Forest Service
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Central Idaho (CI) Variant Overview of the Forest Vegetation Simulator

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Douglas-fir forest in Little West Fork, Salmon-Challis National Forest
(Sharon Skroh Bradley, FS-R4)

Central Idaho (CI) Variant Overview of the 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 1988. The original author was Gary Dixon. 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 major update. Don Vandendriesche cross-checked information contained in this variant overview with the FVS source code. The species list for this variant was expanded and this document was extensively revised by Gary Dixon in 2011.

FVS Staff. 2008 (revised October 5, 2021). Central Idaho (CI) Variant Overview – Forest Vegetation Simulator. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center.62p.

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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)	412 – Payette National Forest	
Plant Association Code	260 (PSME/PHME)	
Slope	5 percent	
Aspect	0 (no meaningful aspect)	
Elevation	50 (5000 feet)	
Latitude / Longitude	Latitude	Longitude
All location codes	44	114
Site Species	DF	
Site Index	50	
Maximum Stand Density Index (R1/R4)	Habitat type specific / species specific	
Maximum Basal Area (R1/R4)	Habitat type specific / species specific	
Volume Equations	National Volume Estimator Library	
Merchantable Cubic Foot Volume Specifications:		
Minimum DBH / Top Diameter	LP	All Other Species
All other location codes	7.0 / 6.0 inches	8.0 / 6.0 inches
Stump Height	1.0 foot	1.0 foot
Merchantable Board Foot Volume Specifications:		
Minimum DBH / Top Diameter	LP	All Other Species
All other location codes	7.0 / 6.0 inches	8.0 / 6.0 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 United States.

The Central Idaho (CI) variant had an interesting development history. The University of Idaho originally developed a CI variant in 1982. This variant was used in Region 4 for several years, but it was not part of the FVS suite of software tools. Model maintenance was problematic for the developers and the growth relationships themselves did not produce reliable results.

In February 1988 the University of Idaho completed work on new large tree diameter increment models for six major commercial species. In July 1988, Region 4 requested the Forest Management Service Center develop a new CI variant using the newly developed large tree diameter models from the University of Idaho, height and crown models from the Northern Idaho (NI) variant, and the mortality model from the Teton (TT) variant. So the true CI variant, as a part of the FVS system, was released in late 1988.

Since the variant’s completion in 1988, many of the functions have been adjusted and improved as more data has become available and as model technology has advanced. In 2011 this variant was expanded from 11 species to 19 species. Species added include whitebark pine, Pacific yew, quaking aspen, western juniper, curl-leaf mountain mahogany, limber pine, and black cottonwood. The “other species” grouping was split into other softwood and other hardwood. Whitebark pine, limber pine, and Pacific yew use whitebark/limber pine equations from the Tetons variant; quaking aspen uses aspen equations from the Utah variant; western juniper uses western juniper equations from the Utah variant; curl-leaf mountain mahogany uses other hardwood equations from the Westside Cascades variant as implemented for curl-leaf mountain mahogany in the Utah variant; black cottonwood and other hardwood use cottonwood equations from the Central Rockies variant as implemented for other hardwood in the Inland Empire variant; and other softwood uses the equations for the original other species grouping in the 11 species version of this 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 CI variant was fit to data representing forest types in central Idaho. Data used in model development came from forest inventories on the Boise, Challis, Payette, Salmon, and Sawtooth National Forests.

The CI variant covers forest types in Central Idaho. The suggested geographic range of use for the CI variant is shown in figure 2.0.1.

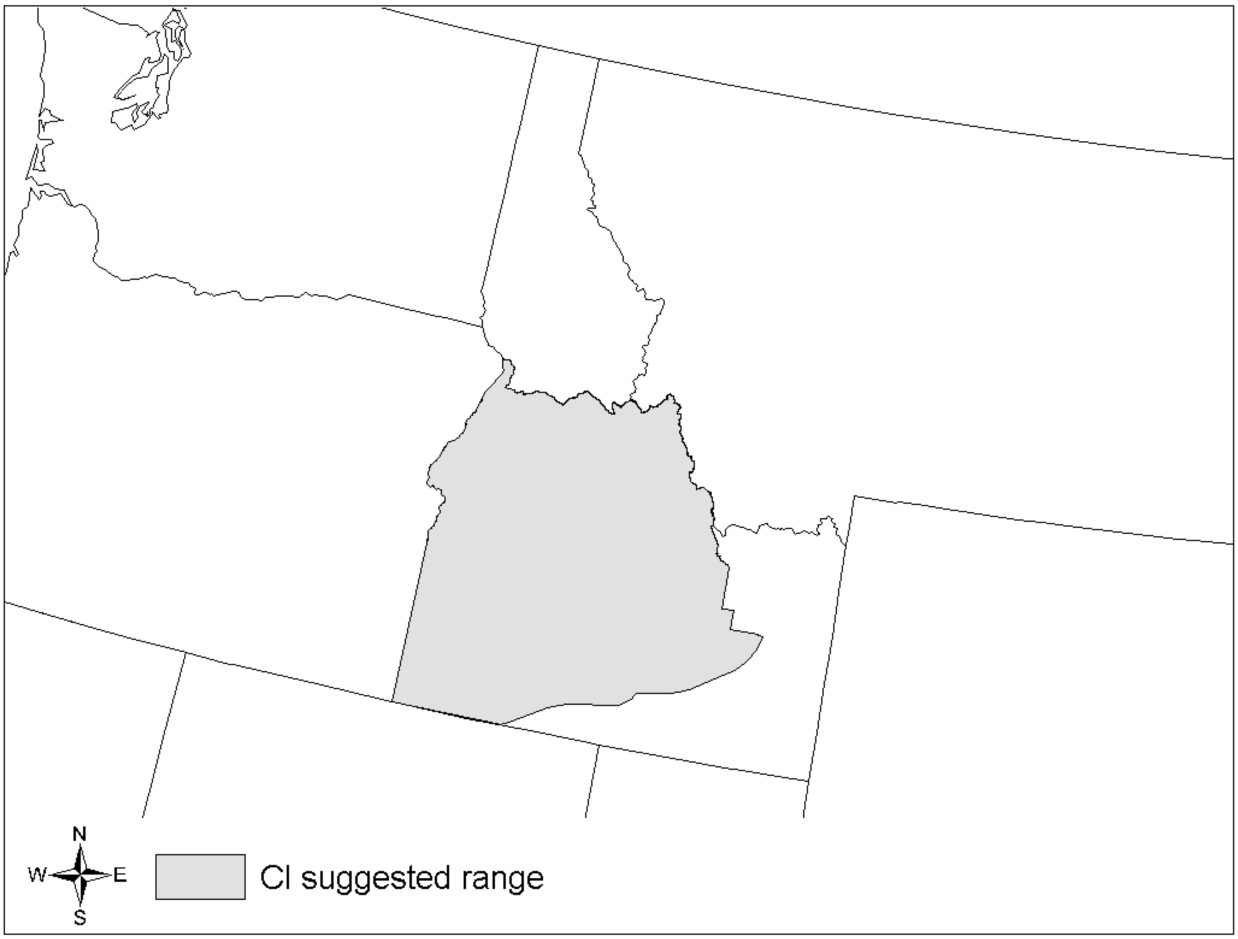

Figure 2.0.1 Suggested geographic range of use for the CI variant.

3.0 Control Variables

FVS users need to specify certain variables used by the CI 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 USDA 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 CI variant, a default forest code of 412 (Payette National Forest) will be used. A complete list of location codes recognized in the CI variant is shown in table 3.1.1.

Table 3.1.1 Location codes used in the CI variant.

Location Code	Location
117	Nez Perce National Forest
402	Boise National Forest
406	Challis National Forest
412	Payette National Forest
413	Salmon National Forest
414	Sawtooth National Forest
7721	Duck Valley Reservation (mapped to 402)
8107	Fort Hall Reservation (mapped to 414)

3.2 Species Codes

The CI variant recognizes 17 species, plus two other composite species categories. 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 code identifying species not recognized by the variant will be mapped to a similar species in the variant. The species mapping crosswalk is available on the FVS website variant documentation webpage. Any non-valid species code will default to the “other hardwood” 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 CI variant.

When entering tree data, users should substitute diameter at root collar (DRC) for diameter at breast height (DBH) for woodland species (western juniper).

Table 3.2.1 Species codes used in the CI variant.

Species Number	Species Code	FIA Code	PLANTS Symbol	Scientific Name[1]	Common Name[1]
1	WP	119	PIMO3	*Pinus monticola*	western white pine
2	WL	73	LAOC	*Larix occidentalis*	western larch
3	DF	202	PSME	*Pseudotsuga menziesii*	Douglas-fir
4	GF	17	ABGR	*Abies grandis*	grand fir
5	WH	263	TSHE	*Tsuga heterophylla*	western hemlock
6	RC	242	THPL	*Thuja plicata*	western redcedar
7	LP	108	PICO	*Pinus contorta*	lodgepole pine
8	ES	93	PIEN	*Picea engelmannii*	Engelmann spruce
9	AF	19	ABLA	*Abies lasiocarpa*	subalpine fir
10	PP	122	PIPO	*Pinus ponderosa*	ponderosa pine
11	WB	101	PIAL	*Pinus albicaulis*	whitebark pine
12	PY	231	TABR2	*Taxus brevifolia*	Pacific yew
13	AS	746	POTR5	*Populus tremuloides*	quaking aspen
14	WJ	64	JUOC	*Juniperus occidentalis*	western juniper
15	MC	475	CELE3	*Cercocarpus ledifolius*	curl-leaf mountain mahogany
16	LM	113	PIFL2	*Pinus flexilis*	limber pine
17	CW	747	POBAT	*Populus balsamifera* ssp. *trichocarpa*	black cottonwood
18	OS	299	2TN		other softwood[2]
19	OH	998	2TB		other hardwood[2]

[1]Set based on the USDA Forest Service NRM TAXA lists and the USDA Plants database.
[2]Other categories use FIA codes and NRM TAXA codes that best match the other category.

3.3 Habitat Type, Plant Association, and Ecological Unit Codes

There are 130 habitat type codes recognized in the CI variant. If the habitat type code is blank or not recognized, the default 260 (PSME/PHMA) will be assigned. The 130 habitat type codes are mapped to one of the 30 original North Idaho (NI) variant habitat type codes. A list of valid CI variant's habitat type codes and the original NI habitat type code equivalents can be found in table 11.1.1 of Appendix A.

3.4 Site Index

Site index is used in equations for some species in the CI variant. These species are whitebark pine, Pacific yew, quaking aspen, western juniper, curl-leaf mountain mahogany, limber pine, black cottonwood, and other hardwood. When possible, users should enter their own site index values instead of relying on the default values assigned by FVS. If site index information is available, a single site index can be specified for the whole stand, a site index for individual species can be specified, or a combination of these can be entered. If the user does not supply site index values, then default values will be used. When entering site index in the CI variant, the sources shown in table 3.4.1 should be used if possible. The default site species is Douglas-fir with a site index of 50.

When site index is not specified for a species, a relative site index value is calculated from the site index of the site species using equations {3.4.1} and {3.4.2}. Minimum and Maximum site indices used in equation {3.4.1} may be found in table 3.4.2. If the site index for the stand is less than or equal to the lower site limit, it is set to the lower limit for the calculation of RELSI. Similarly, if the site index for the stand is greater than the upper site limit, it is set to the upper site limit for the calculation of RELSI.

{3.4.1} $RELSI = (SI_{site} - SITELO_{site}) / (SITEHI_{site} - SITELO_{site})$

{3.4.2} $SI_i = SITELO_i + (RELSI * (SITEHI_i - SITELO_i))$

where:

RELSI	is the relative site index of the site species
SI	is species site index
SITELO	is the lower bound of the *SI* range for a species
SITEHI	is the upper bound of the *SI* range for a species
$_{site}$	is the site species
$_i$	is the species for which site index is to be calculated

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

Species code	Reference	BHA or TTA*	REF Base Age
WP, DF, OS	Brickell, J.E., 1970, USDA-FS Res. Pap. INT-75	TTA	50
WL	Cochran, P.H., 1985, USDA-FS Res. Note PNW-424	BHA	50
GF	Cochran, P.H., 1979, USDA-FS Res. Note PNW-252	BHA	50
WH	Wiley, K.N., 1978, Weyerhaeuser Forestry Paper No. 17, p.4.	BHA	50
RC	Hegyi, R.P.R., et. al., 1979, Province of B.C., Forest Inv. Rep. No. 1. p.6	TTA	100
AS	Edminster, Mowrer, and Shepperd Res. Note RM-453	BHA	80
LP	Alexander, Tackle, and Dahms Res. Paper RM-29	TTA	100
WB, PY, LM	Alexander, Tackle, and Dahms Res. Paper RM-29	TTA	100**
ES, AF	Alexander, R.R., 1967, USDA-FS Res. Paper RM-32	BHA	100
WJ	Any 100-year base age curve	TTA	100
PP	Meyer, W.H., 1961.rev, Tech. Bulletin 630	TTA	100
MC	Curtis, R. O., et. al., 1974, Forest Science	BHA	100
CW, OH	Any hardwood 100 year base total age curve	TTA	100

*Equation is based on total tree age (TTA) or breast height age (BHA)
**Site index for these species will be converted to a 50-year age basis within FVS since growth equations for these species were fit with a 50-year age based site index

Table 3.4.1 *SITELO* and *SITEHI* values for equations {3.4.1} and {3.4.2} in the CI variant.

Species Code	*SITELO*	*SITEHI*
WP	20	80
WL	50	110
DF	30	70
GF	50	110
WH	6	203
RC	29	152
LP	20	100
ES	40	100
AF	40	90
PP	40	80
WB	25	50
PY	25	50
AS	30	70
WJ	5	15
MC	5	15
LM	25	50
CW	30	120
OS	30	70
OH	30	120

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 by species, a default habitat type code, or a user specified basal area maximum. If the location code is in Region 1 or a user specified basal area maximum is present, the maximum SDI for all species is computed using equation {3.5.1}; otherwise, species maximums are assigned from the SDI maximums shown in 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.

For non-Region 1 forests, stand SDI is calculated using the Zeide calculation method (Dixon 2002).

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

where:

$SDIMAX_i$	is the species-specific SDI maximum
BAMAX	is the user-specified basal area maximum or habitat type-specific basal area maximum shown in Appendix A.
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 maximums for Region 4 forests by species in the CI variant.

Species Code	SDI Maximum	Mapped to
WP	529	eastern white pine
WL	423	
DF	570	
GF	562	
WH	682	
RC	762	
LP	679	
ES	620	
AF	602	
PP	446	
WB	621	
PY	576	incense-cedar
AS	562	
WJ	272	
MC	501	
LM	409	
CW	452	
OS	409	limber pine
OH	452	black cottonwood

*Source of SDI maximums is an unpublished analysis of FIA data by John Shaw.

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 CI variant, these relationships are only used to estimate heights missing in the input data, and not to calculate small-tree height growth. Height-diameter relationships are either of a linear form as shown in equation {4.1.2} or a logistic functional form as shown in equation {4.1.1} (Wykoff, et.al 1982). Trees with a DBH greater than 3.0 inches use equation {4.1.1} and trees with a DBH less than or equal to 3.0 inches use equation {4.1.2}. Coefficients for the height-diameter equations are shown are shown in table 4.1.1.

When heights are given in the input data for 3 or more trees of a given species, the value of B1 in equation {4.1.1} for that species is recalculated from the input data and replaces the default value shown in table 4.1.1. In the event that the calculated value is less than zero, the default is used.

{4.1.1} For $DBH \geq 3.0''$: $HT = 4.5 + \exp(B_1 + B_2 / (DBH + 1.0))$

{4.1.2} For $DBH < 3.0''$: $HT = C_0 + C_1 * DBH$

where:

HT is tree height
DBH is tree diameter at breast height
B_1 - B_2 are species-specific coefficients shown in table 4.1.1
C_0 - C_1 are species-specific coefficients shown in table 4.1.1

Table 4.1.1 Coefficients for the height-diameter relationship equations in the CI variant.

Species Code	Default B_1	B_2	C_0	C_1
WP	5.19988	-9.26718	1.74189	4.17687
WL	5.16306	-9.25656	5.30838	6.41536
DF	4.94866	-9.75378	3.05990	6.42592
GF	5.02706	-11.21681	2.77647	5.59435
WH	5.02706	-11.21681	2.77647	5.59435
RC	5.16306	-9.25656	5.30838	6.41536
LP	4.80016	-6.51738	0.74322	9.23147
ES	5.09964	-10.79269	2.88424	5.39267
AF	4.91417	-9.36400	2.74231	5.35911
PP	4.99300	-12.430	1.74189	4.17687

Species Code	Default B_1	B_2	C_0	C_1
WB	4.19200	-5.16510	-	-
PY	4.19200	-5.16510	-	-
AS	4.44210	-6.54050	-	-
WJ	3.2	-5.0	-	-
MC	5.1520	-13.5760	0.0994	4.9767
LM	4.19200	-5.16510	-	-
CW	4.44210	-6.54050	-	-
OS	4.80016	-6.51738	0.74322	9.23147
OH	4.44210	-6.54050		

By default, curl-leaf mountain mahogany will use the Curtis-Arney functional form as shown in equation {4.1.3} or equation {4.1.4} (Curtis 1967, Arney 1985). If the input data contains at least three measured heights for this species, then FVS can switch to a logistic height-diameter equation {4.1.1} (Wykoff, et.al 1982) that may be calibrated to the input data. In the CI variant, this doesn't happen by default for curl-leaf mountain mahogany but can be turned on with the NOHTDREG keyword by entering "1" in field 2. If calibration of the logistic equation is chosen for curl-leaf mountain mahogany, then equation {4.1.1} is used with the B_2 coefficient from table 4.1.1 along with the B_1 coefficient calibrated from the input data for trees with DBH greater than or equal to 5.0 inches; equation {4.1.2} is used with the coefficients shown in table 4.1.1 for trees with DBH less than 5.0 inches.

{4.1.3} For $DBH \geq 3.0''$: $HT = 4.5 + P_2 * \exp[-P_3 * DBH \wedge P_4]$

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

where:

HT is tree height
DBH is tree diameter at breast height
P_2 = 1709.7229
P_3 = 5.8887
P_4 = -0.2286

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. All species except western juniper, black cottonwood, and other hardwood use equation {4.2.1} and coefficients (b1 and b2) shown in table 4.2.1.

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

Note: if a species has a b_2 value equal to 0, then BRATIO = b_1

where:

BRATIO is species-specific bark ratio (bounded to 0 < BRATIO < 0.97)

DBH is tree diameter at breast height
DIB is tree diameter inside bark at breast height
b1 - b2 are species-specific coefficients shown in table 4.2.1

Western juniper, black cottonwood, and other hardwood use equation {4.2.2} to estimate bark ratio.

{4.2.2} $DIB = b1 + b2 * (1/DBH)$; $BRATIO = DIB / DBH$

where:

BRATIO is species-specific bark ratio (bounded to $0.80 < BRATIO < 0.99$)
DBH is tree diameter at breast height (limited to 1.0” < *DBH* < 19.0” for western juniper, and *DBH* > 1.0” for black cottonwood and other hardwood)
DIB is tree diameter inside bark at breast height
b1 - b2 are species-specific coefficients shown in table 4.2.1

Table 4.2.1 Coefficients for the bark ratio equation {4.2.1} in the CI variant.

Species Code	b_1	b_2
WP	0.859045	0
WL	0.9	0
DF	0.903563	0.989388
GF	0.904973	0
WH	0.903563	0.989388
RC	0.837291	0
LP	0.9	0
ES	0.9	0
AF	0.903563	0.989388
PP	0.809427	1.016866
WB	0.969	0
PY	0.969	0
AS	0.950	0
WJ	0.9002	-0.3089
MC	0.9	0
LM	0.969	0
CW	0.892	-0.086
OS	0.9	0
OH	0.892	-0.086

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 CI variant, crown ratios missing in the input data are predicted using different equations depending on tree species and size. For all species other than curl-leaf mountain mahogany, black cottonwood and other hardwood, live trees less than 1.0" in diameter and dead trees of all sizes use equation {4.3.1.1} and {4.3.1.2} to compute crown ratio. Curl-leaf mountain mahogany live trees less than 1.0" in diameter and dead trees of all sizes are assigned a constant crown ratio of 41 percent. Equation coefficients are found in table 4.3.1.1.

{4.3.1.1} $X = R_1 + R_2 * DBH + R_3 * HT + R_4 * BA + R_5 * PCCF + R_6 * HT_{Avg} / HT + R_7 * HT_{Avg} + R_8 * BA * PCCF + R_9 * MAI$

{4.3.1.2} $CR = 1 / (1 + \exp(X + N(0,SD)))$ where absolute value of $(X + N(0,SD)) < 86$

where:

CR	is crown ratio expressed as a proportion (bounded to $0.05 \leq CR \leq 0.95$)
DBH	is tree diameter at breast height
HT	is tree height
BA	is total stand basal area
PCCF	is crown competition factor on the inventory point where the tree is established
HT_{Avg}	is average height of the 40 largest diameter trees in the stand
MAI	is stand mean annual increment
N(0,SD)	is a random increment from a normal distribution with a mean of 0 and a standard deviation of SD
$R_1 - R_9$	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 CI variant.

Coefficient	Species Code						
	WP	WL	DF	GF	WH, OS	RC	LP
R_1	-0.44316	-0.83965	-0.89122	-0.62646	-0.49548	0.11847	-0.32466
R_2	-0.48446	-0.16106	-0.18082	-0.06141	0.00012	-0.39305	-0.20108
R_3	0.05825	0.04161	0.05186	0.02360	0.00362	0.02783	0.04219
R_4	0.00513	0.00602	0.00454	0.00505	0.00456	0.00626	0.00436
R_5	0	0	0	0	0	0	0
R_6	0	0	0	0	0	0	0
R_7	0	0	0	0	0	0	0
R_8	0	0	0	0	0	0	0
R_9	0	0	0	0	0	0	0
SD	0.9476	0.7396	0.8706	0.9203	0.9450	0.8012	0.7707

Coefficient	Species Code					
	ES	AF	PP	WB, PY, LM	AS	WJ
R_1	-0.92007	-0.89014	-0.17561	-1.66949	-0.426688	-2.19723
R_2	-0.22454	-0.18026	-0.33847	-	-	0

				0.209765	0.093105	
R_3	0.03248	0.02233	0.05699	0	0.022409	0
R_4	0.00620	0.00614	0.00692	0.003359	0.002633	0
R_5	0	0	0	0.011032	0	0
R_6	0	0	0	0	- 0.045532	0
R_7	0	0	0	0.017727	0	0
R_8	0	0	0	- 0.000053	0.000022	0
R_9	0	0	0	0.014098	- 0.013115	0
SD	0.9721	0.8871	0.8866	0.5	0.9310	0.2

For all species except western juniper, black cottonwood, and "other hardwood", 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 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. Equation coefficients for each species are shown in table 4.3.1.2.

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

where:

$RELSDI = SDI_{stand} / SDI_{max}$ for WB, PY, AS, MC and LM
$RELSDI = BA_{stand} / BA_{max}$ for WP, WL, DF, GF, WH, RC, LP, ES, AF, PP and OS and *RELSDI* bounded to < 1.5

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

$A = a_0$

$B = b_0 + b_1 * ACR$ where $B > 1$ for WB, PY, AS, MC, and LM and where B > 3 for WP, WL, DF, GF, WH, RC, LP, ES, AF, PP, and OS

$C = c_0 + c_1 * ACR$ where $C > 2$

{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
BA_{stand} is basal area of the stand
BA_{max} is maximum basal area
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_{0-1}, c_{0-1}, and d_{0-1} are species-specific coefficients shown in table 4.3.1.2

Table 4.3.1.2 Coefficients for the Weibull parameter equations {4.3.1.3} and {4.3.1.4} in the CI variant.

Species Code	Model Coefficients						
	a_0	b_0	b_1	c_0	c_1	d_0	d_1
WP	2	-2.12713	1.10526	2.77	0	7.16846	-0.02375
WL	0	0.07609	1.10184	3.01	0	5.50719	-0.01833
DF	1	-1.19297	1.12928	3.42	0	5.52653	0
GF	1	-1.19297	1.12928	3.42	0	5.52653	0
WH	0	0.06593	1.09624	3.71	0	6.61291	-0.02182
RC	1	-1.38636	1.16801	3.02	0	6.17373	-0.01795
LP	0	0.07609	1.10184	3.01	0	5.50719	-0.01833
ES	1	-0.91567	1.06469	3.5	0	6.774	0
AF	1	-0.91567	1.06469	3.5	0	6.12779	-0.01269
PP	0	0.24916	1.04831	4.36	0	6.41166	-0.02041
WB	1	-0.82631	1.06217	3.31429	0	6.19911	-0.02216
PY	1	-0.82631	1.06217	3.31429	0	6.19911	-0.02216
AS	0	-0.08414	1.14765	2.775	0	4.01678	-0.01516
MC	0	-0.23830	1.18016	3.04	0	4.62512	-0.01604
LM	1	-0.82631	1.06217	3.31429	0	6.19911	-0.02216
OS	0	0.07609	1.10184	3.01	0	7.238	0

Black cottonwood and "other hardwood" use equations {4.3.1.7} and {4.3.1.8} to estimate crown ratio for live and dead trees missing crown ratios in the inventory.

{4.3.1.7} $CL = 5.17281 + 0.32552 * HT - 0.01675 * BA$

{4.3.1.8} $CR = (CL / HT)$

where:

HT is total tree height in feet
BA is total stand basal area in square feet/acre
CL is crown length in feet (bounded between 1.0 and HT)
CR is tree crown ratio expressed as a proportion of total tree height (from equation {4.3.1.8})

Live western juniper trees with a diameter of 1.0” and larger use equations {4.3.1.9} and {4.3.1.8} to estimate crown ratio missing in the inventory.

{4.3.1.9} $CL = -0.59373 + 0.67703 * HT$

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}, for all species except black cottonwood, “other hardwood’, and western juniper. For black cottonwood and “other hardwood’, crown ratio predicted at the end of the projection cycle is estimated using equations {4.3.1.7} and {4.3.1.8}. For western juniper, crown ratio predicted at the end of the projection cycle is estimated using equations {4.3.1.9} and {4.3.1.8}. 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 CI 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} and {4.4.2}, 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 01

$DBH \geq MinD: CW = a_1 + (a_2 * DBH) + (a_3 * DBH\text{^}2)$

$DBH < MinD: CW = [a_1 + (a_2 * MinD) * (a_3 * MinD\text{^}2)] * (DBH / MinD)$

{4.4.2} Bechtold (2004); Equation 02

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

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

{4.4.3} 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

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

{4.4.5} Crookston (2005); Equation 05

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

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

where:

BF	is a species-specific coefficient based on forest code (*BF* = 1.0 in the CI variant)
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, where: $HI = (ELEVATION - 5449) / 100) * 1.0 + (LATITUDE - 42.16) * 4.0 + (-116.39 - LONGITUDE) * 1.25$
$a_1 – a_6$	are species-specific coefficients shown in table 4.4.1

Table 4.4.1 Coefficients for crown width equations {4.4.1} and {4.4.2} in the CI variant.

Species Code	Equation Number*	a_1	a_2	a_3	a_4	a_5	a_6
WP	11903	1.0405	1.2799	0.11941	0.42745	0	-0.07182
WL	07303	1.02478	0.99889	0.19422	0.59423	-0.09078	-0.02341
DF	20203	1.01685	1.48372	0.27378	0.49646	-0.18669	-0.01509
GF	01703	1.0303	1.14079	0.20904	0.38787	0	0
WH	26305	6.0384	0.51581	-0.21349	0.17468	0.06143	-0.00571

Species Code	Equation Number*	a_1	a_2	a_3	a_4	a_5	a_6
RC	24203	1.03597	1.46111	0.26289	0.18779	0	0
LP	10803	1.03992	1.58777	0.30812	0.64934	-0.38964	0
ES	09303	1.02687	1.28027	0.2249	0.47075	-0.15911	0
AF	01905	5.8827	0.51479	-0.21501	0.17916	0.03277	-0.00828
PP	12203	1.02687	1.49085	0.1862	0.68272	-0.28242	0
WB	10105	2.2354	0.66680	-0.11658	0.16927	0	0
PY	23104	6.1297	0.45424	0	0	0	0
AS	74605	4.7961	0.64167	-0.18695	0.18581	0	0
WJ	06405	5.1486	0.73636	-0.46927	0.39114	-0.05429	0
MC	47502	4.0105	0.8611	0	0	0	-0.0431
LM	11301	4.0181	0.8528	0	0	0	0
CW	74902	4.1687	1.5355	0	0	0	0.1275
OS	12205	4.7762	0.74126	-0.28734	0.17137	-0.00602	-0.00209
OH	74902	4.1687	1.5355	0	0	0	0.1275

*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} and {4.4.2} in the CI variant.

Species Code	Equation Number*	*MinD*	EL min	*EL* max	*HI* min	*HI* max	*CW* max
WP	11903	1.0	n/a	n/a	n/a	n/a	35
WL	07303	1.0	n/a	n/a	n/a	n/a	40
DF	20203	1.0	n/a	n/a	n/a	n/a	80
GF	01703	1.0	n/a	n/a	n/a	n/a	40
WH	26305	1.0	1	72	n/a	n/a	54
RC	24203	1.0	n/a	n/a	n/a	n/a	45
LP	10803	0.7	n/a	n/a	n/a	n/a	40
ES	09303	0.1	n/a	n/a	n/a	n/a	40
AF	01905	1.0	10	85	n/a	n/a	30
PP	12203	2.0	n/a	n/a	n/a	n/a	46
WB	10105	1.0	n/a	n/a	n/a	n/a	40
PY	23104	1.0	n/a	n/a	n/a	n/a	30
AS	74605	1.0	n/a	n/a	n/a	n/a	45
WJ	06405	1.0	n/a	n/a	n/a	n/a	36
MC	47502	5.0	n/a	n/a	-37	27	29
LM	11301	5.0	n/a	n/a	n/a	n/a	25
CW	74902	5.0	n/a	n/a	-26	-2	35
OS	12205	1.0	13	75	n/a	n/a	50
OH	74902	5.0	n/a	n/a	-26	-2	35

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

4.5 Crown Competition Factor

The CI 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 {4.5.1} and coefficients shown in table 4.5.1. Coefficients for curl-leaf mountain mahogany are from California black oak (Paine and Hann 1982); all other species use Inland Empire variant coefficients (Wykoff, et.al 1982).

{4.5.1} *CCF* equations for individual trees

$DBH \geq d$: $CCF_t = R_1 + (R_2 * DBH) + (R_3 * DBH^2)$
0.1" < *DBH* < 1.0": $CCF_t = R_4 * DBH ^{R_5}$
$DBH \leq 0.1"$ for all species except curl-leaf mountain mahogany: $CCF_t = 0.001$
$DBH < d$ for curl-leaf mountain mahogany: $CCF_t = (R_1 + R_2 + R_3) * DBH$

where:

CCF_t	is crown competition factor for an individual tree
DBH	is tree diameter at breast height
$R_1 – R_5$	are species-specific coefficients shown in table 4.5.1
d	is 10.0" for western white pine, western larch, Douglas-fir, grand fir, western hemlock, western redcedar, lodgepole pine, Engelmann spruce, subalpine fir , ponderosa pine, black cottonwood, other softwood, and other hardwood; 1.0" for whitebark pine, Pacific yew, quaking aspen, western juniper, curl-leaf mountain mahogany, and limber pine

Table 4.5.1 Coefficients ($R_1 – R_5$) for Crown Competition Factor equations {4.5.1} in the CI variant.

Species Code	Model Coefficients				
	R_1	R_2	R_3	R_4	R_5
WP	0.03	0.0167	0.00230	0.009884	1.6667
WL	0.02	0.0148	0.00338	0.007244	1.8182
DF	0.11	0.0333	0.00259	0.017299	1.5571
GF	0.04	0.0270	0.00405	0.015248	1.7333
WH	0.03	0.0215	0.00363	0.011109	1.7250
RC	0.03	0.0238	0.00490	0.008915	1.7800
LP	0.01925	0.01676	0.00365	0.009187	1.7600
ES	0.03	0.0173	0.00259	0.007875	1.7360
AF	0.03	0.0216	0.00405	0.011402	1.7560
PP	0.03	0.0180	0.00281	0.007813	1.7680
WB	0.01925	0.01676	0.00365	0.009187	1.7600

Species Code	Model Coefficients				
	R_1	R_2	R_3	R_4	R_5
PY	0.01925	0.01676	0.00365	0.009187	1.7600
AS	0.03	0.0238	0.00490	0.008915	1.7800
WJ	0.01925	0.01676	0.00365	0.009187	1.7600
MC	0.0204	0.0246	0.0074	0	0
LM	0.01925	0.01676	0.00365	0.009187	1.7600
CW	0.03	0.0215	0.00363	0.011109	1.7250
OS	0.03	0.0215	0.00363	0.011109	1.7250
OH	0.03	0.0215	0.00363	0.011109	1.7250

4.6 Small Tree Growth Relationships

Trees are considered “small trees” for FVS modeling purposes when they are smaller than some threshold diameter. For the CI variant, the threshold diameter is set to 1.0” for black cottonwood and other hardwood; 99.0” for western juniper and curl-leaf mountain mahogany (i.e. trees of all sizes for these two species are considered small trees for FVS modeling purposes); and 3.0” for all other species.

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

4.6.1 Small Tree Height Growth

The small-tree height increment model predicts height growth (*HTG*) for small trees and then uses a ratio adjustment to scale the height growth estimate to match the cycle length. For some species, the height growth equations estimate 10-year height growth; for other species the equations predict 5-year height growth. For species using 5-year height growth equations, the growth cycle is broken down into 5 year sub-cycles and the equations utilize mid-cycle estimates of stand basal area and relative density in the calculation.

For western white pine, western larch, Douglas-fir, grand fir, western hemlock, western redcedar, lodgepole pine, Engelmann spruce, subalpine fir, ponderosa pine, and other softwood, height growth is estimated using equation {4.6.1.1} and coefficients for this equation are shown in table 4.6.1.1. This equation yields a 5-year height growth estimate.

{4.6.1.1} $HTG = c_1 + (c_2 * RELHT * PTBAA) + (c_3 * PBAL) + (c_4 * BA) + (c_5 * RELHT) + (c_6 * CR^2) + (c_7 * CR) + (c_8 * BAL) + (c_9 * HAB_1) + (c_{10} * HAB_2) + (c_{11} * PTBAA)$

where:

HTG	is estimated 5-year height growth
RELHT	is tree height divided by average height of the 40 largest diameter trees in the stand
PTBAA	is basal area of the inventory point on which the tree is located
PBAL	is basal area in trees larger than the subject tree on the tree’s inventory point
BA	is total stand basal area

CR	is a tree's live crown ratio (compacted) expressed as a code (1-9) (1 = 0-10 percent, 2=11-20 percent, …, 9 = > 80 percent)
BAL	is total stand basal area in trees larger than the subject tree
HAB_1	is a habitat-dependent coefficient
	$HAB_1 = 0.0$ — $0 \leq$ Habitat Code < 500; $600 \leq$ Habitat Code
	$HAB_1 = 1.0$ — $500 \leq$ Habitat Code < 600
HAB_2	is a habitat-dependent coefficient
	$HAB_2 = 0.0$ — $0 \leq$ Habitat Code < 600; $700 \leq$ Habitat Code
	$HAB_2 = 1.0$ — $600 \leq$ Habitat Code < 700
$c_1 - c_{11}$	are species-specific coefficients shown in table 4.6.1.1

Table 4.6.1.1 Coefficients ($c_1 - c_{11}$) for equation {4.6.1.1} in the CI variant.

Species Code	Coefficients					
	c_1	c_2	c_3	c_4	c_5	c_6
WP	1.59898	0	-0.00203	0	1.36048	0.01998
WL	1.59898	0	-0.00203	0	1.36048	0.01998
DF	1.59898	0	-0.00203	0	1.36048	0.01998
GF	1.22213	0.00788	-0.00187	-0.00158	0.62556	0.02788
WH	1.22213	0.00788	-0.00187	-0.00158	0.62556	0.02788
RC	1.59898	0	-0.00203	0	1.36048	0.01998
LP	2.13400	-0.01040	0	-0.05702	2.55943	0.05926
ES	1.76880	0	-0.00163	0	1.56488	0.03346
AF	1.25335	0	-0.04330	0	1.91954	0.03055
PP	2.76456	0	0	-0.00964	0	0.02530
OS	2.13400	-0.01040	0	-0.05702	2.55943	0.05926

Species Code	Coefficients				
	c_7	c_8	c_9	c_{10}	c_{11}
WP	0	-0.00424	0	0	0
WL	0	-0.00424	0	0	0
DF	0	-0.00424	0	0	0
GF	-0.05668	0	-0.14824	0	0
WH	-0.05668	0	-0.14824	0	0
RC	0	-0.00424	0	0	0
LP	-0.42992	0.04685	1.34457	0.94168	0
ES	-0.24019	-0.00258	0	-0.17039	0
AF	-0.18446	0	0	-0.35149	0.04162
PP	0	0	0	0	0
OS	-0.42992	0.04685	1.34457	0.94168	0

For western juniper, curl-leaf mountain mahogany, black cottonwood, and other hardwood, the small-tree height increment model predicts 10-year height growth (*HTG*) for small trees based on site index, and is then modified to account for density effects and tree vigor.

Potential height growth for these four species is estimated using equation {4.6.1.2}.

{4.6.1.2} $POTHTG = ((SI / 5.0) * (SI * 1.5 - H) / (SI * 1.5)) * 0.83$

where:

POTHTG is potential height growth
SI is species site index on a base-age basis
H is tree height

Potential height growth is then adjusted based on stand density (*PCTRED*) as computed with equation {4.6.1.3}, and crown ratio (*VIGOR*) as shown in equation {4.6.1.4} or {4.6.1.5}. Western juniper uses equation {4.6.1.5} to estimate *VIGOR*; curl-leaf mountain mahogany, black cottonwood, and other hardwood use equation {4.6.1.4} to estimate *VIGOR*. Height growth is then estimated using equation 4.6.1.6 for these four species.

{4.6.1.3} $PCTRED = 1.1144 – 0.0115*Z + 0.4301E\text{-}04 * Z^2 – 0.7222E\text{-}07 * Z^3 + 0.5607E\text{-}10 * Z^4 – 0.1641E\text{-}13 * Z^5$

$Z = HT_{Avg} * (CCF / 100)$, bounded so $Z \leq 300$

{4.6.1.4} $VIGOR = (150 * CR^3 * \exp(-6 * CR)) + 0.3$

{4.6.1.5} $VIGOR = 1 – [(1 – (150 * CR^3 * \exp(-6 * CR)) + 0.3) / 3]$

{4.6.1.6} $HTG = POTHTG * PCTRED * VIGOR$

where:

PCTRED	is reduction in height growth due to stand density (bounded to $0.01 \leq PCTRED \leq 1$)
HT_{Avg}	is average height of the 40 largest diameter trees in the stand
CCF	is stand crown competition factor
VIGOR	is reduction in height growth due to tree vigor (bounded to $VIGOR \leq 1.0$)
CR	is a tree's live crown ratio (compacted) expressed as a proportion
HTG	is estimated 10-year height growth for the cycle
POTHTG	is potential height growth
A	is tree age

Height growth for small quaking aspen is obtained from a height-age curve from Shepperd (1995). Shepperd's original curve seemed to overestimate height growth when compared with field data from the geographic range of the UT variant, so the UT variant reduces the estimated height growth by 25 percent (as shown in equation {4.6.1.7}). A height is estimated from the tree's current age and then its current age plus 10 years. Height growth is the difference between these two height estimates adjusted to account for cycle length and any user defined small-tree height growth adjustments for aspen, and converted from centimeters to feet. An estimate of the tree's current age is obtained at the start of a projection using the tree's height and solving equation {4.6.1.7} for age.

{4.6.1.7} $HTG = (26.9825 * A^{1.1752}) * 0.75$

where:

HTG	is estimated height growth for the cycle
A	is tree age

Small tree height growth for whitebark pine, Pacific yew, and limber pine is estimated as a function of crown ratio and point crown competition factor using equation {4.6.1.8}. This equation predicts 5-year height growth. FVS uses 5-year sub-cycles when computing height growth with this equation.

{4.6.1.8} $HTG = \exp[c_1 + (c_2 * \ln(TPCCF))] + CR * \exp[c_3 + (c_4 * \ln(TPCCF))]$

where:

HTG	is estimated 5-year height growth

TPCCF	is crown competition factor based on sample point statistics (bounded to $25 \leq TPCCF \leq 300$); this value is updated mid-cycle
CR	is a tree's live crown ratio (compacted) expressed as a percent
c_1	= 1.17527
c_2	= -0.42124
c_3	= -2.56002
c_4	= -0.58642

For all species, a small random error is then added to the height growth estimate. The estimated height growth (*HTG*) is then adjusted to account for cycle length, user defined small-tree height growth adjustments, and adjustments due to small tree height model calibration from the 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 {4.6.1.9}, and applied as shown in equation {4.6.1.10}. The range of diameters for each species is shown in table 4.6.1.2.

{4.6.1.9}

$DBH \leq X_{\min}: XWT = 0$

$X_{\min} < DBH < X_{\max}: \; XWT = (DBH - X_{\min}) / (X_{\max} - X_{\min})$

$DBH \geq X_{\max}: XWT = 1$

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

where:

XWT	is the weight applied to the growth estimates
DBH	is tree diameter at breast height
X_{max}	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 CI variant.

Species Code	X_{min}	X_{max}
WP	2.0	5.0
WL	2.0	5.0
DF	2.0	5.0

Species Code	X_{min}	X_{max}
GF	2.0	5.0
WH	2.0	5.0
RC	2.0	5.0
LP	2.0	5.0
ES	2.0	5.0
AF	2.0	5.0
PP	2.0	5.0
WB	1.5	3.0
PY	1.5	3.0
AS	2.0	4.0
WJ	90.	99.
MC	90.	99.
LM	1.5	3.0
CW	0.5	2.0
OS	2.0	5.0
OH	0.5	2.0

*There is only one growth relationship that applies to trees of all sizes for these species. These relationships are contained in the "small" tree portion of FVS.

4.6.2 Small Tree Diameter Growth

As stated previously, for trees being projected with the small tree equations height growth is predicted first and then diameter growth. So both height at the beginning of the cycle and height at the end of the cycle are known when predicting diameter growth. Small tree diameter growth for trees over 4.5 feet tall is calculated as the difference of predicted diameter at the start of the projection period and the predicted diameter at the end of the projection period, adjusted for bark ratio. By definition, diameter growth is zero for trees less than 4.5 feet tall.

In the CI variant the small-tree diameter for western white pine, western larch, Douglas-fir, grand fir, western hemlock, western redcedar, lodgepole pine, Engelmann spruce, subalpine fir, ponderosa pine, and other softwood is estimated using equation {4.6.2.1} and coefficients shown in table 4.6.2.1.

{4.6.2.1} $DBH = \exp(d_1 + d_2 * \ln(HT) + d_3 * \ln(CR))$

where:

DBH	is tree diameter at breast height
HT	is tree height
CR	is crown ratio expressed as a percent
$d_1 - d_3$	are species-specific coefficients shown in table 4.6.2.1

Table 4.6.2.1 Coefficients for small-tree diameter growth equation {4.6.2.1} in the CI variant.

Species Code	Model Coefficients		
	d_1	d_2	d_3

Species Code	Model Coefficients		
	d_1	d_2	d_3
WP	-1.10700	0.830144	0
WL	-2.47253	1.045526	0
DF	-2.91444	1.234512	0.098784
GF	-2.44705	1.154547	0.019108
WH	-2.23082	1.173253	0.010090
RC	-2.23082	1.173253	0
LP	-2.34117	0.957510	0.191396
ES	-2.51259	1.151275	0.071330
AF	-2.59515	1.236187	0
PP	-1.10700	0.830144	0
OS	-2.23082	1.173253	0

Small-tree diameter for western juniper is estimated using equation {4.6.2.2}.

{4.6.2.2} $DBH = 10 * (HT - 4.5) / (SI - 4.5)$

where:

DBH is tree diameter at breast height
HT is tree height
SI is species site index on a base-age basis

By default, curl-leaf mountain mahogany uses the Curtis-Arney equations shown in {4.6.2.3} and {4.6.2.4} to estimate small-tree diameter. If height calibration is specified with the NOHTDREG keyword, the logistic equations discussed in section 4.1 are used to estimate small tree diameter growth.

{4.6.2.3} $HT > HAT3{:}\ DBH = \exp(\ln((\ln(HT - 4.5) - \ln(a))/\text{-}b) / c)$

{4.6.2.4} $HT \leq HAT3{:}\ DBH = ((HT - 4.51) * 2.7) / (4.5 + a * \exp(-b * (3.0 \wedge c)) - 4.51) + 0.3$

where:

DBH is tree diameter at breast height
HT is tree height
HAT3 $= 4.5 + a * \exp(-b * (3.0 \wedge c))$
a = 1709.7229
b = 5.8887
c = – 0.2286

Quaking aspen, black cottonwood, and other hardwood use the logistic height-diameter equation discussed in section 4.1 solved for diameter as shown in equation {4.6.2.5}. Coefficients for this equation are given in table 4.1.1.

{4.6.2.5} $DBH = (B_2 / (\ln(HT - 4.5) - B_1)) - 1.0$

where:

DBH is tree diameter at breast height (WJ uses diameter at root collar)
HT is tree height

For whitebark pine, Pacific yew, and limber pine, equation {4.6.2.6} is used to estimate small-tree diameter.

{4.6.2.6} $DBH = [b_1 * (HT - 4.5) * CR + b_2 * (HT - 4.5) * PCCF + b_3 * CR + b_4 * (HT - 4.5)] + 0.3$

where:

DBH is tree diameter at breast height
HT is tree height
CR is a tree's live crown ratio (compacted) expressed as a proportion
PCCF is crown competition factor on the inventory point where the tree is established
b_1 = 0.000231
b_2 = – 0.00005
b_3 = 0.001711
b_4 = 0.17023

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. For the CI variant, the threshold diameter is set to 1.0" for black cottonwood and other hardwood; 99.0" for western juniper and curl-leaf mountain mahogany (i.e. trees of all sizes for these two species are considered small trees for FVS modeling purposes); and 3.0" for all other species.

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 CI variant predicts diameter growth using equation {4.7.1.1} for all species except quaking aspen, western juniper, curl-leaf mountain mahogany, black cottonwood and other hardwood. Coefficients for this equation are shown in tables 4.7.1.1, 4.7.1.2, and 4.7.1.4.

{4.7.1.1} $\ln(DDS) = b_1 + (b_2 * EL) + (b_3 * EL^2) + (b_4 * \sin(ASP) * SL) + (b_5 * \cos(ASP) * SL) + (b_6 * SL) + (b_7 * SL^2) + (b_8 * \ln(DBH)) + (b_9 * \ln(BA)) + (b_{10} * CR) + (b_{11} * CR^2) + (b_{12} * DBH^2) + (b_{13} * BAL / (\ln(DBH + 1.0))) + (b_{14} * PBAL / (\ln(DBH + 1.0))) + (b_{15} * PCCF) + HAB + (b_{16} * SI) + (b_{17} * \ln(SI)) + (b_{18} * BAL) + (b_{19} * BA) + (b_{20} * 0.01 * RELDEN)$

where:

DDS	is the square of the diameter growth increment
EL	is stand elevation in hundreds of feet
ASP	is stand aspect; (*ASP* – 0.7854) is used for WB, PY, and LM
SL	is stand slope
CR	is crown ratio expressed as a proportion
DBH	is tree diameter at breast height
BA	is total stand basal area
BAL	is total stand basal area in trees larger than the subject tree; (BAL / 100) is used for WB, PY, and LM
PBAL	is basal area in trees larger than the subject tree on the inventory point where the tree is established
PCCF	is crown competition factor on the inventory point where the tree is established
RELDEN	is stand crown competition factor
HAB	is a plant association code dependent intercept shown in table 4.7.1.4
SI	is site index for the species
b_1	is a location-specific coefficient shown in table 4.7.1.2
b_2-b_{20}	are species-specific coefficients shown in table 4.7.1.4

Table 4.7.1.1 Coefficients (b_2-b_{19}) for equation 4.7.1.1 in the CI variant.

	Species Code				
Coefficient	**WP**	**WL, RC**	**DF**	**GF, WH**	**LP, OS**
b_2	0	-0.000064	0.003527	0.005045	0.006343
b_3	0	-0.000012	-0.000095	-0.000093	-0.000096
b_4	0.076531	0.008765	0.023297	0.009335	0.066831
b_5	0.127311	-0.120816	0.059683	-0.004469	0.081123
b_6	0.024336	-0.293028	-0.133723	-0.033374	0.000452
b_7	-0.781480	0	-0.484626	-0.418343	-0.207088
b_8	0.822203	0.725693	1.045093	1.286963	0.900528
b_9	-0.257322	-0.121785	-0.196025	-0.217923	-0.178038
b_{10}	1.768935	2.362259	1.658968	1.175105	1.913105
b_{11}	-0.176164	-1.719086	-0.361716	0.219013	-0.258206
b_{12}	-0.0004163	-0.0003576	-0.0004562	-0.0004408	-0.0009134
b_{13}	0	0	0	0	0
b_{14}	-0.006065	-0.003403	-0.002579	-0.000578	-0.001641
b_{15}	0	-0.000521	-0.000422	-0.000512	0
b_{16}	0	0	0	0	0
b_{17}	0	0	0	0	0
b_{18}	0	0	0	0	0
b_{19}	0	0	0	0	0
b_{20}	0	0	0	0	0
Coefficient	**Species Code**				

	ES	AF	PP	WB, PY, LM	
b_2	0	0.010618	0	0	
b_3	0	-0.000194	0	0	
b_4	-0.157633	-0.073830	0.076531	-0.01752	
b_5	0.013843	-0.137792	0.127311	-0.609774	
b_6	1.271265	0.161578	0.024336	-2.05706	
b_7	-1.842644	-0.050890	-0.781480	2.113263	
b_8	1.241561	0.968212	0.822203	0.213947	
b_9	-0.204602	-0.113511	-0.257322	0	
b_{10}	0.506551	0.626180	1.768935	1.523464	
b_{11}	0.762026	0.688924	-0.176164	0	
b_{12}	-0.0003958	-0.0002569	-0.0004163	-0.0006538	
b_{13}	0	-0.000926	0	0	
b_{14}	-0.000638	0	-0.006065	0	
b_{15}	-0.000210	-0.000601	0	0	
b_{16}	0	0	0	0.001766	
b_{17}	0	0	0	0	
b_{18}	0	0	0	-0.358634	
b_{19}	0	0	0	0	
b_{20}	0	0	0	-0.199592	

Table 4.7.1.2 b_1 values by location class for equation {4.7.1.1} in the CI variant.

Location Class	Species Code								
	WP	WL, RC	DF	GF, WH	LP, OS	ES	AF	PP	WB, PY, LM
1	2.01782	1.44573	1.11640	0.69134	0.47375	0.25542	0.44264	2.01782	1.56874
2	1.85118	1.55043	1.00427	0.97736	0.42572	0	0.47558	1.85118	0
3	1.87960	0	1.03580	0	0.52382	0	0.59364	1.87960	0

Table 4.7.1.3 Classification of location class by species and location code for equation {4.7.1.1} in the CI variant.

Location Code – USDA National Forest	Species Code								
	WP	WL, RC	DF	GF,WH	LP, OS	ES	AF	PP	WB, PY, LM
117 – Nez Perce	1	1	1	1	1	1	1	1	1
402 – Boise	2	2	2	2	2	1	2	2	1
406 – Challis	2	2	2	2	2	1	2	2	1
412 – Payette	3	2	3	1	3	1	3	3	1
413 – Salmon	2	2	2	2	2	1	2	2	1
414 – Sawtooth	2	2	2	2	2	1	2	2	1

Table 4.7.1.4 HAB values by habitat class and species for equation {4.7.1.1} in the CI variant.

Habitat Class	Species Code								
	WP	WL, RC	DF	GF, WH	LP, OS	ES	AF	PP	WB, PY, LM
0	0	0	0	0	0	0	0	0	0
1	0.00607	0.09873	0.14395	-0.09107	0.15548	0.10820	0.15151	0.00607	0
2	0.18159	-0.06611	0.05452	0.05119	0.25592	0.33219	0.09268	0.18159	0
3	-0.19610	0.17472	0.21625	-0.05798	0.54385	0.16102	0.31844	-0.19610	0
4	-0.05578	0	-0.16060	-0.15754	0.46829	0.37680	-0.03894	-0.05578	0
5	0.13391	0	0.08544	0.09440	0.41230	0.22960	0	0.13391	0
6	0.04586	0	0.33750	-0.19820	0.36708	0	0	0.04586	0
7	0	0	-0.04178	0	0.17123	0	0	0	0
8	0	0	0.01650	0	0.26206	0	0	0	0
9	0	0	0	0	0.04827	0	0	0	0
10	0	0	0	0	0.30118	0	0	0	0
11	0	0	0	0	0.54292	0	0	0	0

Table 4.7.1.5 Classification of habitat class by species and habitat code for equation {4.7.1.1} in the CI variant.

Habitat Code	Species Code								
	WP	WL, RC	DF	GF, WH	LP, OS	ES	AF	PP	WB, PY, LM
50	1	1	1	0	1	0	1	1	0
60	1	1	1	0	1	0	1	1	0
70	1	1	1	0	1	0	1	1	0
80	1	1	1	0	1	0	1	1	0
100	1	1	1	0	1	0	1	1	0
120	1	1	1	0	1	0	1	1	0
130	1	1	1	0	1	0	1	1	0
140	1	1	1	0	1	0	1	1	0
160	1	1	1	0	1	0	1	1	0
161	1	1	1	0	1	0	1	1	0
162	1	1	1	0	1	0	1	1	0
170	1	1	1	0	1	0	1	1	0
190	2	1	1	0	1	0	1	2	0

Habitat Code	Species Code								
	WP	WL, RC	DF	GF, WH	LP, OS	ES	AF	PP	WB, PY, LM
195	2	1	1	0	1	0	1	2	0
200	3	1	1	0	1	0	1	3	0
210	3	1	1	0	1	0	1	3	0
220	3	1	1	0	1	0	1	3	0
221	3	1	1	0	1	0	1	3	0
222	3	1	1	0	1	0	1	3	0
250	4	1	1	0	1	0	1	4	0
260	4	1	1	0	1	0	1	4	0
262	4	1	1	0	1	0	1	4	0
264	4	1	1	0	1	0	1	4	0
265	4	1	1	0	1	0	1	4	0
280	3	1	1	0	1	0	1	3	0
290	3	1	1	0	1	0	1	3	0
310	4	1	1	0	1	0	1	4	0
313	0	1	1	0	1	0	1	0	0
315	0	1	1	0	1	0	1	0	0
320	0	1	1	0	1	0	1	0	0
323	0	1	1	0	1	0	1	0	0
324	0	1	1	0	1	0	1	0	0
325	0	1	1	0	1	0	1	0	0
330	0	1	1	0	1	0	1	0	0
331	0	1	1	0	1	0	1	0	0
332	0	1	1	0	1	0	1	0	0
334	0	1	1	0	1	0	1	0	0
340	4	1	2	0	1	0	1	4	0
341	4	1	2	0	1	0	1	4	0
343	4	1	2	0	1	0	1	4	0
344	4	1	2	0	1	0	1	4	0
360	4	1	2	0	1	0	1	4	0
370	0	1	2	0	1	0	1	0	0
371	0	1	2	0	1	0	1	0	0
372	0	1	2	0	1	0	1	0	0
375	0	1	2	0	1	0	1	0	0
380	0	1	3	0	1	0	1	0	0
385	0	1	3	0	1	0	1	0	0
390	0	1	3	0	1	0	1	0	0
392	0	1	3	0	1	0	1	0	0
393	0	1	3	0	1	0	1	0	0

Habitat Code	Species Code								
	WP	WL, RC	DF	GF, WH	LP, OS	ES	AF	PP	WB, PY, LM
395	0	1	3	0	1	0	1	0	0
396	0	1	3	0	1	0	1	0	0
397	0	1	3	0	1	0	1	0	0
398	0	1	3	0	1	0	1	0	0
400	0	1	3	0	1	0	1	0	0
410	0	1	3	0	1	0	1	0	0
440	0	1	3	0	1	0	1	0	0
490	0	1	3	0	1	0	1	0	0
493	0	1	3	0	1	0	1	0	0
500	5	1	2	0	10	0	1	5	0
505	5	1	2	0	10	1	1	5	0
510	5	1	1	1	10	1	1	5	0
511	5	1	1	1	10	1	1	5	0
515	5	1	3	0	2	1	1	5	0
520	6	1	1	3	5	2	2	6	0
525	6	1	5	4	3	3	2	6	0
526	6	1	3	1	5	4	2	6	0
527	6	1	3	3	5	4	2	6	0
580	6	0	6	5	5	5	1	6	0
585	6	0	6	5	5	5	1	6	0
590	4	0	8	3	5	5	1	4	0
591	4	0	8	3	5	5	1	4	0
592	4	0	8	6	6	5	1	4	0
593	4	0	8	6	6	5	1	4	0
600	0	0	7	0	6	3	0	0	0
605	0	0	7	0	6	3	0	0	0
620	0	0	7	0	6	3	0	0	0
621	0	0	7	0	6	3	0	0	0
625	0	0	7	0	6	3	0	0	0
635	0	0	7	0	6	5	1	0	0
636	0	0	7	0	6	5	1	0	0
637	0	0	7	0	6	5	1	0	0
638	0	0	7	0	6	5	1	0	0
640	0	0	7	0	7	3	1	0	0
645	0	0	7	0	7	3	1	0	0
650	0	0	7	0	7	3	0	0	0
651	0	0	7	0	7	3	0	0	0
652	0	0	7	0	7	3	0	0	0

Habitat Code	Species Code								
	WP	WL, RC	DF	GF, WH	LP, OS	ES	AF	PP	WB, PY, LM
654	0	0	7	0	7	3	0	0	0
655	0	0	7	0	7	3	0	0	0
660	0	0	7	0	7	3	0	0	0
661	0	0	7	0	7	3	0	0	0
662	0	0	7	0	7	3	0	0	0
663	0	0	7	0	7	3	0	0	0
670	0	0	7	0	7	0	1	0	0
671	0	0	7	0	7	0	1	0	0
672	0	0	7	0	7	0	0	0	0
690	0	0	7	0	8	0	1	0	0
691	0	0	7	0	8	0	0	0	0
692	0	0	7	0	9	0	4	0	0
694	0	0	7	0	8	0	1	0	0
700	0	0	0	0	11	0	4	0	0
705	0	0	0	0	11	0	4	0	0
720	0	0	0	0	11	0	4	0	0
721	0	0	0	0	11	0	4	0	0
723	0	0	0	0	11	0	4	0	0
730	0	0	0	0	9	0	4	0	0
731	0	0	0	0	9	0	4	0	0
732	0	0	0	0	9	0	4	0	0
734	0	0	0	0	0	0	4	0	0
740	0	0	0	0	0	0	1	0	0
745	0	0	0	0	0	0	1	0	0
750	0	0	0	0	0	0	0	0	0
780	0	0	0	0	0	0	0	0	0
790	0	0	0	0	0	0	1	0	0
791	0	0	0	0	0	0	1	0	0
793	0	0	0	0	0	0	1	0	0
810	0	0	0	0	0	0	0	0	0
830	0	0	0	0	0	0	0	0	0
831	0	0	0	0	0	0	0	0	0
833	0	0	0	0	0	0	0	0	0
850	0	0	0	0	0	0	0	0	0
870	0	0	0	0	0	0	0	0	0
900	0	0	0	0	0	0	0	0	0
905	0	0	0	0	0	0	0	0	0
920	0	0	0	0	0	0	0	0	0

Habitat Code	Species Code								
	WP	WL, RC	DF	GF, WH	LP, OS	ES	AF	PP	WB, PY, LM
940	0	0	0	0	0	0	0	0	0
955	0	0	0	0	0	0	0	0	0
999	0	0	0	0	0	0	0	0	0

Large-tree diameter growth for quaking aspen is predicted using equation set {4.7.1.2}. Diameter growth is predicted from a potential diameter growth equation that is modified by stand density, average tree size and site. While not shown here, this diameter growth estimate is eventually converted to the *DDS* scale.

{4.7.1.2} Used for quaking aspen

$$POTGR = (0.4755 - 0.0000038336 * DBH^{4.1488}) + (0.04510 * CR * DBH^{0.67266})$$
$$MOD = 1.0 - \exp(-FOFR * GOFAD * ((310-BA)/310)^{0.5})$$
$$FOFR = 1.07528 * (1.0 - \exp(-1.89022 * DBH / QMD))$$
$$GOFAD = 0.21963 * (QMD + 1.0)^{0.73355}$$
$$PREDGR = POTGR * MOD * (0.48630 + 0.01258 * SI)$$

where:

POTGR is potential diameter growth bounded to be ≥ 0.01
DBH is tree diameter at breast height
CR is crown ratio expressed as a percent divided by 10
MOD is a modifier based on tree diameter and stand density
FOFR is the relative density modifier
GOFAD is the average diameter modifier
BA is total stand basal area bounded to be < 310
QMD is stand quadratic mean diameter
PREDGR is predicted diameter growth
SI is the quaking aspen site index on a base age 80 basis

Large-tree diameter growth for black cottonwood and other hardwood is predicted using equations identified in equation set {4.7.1.3}. Diameter at the end of the growth cycle is predicted first. Then diameter growth is calculated as the difference between the diameters at the beginning of the cycle and end of the cycle, adjusted for bark ratio. While not shown here, this diameter growth estimate is eventually converted to the *DDS* scale.

{4.7.1.3} Used for black cottonwood and other hardwood

$$DF = 0.24506 + 1.01291 * DBH - 0.00084659 * BA + 0.00631 * SI$$
$$DG = (DF - DBH) * BRATIO$$

where:

DF is tree diameter at breast height at the end of the cycle; bounded so $DF \leq 36''$
DG is tree diameter growth
DBH is tree diameter at breast height

BA	is total stand basal area
SI	is species site index
DG	is tree diameter growth
BRATIO	is species-specific bark ratio
DDS	is the predicted periodic change in squared inside-bark diameter

For western juniper and curl-leaf mountain mahogany, trees of all sizes are grown with equations presented in section 4.6.

4.7.2 Large Tree Height Growth

In the CI variant, equation {4.7.2.1} is used to estimate large tree height growth for western white pine, western larch, Douglas-fir, grand fir, western hemlock, western redcedar, lodgepole pine, Engelmann spruce, subalpine fir, ponderosa pine, and other softwood. Coefficients for this equation are located in tables 4.7.2.1 – 4.7.2.2.

{4.7.2.1} $HTG = \exp(HAB + b_0 + (b_1 * HT^2) + (b_2 * \ln(DBH)) + (b_3 * \ln(HT)) + (b_4 * \ln(DG))) + .4809$

where:

HTG	is estimated height growth for the cycle
HAB	is a plant association code dependent intercept shown in table 4.7.2.2
HT	is tree height at the beginning of the cycle
DBH	is tree diameter at breast height
DG	is diameter growth for the cycle
b_0, b_2, b_3	are species-specific coefficients shown in table 4.7.2.1
b_1, b_4	are habitat-dependent coefficients shown in table 4.7.2.2

Table 4.7.2.1 Coefficients (b_0, b_2 and b_3) for the height-growth equation in the CI variant.

	Species Code										
Coefficient	**WP**	**WL**	**DF**	**GF**	**WH**	**RC**	**LP**	**ES**	**AF**	**PP**	**OS**
b_0	-0.5342	0.1433	0.1641	-0.6458	-0.6959	-0.9941	-0.6004	0.2089	-0.5478	0.7316	-0.9941
b_2	-0.04935	-0.3899	-0.4574	-0.09775	-0.1555	-0.1219	-0.2454	-0.5720	-0.1997	-0.5657	-0.1219
b_3	0.23315	0.23315	0.23315	0.23315	0.23315	0.23315	0.23315	0.23315	0.23315	0.23315	0.23315

Table 4.7.2.2 Coefficients (b_1, b_4, and HAB) by habitat code for the height-growth equation in the CI variant.

	Coefficient		
Habitat Codes	**b_1**	**b_4**	***HAB***
50 - 195, 221, 222	-0.0001336	0.62144	2.03035
200 - 220, 250 - 410	-0.0000381	1.02372	1.72222
440 – 493	-0.0000372	0.85493	1.19728
500 - 515, 525	-0.0000261	0.75756	1.81759
520, 526, 527	-0.0000520	0.46238	2.14781
580 – 605	-0.0000363	0.37042	2.21104

620 – 655	-0.0000261	0.75756	1.81759
660 – 663	-0.0001336	0.62144	2.03035
670 – 692	-0.0000261	0.75756	1.81759
694 – 723	-0.0000446	0.34003	1.74090
730 – 999	-0.0001336	0.62144	2.03035

Six species use Johnson's SBB (1949) method (Schreuder and Hafley, 1977) to estimate large tree height growth. These species are whitebark pine, Pacific yew, quaking aspen, limber pine, black cottonwood, and other hardwood. Using this method, height growth is obtained by subtracting current height from the estimated future height. Parameters of the SBB distribution cannot be calculated if tree diameter is greater than (C_1 + 0.1) or tree height is greater than (C_2 + 4.5), where C_1 and C_2 are shown in table 4.7.2.3. In this case, height growth is set to 0.1. Otherwise, the SBB distribution "*Z*" parameter is estimated using equation {4.7.2.2}.

{4.7.2.2} $Z = [C_4 + C_6 * FBY2 - C_7 * (C_3 + C_5 * FBY1)] * (1 - C_7\text{^}2)\text{^}{-0.5}$

$FBY1 = \ln[Y1/(1 - Y1)]$
$FBY2 = \ln[Y2/(1 - Y2)]$
$Y1 = (DBH - 0.095) / C_1$
$Y2 = (HT - 4.5) / C_2$

where:

HT is tree height
DBH is tree diameter at breast height
$C_1 - C_7$ are coefficients based on species and crown ratio class shown in table 4.7.2.3

Table 4.7.2.3 Coefficients in the large tree height growth model, by crown ratio, for species using the Johnson's SBB height distribution in the TT variant.

Coefficient by *CR** class	Species Code	
	WB, PY, LM	AS, CW, OH
C_1 ($CR \leq 24$)	37	30
C_1 ($25 \leq CR \leq 74$)	45	30
C_1 ($75 \leq CR \leq 100$)	45	35
C_2 ($CR \leq 24$)	85	85
C_2 ($25 \leq CR \leq 74$)	100	85
C_2 ($75 \leq CR \leq 100$)	90	85
C_3 ($CR \leq 24$)	1.77836	2.00995
C_3 ($25 \leq CR \leq 74$)	1.66674	2.00995
C_3 ($75 \leq CR \leq 100$)	1.64770	1.80388
C_4 ($CR \leq 24$)	-0.51147	0.03288
C_4 ($25 \leq CR \leq 74$)	0.25626	0.03288
C_4 ($75 \leq CR \leq 100$)	0.30546	-0.07682
C_5 ($CR \leq 24$)	1.88795	1.81059
C_5 ($25 \leq CR \leq 74$)	1.45477	1.81059
C_5 ($75 \leq CR \leq 100$)	1.35015	1.70032

Coefficient by CR* class	Species Code	
	WB, PY, LM	AS, CW, OH
C_6 ($CR \leq 24$)	1.20654	1.28612
C_6 ($25 \leq CR \leq 74$)	1.11251	1.28612
C_6 ($75 \leq CR \leq 100$)	0.94823	1.29148
C_7 ($CR \leq 24$)	0.57697	0.72051
C_7 ($25 \leq CR \leq 74$)	0.67375	0.72051
C_7 ($75 \leq CR \leq 100$)	0.70453	0.72343
C_8 ($CR \leq 24$)	3.57635	3.00551
C_8 ($25 \leq CR \leq 74$)	2.17942	3.00551
C_8 ($75 \leq CR \leq 100$)	2.46480	2.91519
C_9 ($CR \leq 24$)	0.90283	1.01433
C_9 ($25 \leq CR \leq 74$)	0.88103	1.01433
C_9 ($75 \leq CR \leq 100$)	1.00316	0.95244

*CR represents percent crown ratio

Quaking aspen, black cottonwood, and other hardwood use equations {4.7.2.3} and {4.7.2.4} to eliminate known bias.

{4.7.2.3} $ZBIAS = 0.1 - 0.10273 * Z + 0.00273 * Z\char`^2$ (bounded ZBIAS $\geq$ 0)

{4.7.2.4} for AS, CW, and OH: $Z = Z + ZBIAS$

If the Z value is 2.0 or less, it is adjusted for all younger aged trees using equation {4.7.2.5}. This adjustment is done for trees with an estimated age between 11 and 39 years and a diameter less than 9.0 inches. After this calculation, the value of Z is bounded to be 2.0 or less for trees meeting these criteria.

{4.7.2.5} $Z = Z * (0.3564 * DG) * \text{CLOSUR} * K$

if $CCF \geq 100$: $CLOSUR = PCT / 100$
if $CCF < 100$: $CLOSUR = 1$
if $CR \geq 75$ %: $K = 1.1$
if $CR < 75$ %: $K = 1.0$

where:

DG	is diameter growth for the cycle
PCT	is the subject tree's percentile in the basal area distribution of the stand
CCF	is stand crown competition factor

Estimated height 10 years later is calculated using equation {4.7.2.6}, and finally, 10-year height growth is calculated by subtraction using equation {4.7.2.7} and adjusted to the cycle length.

{4.7.2.6} $H10 = [(PSI / (1 + PSI)) * C_2] + 4.5$

$PSI = C_8 * [(D10 - 0.095) / (0.095 + C_1 - D10)]\char`^C_9 * [\exp(K)]$
$K = Z * [(1 - C_7\char`^2)\char`^(0.5 / C_6)]$

{4.7.2.7} Height growth equation

$H10 > HT$: $POTHTG = H10 - HT$
$H10 \leq HT$: $POTHTG = 0.1$

where:

H10	is estimated height of the tree in ten years
HT	is height of the tree at the beginning of the cycle
D10	is estimated diameter at breast height of the tree in ten years
POTHTG	is potential height growth
$C_1 - C_9$	are regression coefficients based on crown ratio class shown in table 4.7.2.3

For western juniper and curl-leaf mountain mahogany, trees of all sizes are grown with equations presented in section 4.6.

5.0 Mortality Model

All species in the CI variant use the Prognosis-type mortality model (Wykoff and others 1982 and Hamilton 1986) that is described in detail in section 7.3.1 of Essential FVS: A User's Guide to the Forest Vegetation Simulator (Dixon 2002, abbreviated EFVS). This model independently calculates two mortality rates and then weights them to form the final mortality rate applied to an individual tree record.

The first mortality rate estimate, *RA*, predicts individual tree mortality based on habitat type, species, diameter, diameter increment, estimated potential diameter increment, stand basal area, and a trees' diameter relative to the average stand diameter. The equation used to calculate the first mortality rate for all species is shown in equation set {5.0.1}.

{5.0.1} $RA = [1 / (1 + \exp(X))] * RADJ$

$X = (b_0 + 2.76253 + 0.22231 * \sqrt{DBH} + -0.0460508 * \sqrt{BA} + 11.2007 * G + 0.246301 * RDBH + ((-0.55442 + 6.07129 * G) / DBH))$

Bounded to: $-70 \le X \le 70$ for WB, PY, AS, WJ, MC, LM, CW, and OH

$-88.5 \le X \le 88.5$ for WP, WL, DF, GF, WH, RC, LP, ES, AF, PP, and OS

where:

RA is the estimated annual mortality rate

RADJ is a factor based on Reineke's (1933) Stand Density Index that accounts for expected differences in mortality rates on different habitat types and National Forests where:

for $DBH > 5.0$": $RADJ = (1 - ((0.20 + (0.05 * I)) /20 + 1)^{-1.605}) / 0.06821$

for $DBH \le 5.0$": $RADJ = (1 - ((0.20 + (0.05 * I)) + 1)^{-1.605}) / 0.86610$

DBH is tree diameter at breast height

BA is total stand basal area

RDBH is the ratio of tree *DBH* to the arithmetic mean stand d.b.h.

DG is periodic annual d.b.h. increment for the previous growth period

G is periodic annual d.b.h. increment for the previous growth period adjusted for Differences in potential annual d.b.h. increment indexed by habitat type and National Forest where:

for $DBH > 5.0$": $G = 0.90 / (0.20 + (0.05 * I)) * DG$

for $DBH \le 5.0$": $G = 2.50 / (0.20 + (0.05 * I)) * DG$

I is a diameter growth index value determined by habitat type and location code for *I* values of trees with *DBH* > 5.0", see table 5.0.2 for *I* values of trees with $DBH \le 5.0$", see table 5.0.3

b_0 is a species-specific coefficient shown in table 5.0.1

Table 5.0.1 b_0 values used in the mortality equation set {5.0.1} in the CI variant.

Species Code	b_0
WP	0

Species Code	b_0
WL	-0.17603
DF	0.317888
GF	0.317888
WH	0.607725
RC	1.57976
LP	-0.12057
ES	0.94019
AF	0.21180
PP	0.21180
WB	0
PY	0
AS	0
WJ	0
MC	0
LM	0
CW	0
OS	0
OH	0

Table 5.0.2 *I* values for trees with DBH > 5.0" used in equation set {5.0.1} in the CI variant.

	National Forest Location Code*					
Habitat Codes	**117**	**402**	**406**	**412**	**413**	**414**
50 – 162	15	7	7	15	7	7
170 – 195, 221, 222	15	6	6	15	6	6
200 – 220, 250	15	6	6	15	6	6
260 – 265	15	6	6	15	6	6
280	14	6	6	14	6	6
290	14	6	6	14	6	6
310 – 315	9	5	5	9	5	5
320 – 325	13	6	6	13	6	6
330 – 410	13	5	5	13	5	5
440	14	6	6	14	6	6
490, 493	14	6	6	14	6	6
500 – 515, 525	13	6	6	13	6	6
520, 526, 527	14	6	6	14	6	6
580 – 593	14	7	7	14	7	7
600 – 605	14	7	7	14	7	7
620 – 638	14	7	7	14	7	7
640 – 655	10	5	5	10	5	5
660 – 663	9	3	3	9	3	3

Habitat Codes	National Forest Location Code*					
	117	402	406	412	413	414
670, 671, 672	9	4	4	9	4	4
690, 691, 692	8	3	3	8	3	3
694, 700	11	4	4	11	4	4
705, 720	11	4	4	11	4	4
721, 723	15	6	6	15	6	6
730 – 793	9	5	5	9	5	5
810 – 833	6	1	1	6	1	1
850 – 955	8	1	1	8	1	1
999	15	6	6	15	6	6

* Values from the Inland Empire variant Nez Perce National Forest are used for the Nez Perce and Payette National Forests; values from the Inland Empire variant Bitterroot National Forest are used for the Boise, Challis, Salmon, and Sawtooth National Forests.

Table 5.0.3 *I* values for trees with DBH < 5.0" used in equation set {5.0.1} in the CI variant.

Habitat Codes	National Forest Location Code*					
	117	402	406	412	413	414
50 – 162	45	30	30	45	30	30
170 – 195, 221, 222	45	29	29	45	29	29
200 – 220, 250	45	29	29	45	29	29
260 – 265	45	29	29	45	29	29
280	44	28	28	44	28	28
290	44	28	28	44	28	28
310 – 315	43	27	27	43	27	27
320 – 325	48	31	31	48	31	31
330 – 410	41	27	27	41	27	27
440	42	27	27	42	27	27
490, 493	43	28	28	43	28	28
500 – 515, 525	47	31	31	47	31	31
520, 526, 527	48	32	32	48	32	32
580 – 593	46	32	32	46	32	32
600 – 605	44	31	31	44	31	31
620 – 638	44	31	31	44	31	31
640 – 655	36	25	25	36	25	25
660 – 663	34	23	23	34	23	23
670, 671, 672	37	24	24	37	24	24
690, 691, 692	37	23	23	37	23	23
694, 700	38	24	24	38	24	24
705, 720	37	24	24	37	24	24
721, 723	43	27	27	43	27	27
730 – 793	34	26	26	34	26	26
810 – 833	30	18	18	30	18	18

Habitat Codes	National Forest Location Code*					
	117	**402**	**406**	**412**	**413**	**414**
850 – 955	33	16	16	33	16	16
999	43	27	27	43	27	27

* Values from the Inland Empire variant Nez Perce National Forest are used for the Nez Perce and Payette National Forests; values from the Inland Empire variant Bitterroot National Forest are used for the Boise, Challis, Salmon, and Sawtooth National Forests.

The second mortality rate estimate, *RB*, is dependent on the proximity of stand basal area to the site maximum (see section 3.5 of this variant overview), and the rate of basal area increment. As stand basal area approaches the maximum for the site, *RB* approaches 1. The calculation of *RB* is described in section 7.3.1.2 of EFVS (Dixon 2002) and is not shown here.

The mortality rate applied to a tree record is a weighted average of *RA* and *RB* with the weight also dependent on the proximity of stand basal area to the maximum for the site. This is also described in section 7.3.1.3 of EFVS (Dixon 2002), and is not shown here. The combined estimate is adjusted to the length of the cycle using a compound interest formula as shown in equation {5.0.2}.

{5.0.2} $RT = (1 - (1 - RC)^Y) * m$

where:

RT	is the mortality rate applied to an individual tree record for the growth period
RC	is the combined estimate of the annual mortality rate for the tree record
Y	is length of the current projection cycle in years
m	is a species specific multiplier:

m = 0.6 for whitebark pine, Pacific yew, quaking aspen, curl-leaf mountain mahogany, limber pine, black cottonwood, and other hardwood
m = 0.2 for western juniper
m = 1.0 for all other species

6.0 Regeneration

The CI variant contains the full establishment model which is explained in section 5.4.2 of the Essential FVS Users Guide (Dixon 2002). By default, the full establishment features are turned off. To enable automatic establishment for the Nez Perce, Boise, and Payette National Forests, users need to insert the AuTally, Ingrow, and StockADJ keywords into their run. Currently, enabling features will not have any effect for the Salmon, Challis, and Sawtooth National Forests. For all forests within the CI variant geographic range, regeneration and ingrowth can be input into simulations manually through the establishment model keywords as explained in section 5.4.3 of the Essential FVS Users 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 sprout species (see table 6.0.1 for sprouting species).

Table 6.0.1 Regeneration parameters by species in the CI variant.

Species Code	Sprouting Species	Minimum Bud Width (in)	Minimum Tree Height (ft)	Maximum Tree Height (ft)
WP	No	0.4	1.0	23.0
WL	No	0.3	1.0	27.0
DF	No	0.3	1.0	21.0
GF	No	0.3	0.5	21.0
WH	No	0.2	0.5	22.0
RC	No	0.2	0.5	20.0
LP	No	0.4	1.0	24.0
ES	No	0.3	0.5	18.0
AF	No	0.3	0.5	18.0
PP	No	0.5	1.0	17.0
WB	No	0.3	1.0	27.0
PY	No	0.3	1.0	27.0
AS	Yes	0.2	6.0	16.0
WJ	No	0.3	0.5	6.0
MC	No	0.2	0.5	6.0
LM	No	0.3	1.0	27.0
CW	Yes	0.2	3.0	16.0
OS	No	0.2	0.5	22.0
OH	No	0.2	3.0	16.0

Two sprout records are created for quaking aspen and logic rule {6.0.1} is used to determine the number of sprout records for black cottonwood. The trees-per-acre represented by each sprout record is determined using the general sprouting probability equation {6.0.2}. 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 black cottonwood:

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

{6.0.2} $TPA_s = TPA_i * PS$

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

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 CI variant.

Species Code	Sprouting Probability	Number of Sprout Records	Source
AS	{6.0.3}	2	Keyser 2001
CW	0.9	[6.0.1]	Gom and Rood 2000 Steinberg 2001

Regeneration of seedlings may be specified by using 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 Decimal C). 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 merchantability standards and equation numbers for the CI variant are shown in tables 7.0.1 – 7.0.3.

Table 7.0.1 Default volume merchantability standards for the CI variant.

Merchantable Cubic Foot Volume Specifications:		
Minimum DBH / Top Diameter	LP	All Other Species
All location codes	7.0 / 6.0 inches	8.0 / 6.0 inches
Stump Height	1.0 foot	1.0 foot
Merchantable Board Foot Volume Specifications:		
Minimum DBH / Top Diameter	LP	All Other Species
All location codes	7.0 / 6.0 inches	8.0 / 6.0 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
western white pine	117	I00FW2W119	Flewelling's 2-Point Profile Model
western white pine	All Region 4 codes	400MATW117	Rustagi and Loveless Profile Model
western larch	117	I00FW2W073	Flewelling's 2-Point Profile Model
western larch	All Region 4 codes	400MATW073	Rustagi and Loveless Profile Model
Douglas-fir	117	I00FW2W202	Flewelling's 2-Point Profile Model
Douglas-fir	402, 412, 413	I15FW2W202	Flewelling's 2-Point Profile Model
Douglas-fir	406, 414	400MATW202	Rustagi and Loveless Profile Model
grand fir	117	I00FW2W017	Flewelling's 2-Point Profile Model
grand fir	402, 412, 413	I15FW2W017	Flewelling's 2-Point Profile Model
grand fir	406, 414	400MATW015	Rustagi and Loveless Profile Model

Common Name	Location Code	Equation Number	Reference
western hemlock	117	I00FW2W260	Flewelling's 2-Point Profile Model
western hemlock	All Region 4 codes	400MATW015	Rustagi and Loveless Profile Model
western redcedar	117	I00FW2W242	Flewelling's 2-Point Profile Model
western redcedar	All Region 4 codes	400MATW081	Rustagi and Loveless Profile Model
lodgepole pine	117	I00FW2W108	Flewelling's 2-Point Profile Model
lodgepole pine	All Region 4 codes	400MATW108	Rustagi and Loveless Profile Model
Engelmann spruce	117	I00FW2W093	Flewelling's 2-Point Profile Model
Engelmann spruce	402, 412, 413	I15FW2W093	Flewelling's 2-Point Profile Model
Engelmann spruce	406, 414	400MATW093	Rustagi and Loveless Profile Model
subalpine fir	117	I00FW2W019	Flewelling's 2-Point Profile Model
subalpine fir	All Region 4 codes	400MATW019	Rustagi and Loveless Profile Model
ponderosa pine	117	I00FW2W122	Flewelling's 2-Point Profile Model
ponderosa pine	402, 412, 413	I15FW2W122	Flewelling's 2-Point Profile Model
ponderosa pine	406, 414	400MATW122	Rustagi and Loveless Profile Model
whitebark pine	117	I00FW2W012	Flewelling's 2-Point Profile Model
whitebark pine	All Region 4 codes	400MATW108	Rustagi and Loveless Profile Model
Pacific yew	117	616BEHW231	Behre's Hyperbola
Pacific yew	All Region 4 codes	400DVEW998	Chojnacky Equations
quaking aspen	117	102DVEW746	Kemp Equations
quaking aspen	All Region 4 codes	400MATW746	Rustagi and Loveless Profile Model
western juniper	117	102DVEW060	Kemp Equations
western juniper	All Region 4 codes	400DVEW064	Chojnacky Equations

Common Name	Location Code	Equation Number	Reference
curl-leaf mountain mahogany	All	400DVEW475	Chojnacky Equations
limber pine	117	I00FW2W073	Flewelling's 2-Point Profile Model
limber pine	All Region 4 codes	400MATW108	Rustagi and Loveless Profile Model
black cottonwood	117	102DVEW740	Kemp Equations
black cottonwood	All Region 4 codes	400DVEW998	Chojnacky Equations
other softwood	117	I00FW2W260	Flewelling's 2-Point Profile Model
other softwood	All Region 4 codes	400MATW108	Rustagi and Loveless Profile Model
other hardwood	117	200DVEW746	Edminster Equation
other hardwood	All Region 4 codes	400MATW108	Rustagi and Loveless Profile Model

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.
Chojnacky Equations	Chojnacky, David. 1985. Pinyon-Juniper Volume Equations for the Central Rocky Mountain States. Intermountain Research Station Research Paper INT-339.
Edminster Equation	Edminster, Carleton B., H. Todd Mowrer, and Thomas E. Hinds. 1982. Volume Tables and Point-Sampling Factors for Aspen in Colorado. Rocky Mtn Forest and Range Experiment Station Research Paper RM-232
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.
Kemp Equations	Kemp, P.D. 1958. Unpublished report on file at USDA, Forest Service, Rocky Mountain Research Station, Interior West Resource Inventory, Monitoring, and Evaluation Program, Ogden, UT.
Rustagi and Loveless Profile Model	Rustagi, K.R. and Loveless, R.S.,Jr., 1991. Compatible variable-form volume and stem-profile equations for Douglas-fir. Can. J. For. Res. 21:143-151.

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 CI 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 CI 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).

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11.0 Appendices

11.1 Appendix A. Habitat Codes

Table 11.1.1 Habitat codes recognized and their corresponding original NI variant habitat type codes, basal area maximums and stand density index maximums in the CI variant.

Habitat Code	Abbreviation	Habitat Type Name	Original Habitat Type	BAMAX
50	PIFL2/FEID	*limber pine/Idaho fescue*	130	100
60	PIFL2/CELE3	*limber pine/curl-leaf mountain mahogany*	130	100
70	PIFL2/JUCO6	*limber pine/common juniper*	130	100
80	PIFL2/HEKI2	*limber pine/spike fescue*	130	100
100	PIPO	*ponderosa pine series*	130	100
120	PIPO/ACOCO	*ponderosa pine/western needlegrass*	130	100
130	PIPO/PSSPS	*ponderosa pine/bluebunch wheatgrass*	130	100
140	PIPO/FEID	*ponderosa pine/Idaho fescue*	130	130
160	PIPO/PUTR2	*ponderosa pine/antelope bitterbrush*	130	95
161	PIPO/PUTR2/PSSPS	*ponderosa pine/antelope bitterbrush/bluebunch wheatgrass*	130	95
162	PIPO/PUTR2/FEID	*ponderosa pine/antelope bitterbrush/Idaho fescue*	130	95
170	PIPO/SYAL	*ponderosa pine/common snowberry*	170	220
190	PIPO/PHMA5	*ponderosa pine/mallow ninebark*	170	213
195	PIPO/SYOR2	*ponderosa pine/mountain snowberry*	170	140
200	PSME	*Douglas-fir*	170	175
210	PSME/PSSPS	*Douglas-fir/bluebunch wheatgrass*	170	154
220	PSME/FEID	*Douglas-fir/Idaho fescue*	250	137
221	PSME/FEID-FEID	*Douglas-fir/Idaho fescue-Idaho fescue*	250	122
222	PSME/FEID/PIPO	*Douglas-fir/Idaho fescue/ponderosa pine*	250	152
250	PSME/VACA13	*Douglas-fir/dwarf bilberry*	250	100
260	PSME/PHMA5	*Douglas-fir/mallow ninebark*	260	220
262	PSME/PHMA5/CARU	*Douglas-fir/mallow ninebark/pinegrass*	260	220
264	PSME/PHMA5/PIPO	*Douglas-fir/mallow ninebark/ponderosa pine*	260	233
265	PSME/PHMA5/PSME	*Douglas-fir/mallow ninebark/Douglas-fir*	260	220
280	PSME/VAME	*Douglas-fir/thinleaf huckleberry*	280	175
290	PSME/LIBO3	*Douglas-fir/twinflower*	290	250

Habitat Code	Abbreviation	Habitat Type Name	Original Habitat Type	BAMAX
310	PSME/SYAL	*Douglas-fir/common snowberry*	310	190
313	PSME/SYAL-SYAL	*Douglas-fir/common snowberry-common snowberry*	310	190
315	PSME/SYAL/PIPO	*Douglas-fir/common snowberry/ponderosa pine*	310	226
320	PSME/CARU	*Douglas-fir/pinegrass*	320	140
323	PSME/CARU-CARU	*Douglas-fir/pinegrass-pinegrass*	320	200
324	PSME/CARU/PIPO	*Douglas-fir/pinegrass/ponderosa pine*	320	210
325	PSME/CARU-FEID	*Douglas-fir/pinegrass-Idaho fescue*	320	140
330	PSME/CAGE2	*Douglas-fir/Geyer's sedge*	330	160
331	PSME/CAGE2-CAGE2	*Douglas-fir/Geyer's sedge-Geyer's sedge*	330	200
332	PSME/CAGE2/SYOR2	*Douglas-fir/Geyer's sedge/mountain snowberry*	330	160
334	PSME/CAGE2/PIPO	*Douglas-fir/Geyer's sedge/ponderosa pine*	330	200
340	PSME/SPBE2	*Douglas-fir/white spirea*	330	160
341	PSME/SPBE2-SPBE2	*Douglas-fir/white spirea-white spirea*	330	180
343	PSME/SPBE2-CARU	*Douglas-fir/white spirea-pinegrass*	330	160
344	PSME/SPBE2/PIPO	*Douglas-fir/white spirea/ponderosa pine*	330	200
360	PSME/JUCO6	*Douglas-fir/common juniper*	330	200
370	PSME/ARCO9	*Douglas-fir/heartleaf arnica*	330	200
371	PSME/ARCO9-ARCO9	*Douglas-fir/heartleaf arnica-heartleaf arnica*	330	200
372	PSME/ARCO9-ASMI9	*Douglas-fir/heartleaf arnica/timber milkvetch*	330	160
375	PSME/OSBE	*Douglas-fir/sweetcicely*	330	225
380	PSME/SYOR2	*Douglas-fir/mountain snowberry*	330	160
385	PSME/CELE3	*Douglas-fir/curl-leaf mountain mahogany*	330	160
390	PSME/ACGL	*Douglas-fir/Rocky Mountain maple*	330	170
392	PSME/ACGL/SYOR2	*Douglas-fir/Rocky Mountain maple-mountain snowberry*	330	170
393	PSME/ACGL-ACGL	*Douglas-fir/Rocky Mountain maple-Rocky Mountain maple*	330	215
395	PSME/MARE11	*Douglas-fir/creeping barberry*	330	210
396	PSME/MARE11-MARE11	*Douglas-fir/creeping barberry-creeping barberry*	330	225

Habitat Code	Abbreviation	Habitat Type Name	Original Habitat Type	BAMAX
397	PSME/MARE11-SYOR2	*Douglas-fir/creeping barberry-mountain snowberry*	330	210
398	PSME/MARE11-CAGE2	*Douglas-fir/creeping barberry-Geyer's sedge*	330	220
400	PIEN	*Engelmann spruce series*	330	300
410	PIEN/EQAR	*Engelmann spruce/field horsetail*	330	225
440	PIEN/GATR3	*Engelmann spruce/fragrant bedstraw*	420	350
490	PIEN/CADI6	*Engelmann spruce/softleaf sedge*	470	280
493	PIEN/HYRE70	*Engelmann spruce/revolute hypnum moss*	470	225
500	ABGR	*grand fir series*	510	280
505	ABGR/SPBE2	*grand fir/white spirea*	510	342
510	ABGR/XETE	*grand fir/common beargrass*	510	200
511	ABGR/COOC	*grand fir/Idaho goldthread*	510	230
515	ABGR/VAME	*grand fir/thinleaf huckleberry*	510	282
520	ABGR/CLUN2	*grand fir/bride's bonnet*	510	350
525	ABGR/ACGL	*grand fir/Rocky Mountain maple*	520	280
526	ABGR/ACGL-ACGL	*grand fir/Rocky Mountain maple-Rocky Mountain maple*	520	300
527	ABGR/ACGL-PHMA5	*grand fir/Rocky Mountain maple-mallow ninebark*	520	280
580	ABGR/VACA13	*grand fir/dwarf bilberry*	570	150
585	ABGR/CARU	*grand fir/pinegrass*	570	253
590	ABGR/LIBO3	*grand fir/twinflower*	570	242
591	ABGR/LIBO3-LIBO3	*grand fir/twinflower-twinflower*	570	242
592	ABGR/LIBO3-XETE	*grand fir/twinflower-common beargrass*	570	250
593	ABGR/LIBO3-VAME	*grand fir/twinflower/thinleaf huckleberry*	570	275
600	ABLA	*subalpine fir series*	610	225
605	ABLA/CALEH2	*subalpine fir/Howell's marsh marigold*	610	300
620	ABLA/CLUN2	*subalpine fir/bride's bonnet*	620	220
621	ABLA/CLUN2-CLUN2	*subalpine fir/bride's bonnet-bride's bonnet*	620	270
625	ABLA/CLUN2/MEFE	*subalpine fir/bride's bonnet/rusty menziesia*	620	220
635	ABLA/STAM2	*subalpine fir/claspleaf twistedstalk*	620	225
636	ABLA/STAM2-STAM2	*subalpine fir/claspleaf twistedstalk-claspleaf twistedstalk*	620	225
637	ABLA/STAM2-LICA2	*subalpine fir/claspleaf twistedstalk-*	620	250

Habitat Code	Abbreviation	Habitat Type Name	Original Habitat Type	BAMAX
		Canby's licorice-root		
638	ABLA/COOC	*subalpine fir/Idaho goldthread*	620	250
640	ABLA/VACA13	*subalpine fir/dwarf bilberry*	640	150
645	ABLA/ACGL	*subalpine fir/Rocky Mountain maple*	640	230
650	ABLA/CACA4	*subalpine fir/bluejoint*	640	140
651	ABLA/CACA4-CACA4	*subalpine fir/bluejoint-bluejoint*	640	175
652	ABLA/CACA4/LICA2	*subalpine fir/bluejoint/Canby's licorice-root*	640	240
654	ABLA/CACA4/VACA3	*subalpine fir/bluejoint/dwarf bilberry*	640	140
655	ABLA/CACA4/LEGL	*subalpine fir/bluejoint/western Labrador tea*	640	210
660	ABLA/LIBO3	*subalpine fir/twinflower*	660	200
661	ABLA/LIBO3-LIBO3	*subalpine fir/twinflower-twinflower*	660	250
662	ABLA/LIBO3/XETE	*subalpine fir/twinflower-common beargrass*	660	230
663	ABLA/LIBO3/VASC	*subalpine fir/twinflower/grouse whortleberry*	660	200
670	ABLA/MEFE	*subalpine fir/rusty menziesia*	670	170
671	ABLA/MEFE-MEFE	*subalpine fir/rusty menziesia-rusty menziesia*	670	200
672	ABLA/MEFE/LUGLH	*subalpine fir/rusty menziesia/Hitchcock's smooth woodrush*	670	170
690	ABLA/XETE	*subalpine fir/common beargrass*	680	160
691	ABLA/XETE/VAME	*subalpine fir/common beargrass/thinleaf huckleberry*	680	230
692	ABLA/XETE/VASC	*subalpine fir/common beargrass/grouse whortleberry*	680	220
694	ABLA/LUGLH	*subalpine fir/common beargrass/Hitchcock's smooth woodrush*	690	160
700	TSME	*Mountain hemlock*	690	200
705	ABLA/SPBE2	*subalpine fir/white spirea*	710	200
720	ABLA/VAME	*subalpine fir/thinleaf huckleberry*	710	180
721	ABLA/VAME/VASC	*subalpine fir/thinleaf huckleberry/grouse whortleberry*	720	180
723	ABLA/VAME-VAME	*subalpine fir/thinleaf huckleberry-thinleaf huckleberry*	720	190

Habitat Code	Abbreviation	Habitat Type Name	Original Habitat Type	BAMAX
730	ABLA/VASC	*subalpine fir/grouse whortleberry*	730	120
731	ABLA/VASC/CARU	*subalpine fir/grouse whortleberry/pinegrass*	730	140
732	ABLA/VASC-VASC	*subalpine fir/grouse whortleberry-grouse whortleberry*	730	156
734	ABLA/VASC/PIAL	*subalpine fir/grouse whortleberry/whitebark pine*	730	120
740	ABLA/ALVIS	*subalpine fir/Sitka alder*	730	210
745	ABLA/JUCO6	*subalpine fir/common juniper*	730	140
750	ABLA/CARU	*subalpine fir/pinegrass*	730	160
780	ABLA/ARCO9	*subalpine fir/heartleaf arnica*	730	214
790	ABLA/CAGE2	*subalpine fir/Geyer's sedge*	730	130
791	ABLA/CAGE2-CAGE2	*subalpine fir/Geyer's sedge-Geyer's sedge*	730	154
793	ABLA/CAGE2/ARTR2	*subalpine fir/Geyer's sedge/big sagebrush*	730	120
810	ABLA/RIMO2	*subalpine fir/gooseberry currant*	830	300
830	ABLA/LUGLH	*subalpine fir/Hitchcock's smooth woodrush*	830	130
831	ABLA/LUGLH-VASC	*subalpine fir/Hitchcock's smooth woodrush/grouse whortleberry*	830	130
833	ABLA/LUGLH-LUGLH	*subalpine fir/Hitchcock's smooth woodrush-Hitchcock's smooth woodrush*	830	200
850	PIAL-ABLA	*whitebark pine-subalpine fir*	850	100
870	PIAL	*whitebark pine series*	850	75
900	PICO	*lodgepole pine series*	850	100
905	PICO-FEID	*lodgepole pine/Idaho fescue*	850	100
920	PICO/VACA3	*lodgepole pine/dwarf bilberry*	850	110
940	PICO/VASC	*lodgepole pine/grouse whortleberry*	850	150
955	PIPO/CAGE	*lodgepole pine/Geyer's sedge*	850	150
999	OTHER		999	150

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