosa pine	67	20	7	3	1	1	0	-	-
western white pine	68	25	5	2	0	-	-	-	-
Douglas-fir	66	25	5	2	1	1	0	0	0
western redcedar	60	31	7	2	1	0	-	-	-
western hemlock	71	23	4	1	0	0	0	-	0
mountain hemlock	89	10	1	0	0	-	-	-	-
Pacific madrone	55	25	13	6	1	-	-	-	-
red alder	23	49	22	6	-	1	-	-	-
miscellaneous hardwood	12	4	1	0	-	-	-	-	

Table 11.1.5 Distribution of samples by total stand basal area per acre, (expressed in percent for each species).

	Basal Area							
Species	0-50	51-150	151-250	251-350	351-450	451-550	551-650	651+
Pacific silver fir	0	7	29	40	19	5	1	0
grand fir	1	15	32	31	17	5	1	-
subalpine fir	-	14	41	34	8	3	-	-
California red fir/ Shasta red fir	1	11	21	32	30	6	-	-
noble fir	0	7	29	35	24	4	1	0
Engelmann spruce	0	10	29	37	18	4	2	-
Alaska cedar	-	9	25	46	10	4	5	-
lodgepole pine	2	35	50	9	4	0	-	-
ponderosa pine	4	36	40	15	6	-	-	-
western white pine	1	14	42	27	13	4	-	-
Douglas-fir	0	8	29	34	20	6	2	0
western redcedar	0	4	25	36	23	9	2	2
western hemlock	0	5	26	39	21	8	1	0
mountain hemlock	0	8	35	40	15	3	0	-
Pacific madrone	1	24	40	25	8	2	-	-
red alder	-	21	39	28	10	2	-	-
miscellaneous hardwood	1	21	46	22	9	2	-	-

Table 11.1.6 Distribution of samples by Crown Ratio group (expressed in percent of total observations for each species).

Species	Crown Code (1=1-10,2=11-20,…,9=81-100)								
	1	2	3	4	5	6	7	8	9
Pacific silver fir	2	9	19	24	20	14	7	4	1
grand fir	1	8	23	22	19	13	8	5	2
subalpine fir	1	7	12	20	16	18	10	12	5
California red fir/ Shasta red fir	1	8	25	25	22	11	4	3	1
noble fir	1	12	33	27	11	6	4	4	2
Engelmann spruce	1	6	23	21	19	15	6	7	2
Alaska cedar	3	14	17	19	15	21	9	3	-
lodgepole pine	4	15	28	21	13	9	5	3	1
ponderosa pine	2	16	28	23	13	8	5	4	1
western white pine	1	11	27	27	17	9	5	2	1
Douglas-fir	1	10	29	30	16	7	3	3	1
western redcedar	4	7	16	16	19	17	14	6	2
western hemlock	2	7	14	21	20	17	12	6	2
mountain hemlock	1	5	16	22	21	16	11	7	2
Pacific madrone	2	16	38	20	12	6	3	2	-
red alder	-	13	38	30	12	2	3	2	-
miscellaneous hardwood	2	17	31	28	12	6	2	1	1

Table 11.1.7 Distribution of samples by Aspect Code (expressed in percent of total observations for each species).

Species	Aspect Code								
	North	North -east	East	South -east	South	South -west	West	North -west	Level
Pacific silver fir	19	11	11	8	10	9	12	13	8
grand fir	8	8	8	9	13	15	12	12	15
subalpine fir	5	2	11	1	19	13	17	13	19
California red fir/ Shasta red fir	10	16	12	4	9	9	27	9	4
noble fir	12	7	13	8	10	13	19	11	8
Engelmann spruce	11	5	7	10	12	13	18	8	16
Alaska cedar	27	13	5	1	14	9	7	10	15
lodgepole pine	7	5	4	5	8	12	8	8	44
ponderosa pine	6	6	7	10	24	17	7	5	20
western white pine	12	8	15	7	9	15	13	7	15
Douglas-fir	13	8	9	9	16	12	17	9	8

western redcedar	16	9	7	6	10	7	17	13	15
western hemlock	18	11	11	6	11	11	13	11	9
mountain hemlock	18	12	8	2	6	6	15	16	18
Pacific madrone	19	6	1	3	18	8	16	8	21
red alder	8	6	10	9	19	10	5	4	30
miscellaneous hardwood	5	9	9	12	17	12	11	7	17

Table 11.1.8 Distribution of samples by Slope Code (expressed in percent of total observations for each species).

Species	Slope code									
	< 5	6-15	16-25	26-35	36-45	46-55	56-65	66-75	76-85	> 86
Pacific silver fir	20	18	14	11	10	8	4	2	1	12
grand fir	24	18	15	10	6	6	2	2	0	17
subalpine fir	21	21	7	8	12	2	3	-	-	25
California red fir/ Shasta red fir	24	28	20	6	5	5	-	-	-	11
noble fir	18	18	16	13	8	11	3	2	0	11
Engelmann spruce	21	10	17	11	5	7	5	1	0	25
Alaska cedar	12	15	9	14	11	15	6	3	1	15
lodgepole pine	25	12	3	3	1	1	-	-	-	55
ponderosa pine	25	13	13	8	10	6	3	2	-	21
western white pine	18	19	9	15	6	7	6	3	1	17
Douglas-fir	12	14	12	12	10	13	10	5	2	9
western redcedar	13	13	11	11	11	8	8	6	3	16
western hemlock	14	11	14	12	11	10	8	5	4	11
mountain hemlock	24	21	9	9	4	5	3	1	0	25
Pacific madrone	10	10	7	5	19	9	9	5	8	19
red alder	8	10	18	11	11	2	5	4	2	30
miscellaneous hardwood	18	11	12	6	4	9	5	-	19	

Table 11.1.9 Distribution of samples by elevation (expressed in percent for each species).

Species	Elevation					
	< 2000	2000-3000	3000-4000	4000-5000	5000-6000	> 6000
Pacific silver fir	1	6	31	44	17	1
grand fir	2	10	29	43	15	-
subalpine fir	-	-	6	43	39	12
California red fir/ Shasta red fir	-	0	3	17	65	15
noble fir	0	1	20	51	25	3

Species	Elevation					
	< 2000	2000-3000	3000-4000	4000-5000	5000-6000	> 6000
Engelmann spruce	4	21	32	29	14	-
Alaska cedar	-	9	41	47	3	-
lodgepole pine	-	1	15	40	29	14
ponderosa pine	2	22	52	24	0	1
western white pine	2	14	31	29	22	2
Douglas-fir	9	29	39	22	2	0
western redcedar	14	44	39	3	0	-
western hemlock	7	25	49	19	0	-
mountain hemlock	-	0	6	29	46	19
Pacific madrone	53	42	6	-	-	-
red alder	45	40	15	-	-	-
miscellaneous hardwood	6	34	40	16	4	-

11.2 Appendix B: Plant Association Codes

Table 11.2.1 Plant association codes recognized in the WC variant.

FVS Sequence Number = Plant Association Species Type	Alpha Code	Site Species	Site Index*	Max. SDI*	Source*	Reference
1 = TSME-ABLA2/PONE4 Mountain hemlock-subalpine fir/Newberry's knotweed	CAF211	MH	14	698	H	p. 31 R6 TP-08-95
2 = TSME-ABLA2/ASLE2 Mountain hemlock-subalpine fir/Cascades aster	CAF311	MH	15	541	H	p. 19 R6 TP-08-95
3 = TSME-ABLA2/FEVI Mountain hemlock-subalpine fir/green fescue	CAG211	MH	12	373	H	p. 23 R6 TP-08-95
4 = TSME/LUHI Mountain hemlock/Hitchcock's woodrush	CAG311	MH	17	820	H	p. 35 R6 TP-08-95
5 = TSME-PIAL/LUHI Mountain hemlock-whitebark pine/Hitchc woodrush	CAG312	MH	13	709	H	p. 47 R6 TP-08-95
6 = TSME/PHEM-VADE Mountain hemlock/red mtn heather-delicious huckleberry	CAS211	MH	16	742	H	p. 43 R6 TP-08-95
7 = TSME-ABLA2/JUOC4 Mountain hemlock-subalpine fir/mtn juniper	CAS411	MH	12	1286	H	p. 27 R6 TP-08-95
8 = PSME-TSHE/BENE Douglas-fir-western hemlock/dwarf Oregon grape	CDC711	DF	145	810	C	p. 78 R6 E 257-B-86
9 = PSME-TSHE/RHMA Douglas-fir-western hemlock/rhododendron	CDC712	DF	133	785	C	p. 82 R6 E 257-B-86
10 = PSME-TSHE/GASH Douglas-fir-western hemlock/salal	CDC713	DF	138	685	C	p. 86 R6 E 257-B-86
11 = PSME/HODI-BENE Douglas-fir/oceanspray-dwarf Oregon grape	CDS211	DF	115	770	C	p. 62 R6 E 257-B-86
12 = PSME/HODI/GRASS Douglas-fir/oceanspray/grass	CDS212	DF	121	565	C	p. 66 R6 E 257-B-86
13 = PSME/HODI-WHMO Douglas-fir/oceanspray-whipple vine	CDS213	DF	106	670	C	p. 70 R6 E 257-B-86

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14 = PSME/SYMO-WIL Douglas-fir/snowberry (Willamette)	CDS641	DF	123	740	C	p. 74 R6 E 257-B-86
15 = ABAM-TSHE/RHMA-GASH Pac silver fir-W. hemlock/rhododendron-salal	CFC251	DF	101	762	H	p. 49 R6 E 100-82
16 = ABAM-ABGR/SMST Pac silver fir-grand fir/false solomonseal	CFC311	DF	133	935	C	p. 98 R6 E 257-B-86
17 = ABAM/TIUN Pac silver fir/coolwort foamflower	CFF152	SF	120	1095	C	p. 61 R6 E 130a-83
18 = ABAM/OXOR Pac silver fir/oxalis	CFF153	NF	135	1050	C	p. 33 R6 E 100-82
19 = ABAM/TIUN-STRO Pac silver fir/foamflower-rosy twisted stalk	CFF154	SF	134	960	C	p. 100 R6 E TP-028-91
20 = ABAM/ACTR-MBS Pac silver fir/vanilla leaf (Mt Baker/Snoq)	CFF250	DF	155	900	C	p. 84 R6 E TP-028-91
21 = ABAM/ACTR-CLUN Pac silver fir/vanilla leaf-queencup beadlily	CFF253	NF	134	955	C	p. 57 R6 E 130a-83
22 = ABAM/XETE-MBS Pac silver fir/beargrass (Mt Baker/Snoq)	CFF312	NF	117	1399	H	Devlin; p.132 R6 E TP-028-91
23 = ABAM/RUPE-BLSP Pac silver fir/five-leaved bramble-deerfern	CFF450	SF	142	1110	C	p. 98 R6 E TP-028-91
24 = ABAM/LYAM Pac silver fir/skunkcabbage	CFM111	SF	134	715	C	p. 90 R6 E TP-028-91
25 = ABAM/BENE-MBS Pac silver fir/Oregon grape (Mt Baker/Snoqualamie)	CFS110	NF	109	820	C	p. 86 R6 E TP-028-91
26 = ABAM/BENE Pac silver fir/dwarf Oregon grape	CFS151	WH	64	1035	C	p. 56 R6 E 130a-83
27 = ABAM/GASH-GP Pac silver fir/Salal (Giff Pinchot)	CFS152	SF	108	1035	C	p. 55 R6 E 130a-83
28 = ABAM/GASH-BENE Pac silver fir/salal-Oregon grape	CFS154	SF	115	1040	C	p. 88 R6 E TP-028-91
29 = ABAM/VAAL-BENE Pac silver fir/Alaska huckleberry-Oregon grape	CFS216	SF	124	1015	C	p. 104 R6 E TP-028-91
30 = ABAM/VAME-VASI Pac silver fir/big huckleberry-Sitka valerian	CFS221	SF	99	900	C	p. 128 R6 E TP-028-91
31 = ABAM/VAME-STRO Pac silver fir/big huckleberry-rosy twisted stalk	CFS222	SF	118	975	C	p. 124 R6 E TP-028-91
32 = ABAM/VAME-VAAL Pac silver fir/big huckleberry-Alaska huckleberry	CFS223	SF	102	935	C	p. 126 R6 E TP-028-91
33 = ABAM/VAME Pac silver fir/big huckleberry	CFS224	SF	100	1100	C	p. 120 R6 E TP-028-91
34 = ABAM/VAAL-MADI2 Pac silver fir/Ak huckleberry-false lily-of-the-val	CFS225	SF	126	945	C	p. 110 R6 E TP-028-91
35 = ABAM/VAAL-TIUN-MBS Pac silver fir/Alaska huckleberry-foamflower	CFS226	SF	136	1030	C	p. 116 R6 E TP-028-91
36 = ABAM/VAME-PYSE Pac silver fir/big huckleberry-sidebells pyrola	CFS229	SF	108	1110	C	p. 122 R6 E TP-028-91
37 = ABAM/VAAL-GASH-MBS Pac silver fir/Alaska huckleberry-salal (Mt B/Snoq)	CFS230	SF	101	830	C	p. 108 R6 E TP-028-91
38 = ABAM/VAAL-POMU Pac silver fir/Alaska huckleberry-swordfern	CFS231	SF	148	1035	C	p. 112 R6 E TP-028-91
39 = ABAM/VAME/XETE Pac silver fir/big huckleberry/beargrass	CFS251	SF	94	955	C	p. 66 R6 E 130a-83
40 = ABAM/VAME-XETE-MBS Pac silver fir/big huckleberry-beargrass (Mt B/Snoq)	CFS252	SF	94	1065	H	Devlin; p. 130 R6 E TP-028-91

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41 = ABAM/VAAL/COCA Pac silver fir/Alaska huckleberry/dogwood bunchberry	CFS253	NF	110	975	C	p. 45 R6 E 100-82
42 = ABAM/MEFE Pac silver fir/fool's huckleberry	CFS254	SF	103	1035	C	p. 64 R6 E 130a-83
43 = ABAM/VAAL-GASH Pac silver fir/Alaska huckleberry-salal	CFS255	SF	113	880	C	p. 60 R6 E 130a-83
44 = ABAM/VAME/CLUN Pac silver fir/big huckleberry/queencup beadlily	CFS256	SF	113	980	C	p. 65 R6 E 130a-83
45 = ABAM/VAAL Pac silver fir/Alaska huckleberry	CFS257	SF	111	985	C	p. 59 R6 E 130a-83
46 = ABAM/VAAL-MBS Pac silver fir/Alaska huckleberry (Mt Baker/Snoq)	CFS258	SF	116	1010	H	Devlin; p. 102 R6 E TP-028-91
47 = ABAM/VAAL-XETE-MBS Pac silver fir/Alaska huckleberry-beargrass (MB/SQ)	CFS259	SF	94	626	H	Devlin; p. 118 R6 E TP-028-91
48 = ABAM/VAAL-CLUN-MBS Pac silver fir/AK huckleberry-queen's cup (MB/SQ)	CFS260	SF	128	1535	H	Devlin; p. 106 R6 E TP-028-91
49 = ABAM/OPHO Pac silver fir/devil's club	CFS351	SF	130	825	C	p. 62 R6 E 130a-83
50 = ABAM/OPHO-VAAL Pac silver fir/devil's club-Alaska huckleberry	CFS352	SF	133	1030	C	p. 92 R6 E TP-028-91
51 = ABAM/RHAL-GP Pac silver fir/Cascades azalea (Gifford Pinchot)	CFS550	SF	102	1120	C	p. 63 R6 E 130a-83
52 = ABAM/RHAL/XETE Pac silver fir/Cascades azalea/beargrass	CFS551	DF	73	815	C	p. 37 R6 E 100-82
53 = ABAM/RHAL/CLUN Pac silver fir/Cascades azalea/queencup beadlily	CFS552	DF	73	778	H	p. 35 R6 E 100-82
54 = ABAM/RHAL-VAME Pac silver fir/white rhododendron-big huckleberry	CFS554	SF	93	995	C	p. 96 R6 E TP-028-91
55 = ABAM/RHAL-VAAL Pac silver fir/white rhododendron-Alaska huckleberry	CFS555	SF	98	715	H	p. 94 R6 E TP-028-91
56 = ABAM/ACCI/TIUN Pac silver fir/vine maple/coolwort foamflower	CFS651	NF	140	1030	C	p. 43 R6 E 100-82
57 = ABAM/RHMA-BENE Pac silver fir/rhododendron-dwarf Oregon grape	CFS652	DF	104	1010	C	p. 55 R6 E 100-82
58 = ABAM/RHMA/XETE Pac silver fir/rhododendron/beargrass	CFS653	NF	96	910	C	p. 57 R6 E 100-82
59 = ABAM/RHMA-VAAL/COCA Pac silver fir/rhododendron-Ak huckleb/dogwood bnch	CFS654	DF	97	995	C	p. 47 R6 E 100-82
60 = TSHE-PSME/HODI Western hemlock-Douglas-fir/oceanspray	CHC212	DF	120	675	C	p. 102 R6 E 230A-86
61 = TSHE-PSME-ARME Western hemlock-Douglas-fir-madrone	CHC213	DF	105	1063	H	p. 105 R6 E 230A-86
62 = TSHE/OXOR-WILL Western hemlock/Oregon oxalis (Willamette)	CHF111	DF	158	800	C	p. 202 R6 E 257-86
63 = TSHE/POMU-MTH Western hemlock/swordfern (Mt Hood)	CHF123	WH	95	770	C	p. 73 R6 E 232A-86
64 = TSHE/POMU-OXOR Western hemlock/swordfern-oxalis	CHF124	WH	102	905	C	p. 75 R6 E 232A-86
65 = TSHE/POMU-GP Western hemlock/swordfern (Gifford Pinchot)	CHF125	WH	96	740	C	p. 82 R6 E 230A-86
66 = TSHE/POMU-GASH Western hemlock/swordfern-salal	CHF133	DF	151	1005	C	p. 54 R6 E TP-028-91
67 = TSHE/POMU-BENE Western hemlock/swordfern-Oregon grape	CHF134	DF	154	1090	C	p. 52 R6 E TP-028-91

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68 = TSHE/POMU-TITR-MBS Western hemlock/swordfern-foamflower	CHF135	WH	123	1532	H	Devlin; p. 56 R6 E TP-028-91
69 = TSHE/POMU-WILL Western hemlock/swordfern (Willamette)	CHF151	DF	159	870	C	p. 234 R6 E 257-86
70 = TSHE/ACTR Western hemlock/vanilla leaf	CHF221	DF	147	960	C	p. 90 R6 E 230A-86
71 = TSHE/TITR Western hemlock/coolwort foamflower	CHF222	DF	170	975	C	p. 80 R6 E 230A-86
72 = TSHE/TITR-GYDR Western hemlock/foamflower-oak fern	CHF250	DF	164	965	C	p. 58 R6 E TP-028-91
73 = TSHE/LIBO2 Western hemlock/twinflower	CHF321	DF	148	1020	C	p. 238 R6 E 257-86
74 = TSHE/ATFI Western hemlock/ladyfern	CHF421	DF	174	880	C	p. 72 R6 E 230A-86
75 = TSHE/LYAM Western hemlock/American yellow skunkcabbage	CHM121	DF	128	1126	H	p. 68 R6 E 232A-86
76 = TSHE/GASH-WILL Western hemlock/salal (Willamette)	CHS111	DF	137	740	C	p. 230 R6 E 257-86
77 = TSHE/BENE/OXOR Western hemlock/dwarf Oregon grape/Oregon oxalis	CHS113	DF	159	770	C	p. 190 R6 E 257-86
78 = TSHE/BENE/ACTR Western hemlock/dwarf Oregon grape/vanilla leaf	CHS114	DF	158	1010	C	p. 198 R6 E 257-86
79 = TSHE/BENE-GASH Western hemlock/dwarf Oregon grape-salal	CHS124	WH	93	845	C	p. 62 R6 E 232A-86
80 = TSHE/BENE Western hemlock/dwarf Oregon grape	CHS125	WH	82	1020	C	p. 93 R6 E 230A-86
81 = TSHE/BENE/POMU Western hemlock/dwarf Oregon grape/swordfern	CHS126	WH	89	835	C	p. 64 R6 E 232A-86
82 = TSHE/BENE-GASH-GP Western hemlock/dwarf Oregon grape-salal (Giff Pin)	CHS127	DF	134	925	C	p. 95 R6 E 230A-86
83 = TSHE/GASH-GP Western hemlock/salal (Gifford Pinchot)	CHS128	DF	123	820	C	p. 97 R6 E 230A-86
84 = TSHE/GASH-MBS Western hemlock/salal (Mt Baker/Snoqual)	CHS129	DF	100	789	H	Devlin; p. 40 R6 E TP-028-91
85 = TSHE/BENE-MBS Western hemlock/Oregon grape (Mt Baker/Snoq)	CHS130	DF	122	1101	H	Devlin; p. 36 R6 E TP-028-91
86 = TSHE/GASH-BENE Western hemlock/salal-Oregon grape	CHS135	DF	117	1225	C	p. 42 R6 E TP-028-91
87 = TSHE/GASH-VAME Western hemlock/salal-big huckleberry	CHS140	DF	89	890	C	p. 44 R6 E TP-028-91
88 = TSHE/BENE-CHME Western hemlock/Oregon grape-little prince's pine	CHS141	DF	103	1070	C	p. 38 R6 E TP-028-91
89 = TSHE/ACCI/ACTR Western hemlock/vine maple/vanilla leaf	CHS223	DF	141	880	C	p. 56 R6 E 232A-86
90 = TSHE/CONU/ACTR Western hemlock/dogwood/vanilla leaf	CHS224	DF	142	1159	H	p. 100 R6 E 230A-86
91 = TSHE/ACCI-BENE Western hemlock/vine maple-Oregon grape	CHS251	DF	136	955	C	p. 34 R6 E TP-028-91
92 = TSHE/RHMA/XETE-MTH Western hemlock/rhododendron/beargrass (Mt Hood)	CHS325	DF	97	845	C	p. 83 R6 E 232A-86
93 = TSHE/RHMA-VAAL/COCA W hemlock/rhododendron-AK huckleberry/dogw. bunchb.	CHS326	DF	130	885	C	p. 81 R6 E 232A-86
94 = TSHE/RHMA-GASH-MTH Western hemlock/rhododendron-salal (Mt Hood)	CHS327	WH	77	700	C	p. 79 R6 E 232A-86

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95 = TSHE/RHMA-BENE-MTH W hemlock/rhododendron-dwarf Oregon grape (Mt Hood)	CHS328	WH	82	835	C	p. 77 R6 E 232A-86
96 = TSHE/RHMA-GASH-WILL Western hemlock/rhododendron-salal (Willamette)	CHS351	DF	128	890	C	p. 222 R6 E 257-86
97 = TSHE/RHMA-BENE-WILL W hemlock/rhododendron-dwarf OR grape (Willamette)	CHS352	DF	136	930	C	p. 214 R6 E 257-86
98 = TSHE/RHMA/XETE-WILL Western hemlock/rhododendron/beargrass (Willamette)	CHS353	DF	122	970	C	p. 210 R6 E 257-86
99 = TSHE/RHMA/OXOR Western hemlock/rhododendron/Oregon oxalis	CHS354	DF	135	670	C	p. 218 R6 E 257-86
100 = TSHE/RHMA/LIBO2 Western hemlock/rhododendron/twinflower	CHS355	DF	130	1100	C	p. 226 R6 E 257-86
101 = TSHE/OPHO-WILL Western hemlock/devil's club (Willamette)	CHS511	DF	168	685	C	p. 182 R6 E 257-86
102 = TSHE/OPHO-ATFI Western hemlock/devil's club-ladyfern	CHS513	WH	101	980	C	p. 50 R6 E TP-028-91
103 = TSHE/OPHO/OXOR Western hemlock/devil's club/Oregon oxalis	CHS522	WH	93	815	C	p. 69 R6 E 232A-86
104 = TSHE/OPHO/SMST Western hemlock/devil's club/starry solomonseal	CHS523	DF	156	585	H	p. 71 R6 E 232A-86
105 = TSHE/OPHO/POMU Western hemlock/devil's club/swordfern	CHS524	WH	88	965	C	p. 74 R6 E 230A-86
106 = TSHE/VAAL-OPHO Western hemlock/Alaska huckleberry-devil's club	CHS611	DF	165	767	H	p. 90 R6 E 232A-86
107 = TSHE/VAME/XETE Western hemlock/big huckleberry/beargrass	CHS612	DF	90	795	C	p. 93 R6 E 232A-86
108 = TSHE/VAAL/OXOR Western hemlock/Alaska huckleberry/Oregon oxalis	CHS613	WH	84	985	C	p. 78 R6 E 230A-86
109 = TSHE/VAAL-GASH Western hemlock/Alaska huckleberry-salal	CHS614	WH	81	710	C	p. 88 R6 E 230A-86
110 = TSHE/VAAL/COCA W hemlock/Alaska huckleberry/dogwood bunchberry	CHS615	WH	87	770	C	p. 86 R6 E 230A-86
111 = TSHE/VAAL-POMU Western hemlock/Alaska huckleberry-swordfern	CHS625	DF	154	1050	C	p. 64 R6 E TP-028-91
112 = TSHE/VAAL-BENE Western hemlock/Alaska huckleberry-Oregon grape	CHS626	DF	110	940	C	p. 62 R6 E TP-028-91
113 = TSME/TIUN-STRO Mountain hemlock/foamflower-rosy twistedstalk	CMF250	MH	36	820	C	p. 162 R6 E TP-028-91
114 = TSME/CABI Mountain hemlock/marshmarigold	CMF251	MH	14	795	C	p. 150 R6 E TP-028-91
115 = TSME/VASC Mountain hemlock/grouse huckleberry	CMS114	MH	16	925	C	p. 73 R6 E 08-95
116 = TSME/VAME-GP Mountain hemlock/big huckleberry (Gifford Pinchot)	CMS210	MH	25	970	C	p. 68 R6 E 130-83
117 = TSME/VAME/XETE Mountain hemlock/big huckleberry/beargrass	CMS216	MH	19	880	C	p. 67 R6 E 08-95
118 = TSME/VAME/CLUN Mountain hemlock/big huckleberry/queen's cup	CMS218	MH	20	955	C	p. 61 R6 E 08-95
119 = TSME/MEFE Mountain hemlock/fool's huckleberry	CMS221	MH	22	1005	C	p. 39 R6 E 08-95
120 = TSME/RHAL Mountain hemlock/Cascades azalea	CMS223	MH	21	955	C	p. 51 R6 E 08-95
121 = TSME/VAAL Mountain hemlock/Alaska huckleberry	CMS241	MH	34	1015	C	p. 164 R6 E TP-028-91

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122 = TSME/VAME-VAAL Mountain hemlock/big huckleberry-Alaska huckleberry	CMS244	MH	29	995	C	p. 178 R6 E TP-028-91
123 = TSME/VAME/XETE-WASH Mountain hemlock/big huckleberry/beargrass	CMS245	MH	25	935	C	p. 182 R6 E TP-028-91
124 = TSME/VAME-MBS Mountain hemlock/big huckleberry (Mt Baker/Snoqual)	CMS246	MH	25	1075	C	p. 172 R6 E TP-028-91
125 = TSME/VAME-STRO Mountain hemlock/big huckleberry-rosy twistedstalk	CMS250	MH	31	780	C	p. 176 R6 E TP-028-91
126 = TSME/VAME-VASI Mountain hemlock/big huckleberry-Sitka valerian	CMS251	MH	25	770	C	p. 180 R6 E TP-028-91
127 = TSME/VAAL-STRO Mountain hemlock/Alaska huckleberry-rosy twistedstalk	CMS252	MH	35	960	C	p. 170 R6 E TP-028-91
128 = TSME/VAAL-CLUN Mountain hemlock/Alaska huckleberry-queen's cup	CMS253	MH	29	1090	C	p. 166 R6 E TP-028-91
129 = TSME/VAME-RULA Mountain hemlock/big huckleberry-trailing bramble	CMS254	MH	28	1155	C	p. 174 R6 E TP-028-91
130 = TSME/VAAL-MADI2 M hemlock/Alaska huckleberry-false lily-of-the-valley	CMS255	MH	29	710	C	p. 168 R6 E TP-028-91
131 = TSME/PHEM-VADE M hemlock/red heather-blueleaf huckleberry	CMS350	MH	20	750	C	p. 156 R6 E TP-028-91
132 = TSME/RHAL-VAAL M hemlock/white rhododendron-Alaska huckleberry	CMS351	MH	23	820	C	p. 158 R6 E TP-028-91
133 = TSME/RHAL-VAME Mountain hemlock/white rhododendron-big huckleberry	CMS352	MH	23	970	C	p. 160 R6 E TP-028-91
134 = TSME/CLPY-RUPE Mountain hemlock/copperbush-five leaved bramble	CMS353	MH	20	675	C	p. 152 R6 E TP-028-91
135 = TSME/OPHO-VAAL Mountain hemlock/devil's club-Alaska huckleberry	CMS450	SF	138	855	C	p. 154 R6 E TP-028-91
136 = TSME/RHMA Mountain hemlock/rhododendron	CMS612	SF	78	1010	C	p. 57 R6 E TP-08-95
137 = ABGR/CHUM Grand fir/prince's pine	CWF211	DF	132	730	C	p. 96 R6 E 257-86
138 = ABGR/ARUV Grand fir/bearberry	CWS521	DF	86	820	C	p. 90 R6 E 257-86
139 = ABGR/BENE Grand fir/dwarf Oregon grape	CWS522	DF	131	860	C	p. 92 R6 E 257-86

*Site index estimates are from GBA analysis. SDI maximums are set by GBA analysis (Source=H) or CVS plot analysis (Source=C).

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