Forest Service
U.S. DEPARTMENT OF AGRICULTURE

ORGANON Pacific Northwest (OP) Variant Overview of the Forest Vegetation Simulator

December 2022

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The FVS staff has maintained model documentation for this variant in the form of a variant overview since its release in July 2015.

Smith-Mateja, Erin, comp. 2015 (revised December 22, 2022). ORGANON Pacific Northwest (OP) Variant Overview – Forest Vegetation Simulator. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 84p.

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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	5 years	
Location Code (National Forest)	708 – BLM Salem ADU	
Plant Association Code	40 (CHS133 TSHE/GASH VAOV2)	
Slope	5 percent	
Aspect	0 (no meaningful aspect)	
Elevation	7 (700 feet)	
Latitude / Longitude	Latitude	Longitude
All location codes	46	123
Site Species	Plant Association Code specific	
Site Index	Plant Association Code specific	
Maximum Stand Density Index	Plant Association Code specific	
Maximum Basal Area	Based on maximum stand density index for site species	
Volume Equations	National Volume Estimator Library	
Merchantable Cubic Foot Volume Specifications:		
Minimum DBH / Top Diameter	LP	All Other
708 – BLM Salem; 709 – BLM Eugene; 712 – BLM Coos Bay	7.0 / 5.0 inches	7.0 / 5.0 inches
All other location codes	6.0 / 4.5 inches	7.0 / 4.5 inches
Stump Height	1.0 foot	1.0 foot
Merchantable Board Foot Volume Specifications:		
Minimum DBH / Top Diameter	LP	All Other
708 – BLM Salem; 709 BLM Eugene; 712 – BLM Coos Bay	7.0 / 5.0 inches	7.0 / 5.0 inches
All other location codes	6.0 / 4.5 inches	7.0 / 4.5 inches
Stump Height	1.0 foot	1.0 foot
Sampling Design:		
Basal Area Factor	40 BAF	
Small-Tree Fixed Area Plot	1/300th Acre	
Breakpoint DBH	5.0 inches	

1.0 Introduction

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

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

The OP variant uses the ORGANON Northwest Oregon or Stand Management Cooperative growth equations embedded into the existing PN variant code framework. The ORGANON model was developed by David Hann PhD, his graduate students, and cooperators at Oregon State University. Like FVS, ORGANON is also an individual tree distance independent model.

Using the PN variant framework allows for extensions which are part of the PN variant to be available in the OP variant. These include the Fire and Fuels, regeneration establishment, event monitor, climate, and dwarf mistletoe extensions.

The OP variant is limited to a maximum of 2000 individual tree records.

For background on the development of the ORGANON model users should consult the ORGANON web site:

- http://www.cof.orst.edu/cof/fr/research/organon/

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.

1.1 FVS-Organon

ORGANON recognizes less species codes than FVS and has minimum size restrictions. FVS can accommodate trees of any size including seedlings. So an FVS simulation file representing a stand may contain tree records that cannot be directly handled within the ORGANON code.

The Northwest Oregon (NWO) and Stand Management Cooperative (SMC) versions of ORGANON recognizes 11 species found in western Oregon or Washington, or southwestern British Columbia. Trees must be greater than 4.5 feet tall and 0.09" in diameter-at-breast-height. Tree records with parameters meeting these species and size requirements will be referred to as valid ORGANON tree records in the remainder of this document; all others will be referred to as non-valid ORGANON tree records. Valid ORGANON tree records get their growth and mortality estimates using ORGANON equations; non-valid ORGANON tree records get their growth and mortality estimates using FVS PN variant equations.

Of the 11 species recognized in NWO and SMC, two species are designated as “the big 6”. These are grand fir and Douglas-fir. At least one of these species must be in the stand for the ORGANON growth routines to run. In FVS, if one of these species is not present, then all tree records are designated as non-valid ORGANON tree records and will get their growth and mortality estimates from FVS PN variant equations.

The OP variant recognizes 38 individual species or species groups (see section 3.2 and table 3.2.1). When the ORGANON growth routines are being called, all tree records get passed into the ORGANON growth routines so stand density measures are correct in the ORGANON growth and mortality equations. This is done by making sure all non-valid ORGANON tree records have temporarily assigned to them a valid ORGANON species code and the tree diameter and height meet the minimum ORGANON requirements. This species mapping is shown in table 1.1.1. If tree height is less than or equal to 4.5’ it is temporarily set to 4.6’; if tree diameter is less than or equal to 0.09” it is temporarily set to 0.1”.

Table 1.1.1 Species code mapping used in the OP variant when calling ORGANON growth routines.

Valid NWO/SMC ORGANON Species Code	OP Variant FVS Alpha Code*	OP Variant FVS Alpha Codes* mapped to the valid ORGANON Species Code
017	GF	GF, WF, SF, AF, NF, LL
202	DF	DF, RF, SS, ES, LP, JP, SP, WP, PP, WB, KP
231	PY	PY, WJ
242	RC	RC, YC, IC
263	WH	WH, RW, MH
312	BM	BM, TO, AS, CW
351	RA	RA
361	MA	MA, GC
492	DG	DG, HT, CH, OT
815	WO	WO
920	WI	WI

*See table 3.2.1 for alpha code definitions

The intent of this variant is to give users access to the ORGANON growth model growth prediction equations and the functionality of FVS. ORGANON model code is called from two places within the FVS code and performs two different tasks just as it does when running ORGANON separately.

The first call is to edit the input data, estimate missing values such as tree height and crown ratio, and calibrate growth equations to the input data. This only happens at most one time when a tree input file is provided which contains valid ORGANON tree records (discussed in the next paragraph). In cases such as a bare ground plant management scenario, or when the tree input file does not contain valid ORGANON tree records, or when the provided tree input file has already been through the ORGANON edit process (i.e. an existing ORGANON .INP file), it won't happen at all. Any errors in the input data will be noted in the main FVS output file so users can correct them and rerun the simulation at their discretion.

The second call is made to the ORGANON model code to estimate tree growth and mortality. This happens every growth projection cycle when there are valid ORGANON tree records in the run. Estimates include large tree diameter growth, height growth, and crown ratio change, and tree mortality.

2.0 Geographic Range

The ORGANON Northwest Oregon version was built with data from Douglas-fir and Western Hemlock dominated stands collected from 179 stands in Northwestern Oregon. The Stand Management Cooperative version data came from 3,359 plots, which range from southwest British Columbia, western Washington and western Oregon stands dominated with Douglas-fir and Western Hemlock. The PN variant was fit to data representing forest types in the Coast Range and Olympic Peninsula physiographic provinces. Data used in initial model development came from forest inventories, managed stand surveys. Forest inventories came from US. Forest Service Siuslaw and Olympic National Forests, BLM – Oregon, and BIA – Quinault Indian Reservation.

The OP variant covers forest types on the coast of the Pacific Northwest states of Washington and Oregon. The suggested geographic range of use for the OP variant is shown in figure 2.0.1. The light green covering the Stand Management Cooperative version and dark green the Northwest Oregon version.

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

3.0 Control Variables

FVS users need to specify certain variables used by the OP 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 OP variant, a default forest code of 708 (BLM Salem ADU) will be used. Location codes recognized in the OP variant are shown in tables 3.1.1 and 3.1.2.

Table 3.1.1 Location codes used in the OP variant.

Location Code	Location
609	Olympic National Forest
612	Siuslaw National Forest
708	BLM Salem Admin Unit
709	BLM Eugene Admin Unit
712	BLM Coos Bay Admin Unit
800	Quinault Indian Reservation

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

Location Code	Location
8101	Grand Ronde Community (mapped to 612)
8102	Siletz Reservation (mapped to 612)
8103	Coos, Lower Umpqua, Siuslaw Off-Res. Trust Land (mapped to 612)
8104	Cow Creek Reservation (mapped to 712)
8105	Coquille Reservation (mapped to 712)
8110	Chehalis Reservation (mapped to 609)
8111	Hoh Indian Reservation (mapped to 609)
8113	Shoalwater Bay Indian Reservation (mapped to 609)
8114	Skokomish Reservation (mapped to 609)
8115	Squaxin Island Reservation (mapped to 609)
8116	Lower Elwha Off-Res. Trust Land (mapped to 609)
8119	Lummi Reservation (mapped to 609)
8120	Muckleshoot Reservation (mapped to 609)
8121	Nisqually Reservation (mapped to 609)
8122	Port Gamble Reservation (mapped to 609)

Location Code	Location
8123	Port Madison Reservation (mapped to 609)
8125	Swinomish Reservation (mapped to 609)
8126	Tulalip Reservation (mapped to 609)
8127	Upper Skagit Reservation (mapped to 609)
8128	Samish Tdsa (mapped to 609)
8129	Snoqualmie Reservation (mapped to 609)

3.2 Species Codes

The OP variant recognizes 37 species, plus one other composite species category. 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 OP 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 OP variant.

Species Number	Species Code	FIA Code	PLANTS Symbol	Scientific Name[1]	Common Name[1]
1	SF	011	ABAM	*Abies amabilis*	Pacific silver fir
2	WF	015	ABCO	*Abies concolor*	white fir
3	GF	017	ABGR	*Abies grandis*	grand fir
4	AF	019	ABLA	*Abies lasiocarpa*	subalpine fir
5	RF	020	ABMA	*Abies magnifica*	California red fir
6	SS	098	PISI	*Picea sitchensis*	Sitka spruce
7	NF	022	ABPR	*Abies procera*	noble fir
8	YC	042	CANO9	*Callitropsis nootkatensis*	Alaska cedar
9	IC	081	CADE27	*Calocedrus decurrens*	incense cedar
10	ES	093	PIEN	*Picea engelmannii*	Engelmann spruce
11	LP	108	PICO	*Pinus contorta*	lodgepole pine
12	JP	116	PIJE	*Pinus jeffreyi*	Jeffrey pine
13	SP	117	PILA	*Pinus lambertiana*	sugar pine
14	WP	119	PIMO3	*Pinus monticola*	western white pine

Species Number	Species Code	FIA Code	PLANTS Symbol	Scientific Name[1]	Common Name[1]
15	PP	122	PIPO	*Pinus ponderosa*	ponderosa pine
16	DF	202	PSME	*Pseudotsuga menziesii*	Douglas-fir
17	RW	211	SESE3	*Sequoia sempervirens*	redwood
18	RC	242	THPL	*Thuja plicata*	western redcedar
19	WH	263	TSHE	*Tsuga heterophylla*	western hemlock
20	MH	264	TSME	*Tsuga mertensiana*	mountain hemlock
21	BM	312	ACMA3	*Acer macrophyllum*	bigleaf maple
22	RA	351	ALRU2	*Alnus rubra*	red alder
23	MA	361	ARME	*Arbutus menziesii*	Pacific madrone
24	TO	631	LIDE3	*Lithocarpus densiflorus*	tanoak
25	GC	431	CHCHC4	*Chrysolepis chrysophylla* var. *chrysophylla*	giant chinquapin
26	AS	746	POTR5	*Populus tremuloides*	quaking aspen
27	CW	747	POBAT	*Populus balsamifera* ssp. *trichocarpa*	black cottonwood
28	WO	815	QUGA4	*Quercus garryana*	Oregon white oak
29	WJ	064	JUOC	*Juniperus occidentalis*	western juniper
30	LL	072	LALY	*Larix lyallii*	subalpine larch
31	WB	101	PIAL	*Pinus albicaulis*	whitebark pine
32	KP	103	PIAT	*Pinus attenuata*	knobcone pine
33	PY	231	TABR2	*Taxus brevifolia*	Pacific yew
34	DG	492	CONU4	*Cornus nuttallii*	Pacific dogwood
35	HT	500	CRATA	*Crataegus*	hawthorn
36	CH	768	PREM	*Prunus emarginata*	bitter cherry
37	WI	920	SALIX	*Salix*	willow
39	OT	999	2TREE		other[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

Plant association codes recognized in the OP variant are shown in Appendix B. If an incorrect plant association code is entered or no code is entered FVS will use the default plant association code, which is 40 (CHS133 TSHE/GASH-VAOV2). Plant association codes are used to set default site information such as site species, site indices, and maximum stand density indices. The site species, site index and maximum stand density indices can be reset via FVS keywords. Users may enter the plant association code or the plant association FVS sequence number on the STDINFO keyword, when entering stand information from a database, or when using the SETSITE keyword without the PARMS option. If using the PARMS option with the SETSITE keyword, users must use the FVS sequence number for the plant association.

3.4 Site Index

Site index is used in some of the growth equations in the OP variant. Users should always use the same site curves that FVS uses as shown in table 3.4.1.

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

Species Code	Reference	BHA or TTA[1]	Base Age
SF	Hoyer and Herman (1989)	BHA	100
GF, WF	Cochran (1979)	BHA	50
AF, ES	Alexander (1967)	BHA	100
RF	Dolph (1991)	BHA	50
SS, RC	Farr (1984)	BHA	50
NF	Herman et al. (1978)	BHA	100
LP	Dahms (1964)	TTA	50
WP, SP	Curtis et al. (1990)	BHA	100
PP, IC, JP	Barrett (1978)	BHA	100
DF	King (1966)	BHA	50
WH	Flewelling (unpublished)	BHA	50
MH	Means et al. (1986)[2]	BHA	100
RA	Harrington and Curtis (1986)	TTA	20
LL	Cochran (1985)	BHA	50
Other[3]	Curtis et al. (1974)	BHA	100
RW[4]	Krumland and Eng (2005)	BHA	50

[1] Equation is based on total tree age (TTA) or breast height age (BHA)
[2] The source equation is in metric units; site index values for mountain hemlock are assumed to be in meters.
[3] Other includes all the following species: Alaska cedar, redwood, bigleaf maple, Pacific madrone, tanoak, giant chinquapin, quaking aspen, black cottonwood, western juniper, whitebark pine, knobcone pine, Pacific yew, Pacific dogwood, hawthorn, bitter cherry, and willow.
[4] Equation form is presented on page 34 and coefficients are provided on page 68

If site index is missing or incorrect, the default site species and site index are determined by plant association codes found in Appendix B. If the plant association code is missing or incorrect, the site species is set to Douglas-fir with a default site index set to 100.

In the OP variant, if site index is provided for Douglas-fir but not for western hemlock, then western hemlock site index is estimated from the Douglas-fir site index using equation {3.4.1}; if site index is provided for western hemlock but not for Douglas-fir, then Douglas-fir site index is estimated from ponderosa pine site index using equation {3.4.2}.

{3.4.1} WHSI = -0.432 + (0.899 * DFSI)

{3.4.2} DFSI = 0.480 + (1.110 * WHSI)

where:

WHSI is site index for western hemlock
DFSI is site index for Douglas-fir

Site indices for species not assigned a site index are determined based on the site index of the site species (height at base age) with an adjustment for the reference age differences between the site species and the target species. For species that use the Curtis et al. (1974) equation, the site index estimate is adjusted by multiplying the site index estimate by an adjustment factor in table 3.4.2, if the species is not listed as the site species. Similarly, for Oregon white oak, which does not have a site curve, an adjustment is made from the site species entered to a King (1966) site index which is then adjusted for Oregon white oak using equation {3.4.3} from Gould and Harrington (2009).

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

Species	Base Age
BM	0.75
MA	0.65
TO	0.70
GC	0.70
AS	0.75
CW	0.85
WJ	0.23
WB	0.70
PY	0.25
DG	0.60
HT	0.25
CH	0.50
WI	0.50

{3.4.3} $MaxHT = 114.24569[1-\exp(-.02659*SI_{King})]^{\wedge}2.25993$

where:

MaxHT maximum height obtained by Oregon white oak (Gould and Harrington, 2009)
SI_{King} Site Index based on King (1966)

3.5 Maximum Density

Maximum stand density index can be set for each species using the SDIMAX or SETSITE keywords. If not set by the user, a default value is assigned as discussed below.

The default maximum SDI is set based on a user-specified, or default, plant association code. The SDI maximum for all species is assigned from the SDI maximum associated with the site species for the plant association code shown in Appendix A. SDI maximums were set based on growth basal area (GBA) analysis developed by Hall (1983) or an analysis of Current Vegetation Survey (CVS) plots in USFS Region 6 by Crookston (2008). Some SDI maximums associated with plant associations are unreasonably large, so SDI maximums are capped at 950. Maximum stand density index at the stand level is a weighted average, by basal area, of the individual species SDI maximums.

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 OP variant, FVS will dub in heights by one of three methods. By default non-valid ORGANON tree records will use the Curtis-Arney functional form as shown in equation {4.1.1} (Curtis 1967, Arney 1985). If the input data contains at least three measured heights for a species, then FVS can use a logistic height-diameter equation {4.1.2} (Wykoff, et.al 1982) that may be calibrated to the input data. In the OP variant, this doesn't happen by default, but can be turned on with the NOHTREG keyword by entering "1" in field 2. Coefficients for all height-diameter equations are given in tables 4.1.1 and 4.1.2.

{4.1.1} Curtis-Arney functional form

$DBH \geq 3.0''$: $HT = 4.5 + P_2 * \exp[-P_3 * DBH^{\wedge}P_4]$
$DBH < 3.0''$: $HT = [(4.5 + P_2 * \exp[-P_3 * 3.0^{\wedge}P_4] - 4.51) * (DBH - 0.3) / 2.7] + 4.51$
For Douglas-fir at locations 612, 708, and 712 where $DBH < 0.09''$: $HT = [(4.5 + P_2 * \exp[-P_3 * 5.0^{\wedge}P_4] - 4.51) * (DBH - 0.3) / 4.7] + 4.51$

{4.1.2} Wykoff functional form

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

All valid ORGANON tree records use equation {4.1.3}. If equation {4.1.2} is being used for non-valid ORGANON tree records then heights estimated for valid ORGANON tree records are used along with measured tree heights in calibrating equation {4.1.2} to better align equation {4.1.2} with the equation ORGANON is using.

{4.1.3} ORGANON

$HT = 4.5+\exp(X_1+X_2*DBH**X_3)$

{4.1.4} Other functional form

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

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

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

$DBH < 5.0''$: $HT = H_1 + (H_2 * DBH) + (H_3 * CR) + (H_4 * DBH^{\wedge}2) + H_5$

Species: 15

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

Species: 6

DBH ≥ 100.0”: *HT* = 248 + (0.25 * *DBH*)

where:

HT	is tree height
DBH	is tree diameter at breast height
CR	is crown ratio expressed in percent
CRC	is crown ratio code (CRC=6)
B_1 - B_2	are species-specific coefficients shown in table 4.1.3
P_2 - P_4	are species and location specific coefficients shown in table 4.1.1
X_1 - X_3	are species-specific coefficients shown in table 4.1.2
H_1 - H_5	are species-specific coefficients shown in table 4.1.3

Table 4.1.1 Coefficients for equation {4.1.1} in the PN variant.

Species Code	Coefficient	609 - Olympic, 800 - Quinalt	612 – Siuslaw, 712 – BLM Coos	708 – BLM Salem	709 – BLM Eugene
SF	P_2	697.6316	697.6316	223.3492	237.9189
	P_3	6.6807	6.6807	6.3964	7.7948
	P_4	-0.4161	-0.4161	-0.6566	-0.7261
WF	P_2	604.845	604.845	475.1698	475.1698
	P_3	5.9835	5.9835	6.2472	6.2472
	P_4	-0.3789	-0.3789	-0.4812	-0.4812
GF	P_2	356.1148	432.2186	432.2186	432.2186
	P_3	6.41	6.2941	6.2941	6.2941
	P_4	-0.5572	-0.5028	-0.5028	-0.5028
AF	P_2	89.0298	133.8689	290.5142	133.8689
	P_3	6.9507	6.7798	6.4143	6.7798
	P_4	-0.9871	-0.7375	-0.4724	-0.7375
RF	P_2	202.886	202.886	375.382	375.382
	P_3	8.7469	8.7469	6.088	6.088
	P_4	-0.8317	-0.8317	-0.472	-0.472
SS	P_2	3844.388	708.7788	375.382	375.382
	P_3	7.068	5.7677	6.088	6.088
	P_4	-0.2122	-0.3629	-0.472	-0.472
NF	P_2	483.3751	483.3751	247.7348	483.3751
	P_3	7.2443	7.2443	6.183	7.2443
	P_4	-0.5111	-0.5111	-0.6335	-0.5111
YC	P_2	1220.096	1220.096	255.4638	97.7769
	P_3	7.2995	7.2995	5.5577	8.8202
	P_4	-0.3211	-0.3211	-0.6054	-1.0534
IC	P_2	4691.634	4691.634	4691.634	4691.634

Species Code	Coefficient	609 - Olympic, 800 - Quinalt	612 – Siuslaw, 712 – BLM Coos	708 – BLM Salem	709 – BLM Eugene
	P_3	7.4671	7.4671	7.4671	7.4671
	P_4	-0.1989	-0.1989	-0.1989	-0.1989
ES	P_2	206.3211	206.3211	206.3211	206.3211
	P_3	9.1227	9.1227	9.1227	9.1277
	P_4	-0.8281	-0.8281	-0.8281	-0.8281
LP	P_2	100	100	139.7159	105.4453
	P_3	6	6	4.0091	7.9694
	P_4	-0.86	-0.86	-0.708	-1.0916
JP	P_2	1031.52	1031.52	1031.52	1031.52
	P_3	7.6616	7.6616	7.6616	7.6616
	P_4	-0.3599	-0.3599	-0.3599	-0.3599
SP	P_2	702.1856	702.1856	702.1856	702.1856
	P_3	5.7025	5.7025	5.7025	5.7025
	P_4	-0.3798	-0.3798	-0.3798	-0.3798
WP	P_2	433.7807	514.1575	1333.818	514.1575
	P_3	6.3318	6.3004	6.6219	6.3004
	P_4	-0.4988	-0.4651	-0.312	-0.4651
PP	P_2	1181.724	1181.724	1181.724	1181.724
	P_3	6.6981	6.6981	6.6981	6.6981
	P_4	-0.3151	-0.3151	-0.3151	-0.3151
DF	P_2	1091.853	407.1595	949.1046	439.1195
	P_3	5.2936	7.2885	5.8482	5.8176
	P_4	-0.2648	-0.5908	-0.3251	-0.4854
RW	P_2	595.1068	595.1068	595.1068	595.1068
	P_3	5.8103	5.8103	5.8103	5.8103
	P_4	-0.3821	-0.3821	-0.3821	-0.3821
RC	P_2	665.0944	227.14	1560.685	1012.127
	P_3	5.5002	6.1092	6.2328	6.0957
	P_4	-0.3246	-0.6009	-0.2541	-0.3083
WH	P_2	609.4235	1196.619	317.8257	395.4976
	P_3	5.5919	5.7904	6.8287	6.4222
	P_4	-0.3841	-0.2906	-0.6034	-0.532
MH	P_2	170.2653	170.2653	2478.099	192.9609
	P_3	10.0684	10.0684	7.0762	7.3876
	P_4	-0.8791	-0.8791	-0.2456	-0.7231
BM	P_2	600.0957	92.2964	76.517	160.2171
	P_3	3.8297	4.189	2.2107	3.3044
	P_4	-0.238	-0.983	-0.6365	-0.5299
RA	P_2	139.4551	254.9634	484.4591	10099.72
	P_3	4.6989	3.8495	4.5713	7.6375

Species Code	Coefficient	609 - Olympic, 800 - Quinalt	612 – Siuslaw, 712 – BLM Coos	708 – BLM Salem	709 – BLM Eugene
	P_4	-0.7682	-0.4149	-0.3643	-0.1621
MA	P_2	139.4551	254.8634	133.7965	133.7965
	P_3	4.6989	3.8495	6.405	6.405
	P_4	-0.7682	-0.4149	-0.8329	-0.8329
TO	P_2	1709.723	1709.723	1709.723	1709.723
	P_3	5.8887	5.8887	5.8887	5.8887
	P_4	-0.2286	-0.2286	-0.2286	-0.2286
GC	P_2	10707.39	10707.39	10707.39	10707.39
	P_3	8.467	8.467	8.467	8.467
	P_4	-0.1863	-0.1863	-0.1863	-0.1863
AS	P_2	1709.723	1709.723	1709.723	1709.723
	P_3	5.8887	5.8887	5.8887	5.8887
	P_4	-0.2286	-0.2286	-0.2286	-0.2286
CW	P_2	178.6441	178.6441	178.6441	178.6441
	P_3	4.5852	4.5852	4.5852	4.5852
	P_4	-0.6746	-0.6746	-0.6746	-0.6746
WO	P_2	89.4301	89.4301	59.4214	55
	P_3	6.6321	6.6321	5.3178	5.5
	P_4	-0.8876	-0.8876	-1.367	-0.95
WJ	P_2	503.6619	503.6619	503.6619	503.6619
	P_3	4.9544	4.9544	4.9544	4.9544
	P_4	-0.2085	-0.2085	-0.2085	-0.2085
LL	P_2	503.6619	503.6619	503.6619	503.6619
	P_3	4.9544	4.9544	4.9544	4.9544
	P_4	-0.2085	-0.2085	-0.2085	-0.2085
WB	P_2	89.5535	89.5535	73.9147	73.9147
	P_3	4.2281	4.2281	3.963	3.963
	P_4	-0.6438	-0.6438	-0.8277	-0.8277
KP	P_2	34749.47	34749.47	34749.47	34749.47
	P_3	9.1287	9.1287	9.1287	9.1287
	P_4	-0.1417	-0.1417	-0.1417	-0.1417
PY	P_2	127.1698	139.0727	77.2207	139.0727
	P_3	4.8977	5.2062	3.5181	5.2062
	P_4	-0.4668	-0.5409	-0.5894	-0.5409
DG	P_2	403.3221	403.3221	403.3221	444.5618
	P_3	4.3271	4.3271	4.3271	3.9205
	P_4	-0.2422	-0.2422	-0.2422	-0.2397
HT	P_2	55	55	55	55
	P_3	5.5	5.5	5.5	5.5
	P_4	-0.95	-0.95	-0.95	-0.95

Species Code	Coefficient	609 - Olympic, 800 - Quinalt	612 – Siuslaw, 712 – BLM Coos	708 – BLM Salem	709 – BLM Eugene
CH	P_2	73.3348	73.3348	73.3348	73.3348
	P_3	2.6548	2.6548	2.6548	2.6548
	P_4	-1.246	-1.246	-1.246	-1.246
WI	P_2	149.5861	149.5861	149.5861	149.5861
	P_3	2.4231	2.4231	2.4231	2.4231
	P_4	-0.18	-0.18	-0.18	-0.18
OT	P_2	1709.723	1709.723	1709.723	1709.723
	P_3	5.8887	5.8887	5.8887	5.8887
	P_4	-0.2286	-0.2286	-0.2286	-0.2286

Table 4.1.2 Coefficients for equations {4.1.2} in the OP variant.

Species Code	NWO X_1	NWO X_2	NWO X_3	SMC X_1	SMC X_2	SMC X_3
DF	7.04524	-5.16836	-0.25387	7.262195	-5.89976	-0.28721
GF	7.42808	-5.80832	-0.24032	7.42808	-5.80832	-0.24032
WH	5.93792	-4.43822	-0.41137	6.555345	-5.13717	-0.36455
RC	6.148174	-5.40093	-0.38922	6.148174	-5.40093	-0.38922
PY	9.30172	-7.50951	-0.1	9.30172	-7.50951	-0.1
MA	5.84487	-3.84795	-0.28921	5.84487	-3.84795	-0.28921
BM	5.21462	-2.70252	-0.35476	5.21462	-2.70252	-0.35476
WO	4.697531	-3.51587	-0.57665	4.697531	-3.51587	-0.57665
RA	5.597591	-3.19943	-0.38783	5.597591	-3.19943	-0.38783
PD	4.49727	-2.07667	-0.38865	4.49727	-2.07667	-0.38865
WI	4.88361	-2.47605	-0.30905	4.88361	-2.47605	-0.30905

Table 4.1.2 Coefficients for equations {4.1.3} – {4.1.4} in the OP variant.

Species Code	Default B_1	B_2	H_1	H_2	H_3	H_4	H_5
SF	5.487	-16.701	1.3134	0.3432	0.0366	0	0
WF	5.308	-13.624	1.4769	0.3579	0	0	0
GF	5.308	-13.624	1.4769	0.3579	0	0	0

Species Code	Default B_1	B_2	H_1	H_2	H_3	H_4	H_5
AF	5.313	-15.321	1.4261	0.3334	0	0	0
RF	5.313	-15.321	1.3526	0.3335	0.0367	0	0
SS	5.517	-17.944	1.3526	0.3335	0.0367	0	0
NF	5.327	-15.450	1.7100	0.2943	0	0	0.1054
YC	5.143	-13.497	1.5907	0.3040	0	0	0
IC	5.188	-13.801	1.5907	0.3040	0	0	0
ES	5.188	-13.801	1.5907	0.3040	0	0	0
LP	4.865	-9.305	0.9717	0.3934	0.0339	0	0.3044
JP	5.333	-17.762	1.0756	0.4369	0	0	0
SP	5.382	-15.866	0.9717	0.3934	0.0339	0	0.3044
WP	5.382	-15.866	0.9717	0.3934	0.0339	0	0.3044
PP	5.333	-17.762	1.0756	0.4369	0	0	0
DF	5.563	-16.475	7.1391	4.2891	-0.7150	0.2750	2.0393
RW	5.3401	-15.9354	1.5907	0.3040	0	0	0
RC	5.233	-14.737	2.3115	0.2370	-0.0556	0	0.3218
WH	5.355	-13.878	1.3608	0.6151	0	-0.0442	0.0829
MH	5.081	-13.430	1.2278	0.4000	0	0	0
BM	4.700	-6.326	0.0994	4.9767	0	0	0
RA	4.875	-8.639	0.0994	4.9767	0	0	0
MA	5.152	-13.576	0.0994	4.9767	0	0	0
TO	5.152	-13.576	0.0994	4.9767	0	0	0
GC	5.152	-13.576	0.0994	4.9767	0	0	0
AS	5.152	-13.576	0.0994	4.9767	0	0	0
CW	5.152	-13.576	0.0994	4.9767	0	0	0
WO	5.152	-13.576	0.0994	4.9767	0	0	0
WJ	5.152	-13.576	0.0994	4.9767	0	0	0
LL	5.188	-13.801	1.5907	0.3040	0	0	0
WB	5.188	-13.801	1.5907	0.3040	0	0	0
KP	5.188	-13.801	1.5907	0.3040	0	0	0
PY	5.188	-13.801	1.5907	0.3040	0	0	0
DG	5.152	-13.576	0.0994	4.9767	0	0	0
HT	5.152	-13.576	0.0994	4.9767	0	0	0
CH	5.152	-13.576	0.0994	4.9767	0	0	0
WI	5.152	-13.576	0.0994	4.9767	0	0	0
OT	5.152	-13.576	0.0994	4.9767	0	0	0

4.2 Bark Ratio Relationships

Bark ratio estimates are used to convert between diameter outside bark and diameter inside bark in various parts of the model. In the OP variant, bark ratio values are determined using estimates from DIB equations. Equations used in the OP variant are shown in {4.2.1} -{4.2.3}. Coefficients (b_1 and b_2) and equation reference for each species are shown in table 4.2.1.

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

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

{4.2.3} $DIB = b_1 * DBH$; $BRATIO = b_1$

where:

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

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

Species Code	b_1	b_2	Equation Used	Equation Source
SF	0.904973	1.0	{4.2.1}	Larsen and Hann, 1985
WF	0.904973	1.0	{4.2.1}	Larsen and Hann, 1985
GF	0.904973	1.0	{4.2.1}	ORGANON Larsen and Hann, 1985
AF	0.904973	1.0	{4.2.1}	Larsen and Hann, 1985
RF	0.904973	1.0	{4.2.1}	Larsen and Hann, 1985
SS	0.958330	1.0	{4.2.1}	Harlow and Harrar, p. 129
NF	0.904973	1.0	{4.2.1}	Larsen and Hann, 1985
YC	0.837291	1.0	{4.2.1}	Larsen and Hann, 1985
IC	0.837291	1.0	{4.2.1}	Larsen and Hann, 1985
ES	0.90	0	{4.2.3}	Wykoff et al, 1982
LP	0.90	0	{4.2.3}	Wykoff et al, 1982
JP	0.859045	1.0	{4.2.1}	Larsen and Hann, 1985
SP	0.859045	1.0	{4.2.1}	Larsen and Hann, 1985
WP	0.859045	1.0	{4.2.1}	Larsen and Hann, 1985
PP	0.809427	1.016866	{4.2.1}	Larsen and Hann, 1985
DF	0.97133	0.966365	{4.2.1}	ORGANON
RW	0.7012	1.04862	{4.2.1}	Castle 2021
RC	0.949670	1.0	{4.2.1}	Wykoff et al, 1982
WH	0.933710	1.0	{4.2.1}	Wykoff et al, 1982
MH	0.949670	1.0	{4.2.1}	Wykoff et al, 1982
BM	0.97059	0.993585	{4.2.1}	ORGANON
RA	0.947	1.0	{4.2.1}	ORGANON
MA	0.96317	1.0	{4.2.1}	ORGANON
TO	0.08360	0.94782	{4.2.2}	Pillsbury and Kirkley, 1984
GC	0.15565	0.90182	{4.2.2}	Pillsbury and Kirkley, 1984
AS	0.075256	0.94373	{4.2.2}	Pil. & Kirk.; Harlow & Harrar
CW	0.075256	0.94373	{4.2.2}	Pil. & Kirk.; Harlow & Harrar
WO	0.878457	1.02393	{4.2.1}	ORGANON

Species Code	b_1	b_2	Equation Used	Equation Source
WJ	0.949670	1.0	{4.2.1}	Wykoff et al, 1982
LL	0.90	0	{4.2.3}	Wykoff et al, 1982
WB	0.933290	1.0	{4.2.1}	Walters et al; Wykoff et al
KP	0.933290	1.0	{4.2.1}	Walters et al; Wykoff et al
PY	0.97	1.0	{4.2.1}	ORGANON
DG	0.94448	0.987517	{4.2.1}	ORGANON
HT	0.075256	0.94373	{4.2.2}	Pil. & Kirk.; Harlow & Harrar
CH	0.075256	0.94373	{4.2.2}	Pil. & Kirk.; Harlow & Harrar
WI	0.94448	0.987517	{4.2.1}	ORGANON
OT	0.90	0	{4.2.3}	Wykoff et al, 1982

4.3 Crown Ratio Relationships

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

4.3.1 Crown Ratio Dubbing

In the OP variant, crown ratios missing in the input data for live and dead trees are predicted using different equations depending on tree size. For all species except redwood, tree records representing dead trees, and tree records representing non-valid ORGANON live trees less than 1.0” in diameter use equations {4.3.1.1} and {4.3.1.2} to compute crown ratio. Equation coefficients are found in table 4.3.1.1.

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

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

where:

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

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

Species Code	R_1	R_2	R_3	SD
SF	8.042774	0.007198	-0.016163	1.3167
WF	8.042774	0.007198	-0.016163	1.3167
GF	8.042774	0.007198	-0.016163	1.3167

Species Code	R_1	R_2	R_3	SD
AF	8.042774	0.007198	-0.016163	1.3167
RF	8.042774	0.007198	-0.016163	1.3167
SS	8.042774	0.007198	-0.016163	1.3167
NF	8.042774	0.007198	-0.016163	1.3167
YC	7.558538	-0.015637	-0.009064	1.9658
IC	7.558538	-0.015637	-0.009064	1.9658
ES	8.042774	0.007198	-0.016163	1.3167
LP	6.489813	-0.029815	-0.009276	2.0426
JP	6.489813	-0.029815	-0.009276	2.0426
SP	6.489813	-0.029815	-0.009276	2.0426
WP	6.489813	-0.029815	-0.009276	2.0426
PP	8.477025	-0.018033	-0.018140	1.3756
DF	8.477025	-0.018033	-0.018140	1.3756
RC	7.558538	-0.015637	-0.009064	1.9658
WH	7.558538	-0.015637	-0.009064	1.9658
MH	5.000000	0.000000	0.000000	0.5
BM	5.000000	0.000000	0.000000	0.5
RA	5.000000	0.000000	0.000000	0.5
MA	5.000000	0.000000	0.000000	0.5
TO	5.000000	0.000000	0.000000	0.5
GC	5.000000	0.000000	0.000000	0.5
AS	5.000000	0.000000	0.000000	0.5
CW	5.000000	0.000000	0.000000	0.5
WO	5.000000	0.000000	0.000000	0.5
WJ	9.000000	0.000000	0.000000	0.5
LL	6.489813	-0.029815	-0.009276	2.0426
WB	6.489813	-0.029815	-0.009276	2.0426
KP	6.489813	-0.029815	-0.009276	2.0426
PY	6.489813	-0.029815	-0.009276	2.0426
DG	5.000000	0.000000	0.000000	0.5
HT	5.000000	0.000000	0.000000	0.5
CH	5.000000	0.000000	0.000000	0.5
WI	5.000000	0.000000	0.000000	0.5
OT	5.000000	0.000000	0.000000	0.5

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

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

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

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

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

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

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

where:

ACR is predicted average stand crown ratio for the species
SDI_{stand} is stand density index of the stand
SDI_{max} is maximum stand density index
A, B, C are parameters of the Weibull crown ratio distribution
X is a tree's crown ratio expressed as a percent / 10
Y is a trees rank in the diameter distribution (1 = smallest; ITRN = largest) divided by the total number of trees (ITRN) multiplied by *SCALE*
SCALE is a density dependent scaling factor (bounded to $0.3 \leq SCALE \leq 1.0$)
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 Species index number used in assigning Weibull parameters in the OP variant.

Species Code	Species Index Number	Species Code	Species Index Number
SF	1	BM	12
WF	2	RA	13
GF	2	MA	14
AF	3	TO	14
RF	3	GC	14
SS	17	AS	14
NF	4	CW	14
YC	15	WO	14
IC	11	WJ	14
ES	11	LL	11

Species Code	Species Index Number
LP	16
JP	6
SP	5
WP	5
PP	6
DF	7
RC	8
WH	9
MH	10

Species Code	Species Index Number
WB	11
KP	11
PY	11
DG	14
HT	14
CH	14
WI	14
OT	14

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

Species Index	a_0	b_0	b_1	c_0	c_1	d_0	d_1
1	0.0	-0.171680	1.161549	2.8263	0.0	5.073342	-0.011430
2	0.0	0.130939	1.093406	1.355139	0.350472	5.212394	-0.011623
3	1.0	-0.981113	1.092273	1.326047	0.318386	4.860467	-0.006173
4	0.0	-0.135807	1.147712	3.017494	0.0	5.568864	-0.021293
5	0.0	0.019948	1.108738	2.621230	0.186734	4.279655	-0.002484
6	0.0	-0.036696	1.132792	2.876094	0.0	5.073273	-0.020988
7	0.0	-0.012061	1.119712	3.2126	0.0	5.666442	-0.025199
8	0.0	-0.062693	1.139657	1.7664	0.0	4.481330	-0.018092
9	0.0	0.073435	1.107183	2.6237	0.0	5.671345	-0.023463
10	0.0	0.162672	1.073404	3.288501	0.0	6.484942	-0.023248
11	0.0	0.196054	1.073909	0.345647	0.620145	5.417431	-0.011608
12	1.0	-0.818809	1.054176	-2.366108	1.202413	4.420000	-0.010660
13	1.0	0.035786	1.121389	2.0408	0.0	4.656659	-0.022612
14	0.0	-0.238295	1.180163	3.044134	0.0	4.625125	-0.016042
15	1.0	-0.811424	1.056190	-3.831124	1.401938	5.200550	-0.014890
16	0.0	-0.131210	1.159760	.598238	0.0	4.890318	-0.018837
17	0.0	-0.107413	1.140775	3.0712	0.0	5.812879	-0.028504

For redwood, equation {4.3.1.7} and equation {4.3.1.8} are used to compute crown ratio for live trees less than 1” and dead trees of all sizes. For live trees greater than 1”, equation {4.3.1.7} and equation {4.3.1.9} are used to compute crown ratio.

{4.3.1.7} $X = -1.021064 + 0.309296 * \ln(H*12/D) + 0.869720 * PRD - 0.116274 * D/QMDPLT$

{4.3.1.8} $CR = 1 / (1 + \exp(X + N(0,SD)))$

{4.3.1.9} $CR = 1 / (1 + \exp(X))$

where:

CR	is crown ratio expressed as a proportion (bounded to 0.05 ≤ *CR* ≤ 0.95)
D	is tree diameter at breast height
H	is tree height
PRD	is relative density of the inventory point (point Zeide SDI / point SDI max)
QMDPLT	is quadratic mean diameter of the inventory point (constrained to minimum of 1”)
N(0,SD)	is a random increment from a normal distribution with a mean of 0 and a standard deviation of SD (0.15)

All valid ORGANON tree records use equations {4.3.1.10} and {4.3.1.11}. Coefficients and references can be found in table 4.3.1.4

{4.3.1.10}
HCB=HT/(1.0+EXP(X0+X1*HT+X2*CCFL+X3*ALOG(BA)+X4*(DBH/HT)+X5*SITE+X6*OG**2))

{4.3.1.11} CR=1.0-HCB/HT

where:

CR	is predicted average stand crown ratio for the species
HCB	is the height to crown base
HT	tree height
CCFL	is stand crown competition factor for trees with DBH larger than subject tree’s DBH
BA	Stand basal area
SITE	Douglas-for site Index, unless species is western hemlock then use western hemlock’s.

X_{0-6}, are species-specific coefficients shown in tables 4.3.1.4

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

Species Index	X_0	X_1	X_2	X_3	X_4	X_5	Ref
DF-NWO	1.94093	-0.0065	-0.00487	-0.26157	1.08785	0	1
DF-SMC	6.184647	-0.00329	-0.00137	-1.19702	3.170283	0	2
GF	1.04746	-0.00666	-0.00671	0	0	0	1
DF	1.92682	-0.0028	-0.00119	-0.51313	3.68901	0.007422	3
WH	4.49102	0	-0.00132	-1.01461	0	0.013406	4
RC	0	0	0	0	2.03094	0	5

Species Index	X_0	X_1	X_2	X_3	X_4	X_5	Ref
PY	2.955339	0	0	-0.79861	3.095269	0	5
MA	0.94114	-0.00768	-0.00548	0	0	0	5
BM	1.057866	0	-0.00183	-0.28645	0	0	6
WO	0.567138	-0.01038	-0.00207	0	1.397962	0	4
RA	0	0	-0.00567	-0.74554	0	0.038477	5
DG	0	0	-0.00567	-0.74554	0	0.038477	5
WI	1.94093	-0.0065	-0.00487	-0.26157	1.08785	0	1

1: Zumrawi and Hann (1989) FRL Research Paper 52
2: Hann and Hanus (2004) FS 34: 1193-2003
3: Johnson (2002) Willamette Industries Report
4: Hann and Hanus (2002) OSU Department of Forest Management Internal Report #1&#2
5: Hanus, Hann, and Marshall (2000) FRL Research Contribution 29
6: Gould, Marshall, and Harrington (2008) West. J. Appl. For. 23: 26-33

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 non-valid ORGANON live tree records using the Weibull distribution, equations {4.3.1.3}-{4.3.1.6}, for all species except redwood. For redwood, crown ratio predicted at the end of the projection cycle is estimated using equations {4.3.1.7) and {4.3.1.9}. Crown ratio at the end of the projection cycle for valid ORGANON tree records is predicted using equations {4.3.1.10} and {4.3.1.11}. 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.

4.3.3.1 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

In the OP variant all species use the FVS logic {4.4.1 – 4.4.6} to calculate 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. Within the ORGANON model routines, crown widths for stand density measures are calculated using ORGANON equations. However, ORGANON crown widths are not reported in any FVS output files or used outside the ORGANON routines so the equations are not reported here.

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

{4.4.1} Bechtold (2004); Equation 02

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

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

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

$HT < 5.0$: $CW = [0.8 * HT * MAX(0.5, CR * 0.01)] * [1 - (HT - 5) * 0.1] * a_1 * DBH^{a_2} * HT^{a_3} * CL^{a_4} * (HT-5) * 0.1$
$5.0 \leq HT < 15.0$: $CW = 0.8 * HT * MAX(0.5, CR * 0.01)$

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

{4.4.3} Crookston (2003); Equation 03

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

{4.4.4} Crookston (2005); Equation 04

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

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

{4.4.5} Crookston (2005); Equation 05

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

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

{4.4.6} Donnelly (1996); Equation 06

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

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

where:

BF	is a species-specific coefficient based on forest code shown in table 4.4.3
CW	is tree maximum crown width
CL	is tree crown length
CR%	is crown ratio expressed as a percent
DBH	is tree diameter at breast height
HT	is tree height
BA	is total stand basal area
EL	is stand elevation in hundreds of feet
MinD	is the minimum diameter
HI	is the Hopkins Index

$HI = (ELEVATION - 5449) / 100) * 1.0 + (LATITUDE - 42.16) * 4.0 + (-116.39 - LONGITUDE) * 1.25$

$a_1 - a_6$ are species-specific coefficients shown in table 4.4.1

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

Species Code	Equation Number*	a_1	a_2	a_3	a_4	a_5	a_6
SF	01105	4.47990	0.45976	-0.10425	0.11866	0.06762	-0.00715
WF	01505	5.03120	0.53680	-0.18957	0.16199	0.04385	-0.00651
GF	01703	1.03030	1.14079	0.20904	0.38787	0	0
AF	01905	5.88270	0.51479	-0.21501	0.17916	0.03277	-0.00828
RF	02006	3.11460	0.57800	0	0	0	0
SS	09805	8.48000	0.70692	-0.38812	0.17127	0	0
NF	02206	3.06140	0.62760	0	0	0	0
YC	04205	3.37560	0.45445	-0.11523	0.22547	0.08756	-0.00894
IC	08105	5.04460	0.47419	-0.13917	0.14230	0.04838	-0.00616
ES	09305	6.75750	0.55048	-0.25204	0.19002	0	-0.00313
LP	10805	6.69410	0.81980	-0.36992	0.17722	-0.01202	-0.00882
JP	11605	4.02170	0.66815	-0.11346	0.09689	-0.63600	0
SP	11705	3.59300	0.63503	-0.22766	0.17827	0.04267	-0.00290
WP	11905	5.38220	0.57896	-0.19579	0.14875	0	-0.00685
PP	12205	4.77620	0.74126	-0.28734	0.17137	-0.00602	-0.00209
DF	20205	6.02270	0.54361	-0.20669	0.20395	-0.00644	-0.00378

Species Code	Equation Number*	a_1	a_2	a_3	a_4	a_5	a_6
RW	21104	3.70230	0.52618	0	0	0	0
RC	24205	6.23820	0.29517	-0.10673	0.23219	0.05341	-0.00787
WH	26305	6.03840	0.51581	-0.21349	0.17468	0.06143	-0.00571
MH	26403	6.90396	0.55645	-0.28509	0.20430	0	0
BM	31206	7.51830	0.44610	0	0	0	0
RA	35106	7.08060	0.47710	0	0	0	0
MA	36102	4.9133	0.9459	0	0.0611	0	0.0523
TO	63102	3.11500	0.79660	0	0.07450	-0.0053	0.05230
GC	63102	3.11500	0.79660	0	0.07450	-0.0053	0.05230
AS	74605	4.79600	0.64167	-0.18695	0.18581	0	0
CW	74705	4.4327	0.41505	-0.23264	0.41477	0	0
WO	81505	2.48570	0.70862	0	0.10168	0	0
WJ	06405	5.14860	0.73636	-0.46927	0.39114	-0.05429	0
LL	07204	2.25860	0.68532	0	0	0	0
WB	10105	2.23540	0.66680	-0.11658	0.16927	0	0
KP	10305	4.00690	0.84628	-0.29035	0.13143	0	-0.00842
PY	23104	6.12970	0.45424	0	0	0	0
DG	35106	7.08060	0.47710	0	0	0	0
HT	35106	7.08060	0.47710	0	0	0	0
CH	35106	7.08060	0.47710	0	0	0	0
WI	31206	7.51830	0.44610	0	0	0	0
OT	12205	4.77620	0.74126	-0.28734	0.17137	-0.00602	-0.00209

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

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

Species Code	Equation Number*	MinD	EL min	*EL* max	*HI* min	*HI* max	*CW* max
SF	01105	1.0	4	72	n/a	n/a	33
WF	01505	1.0	2	75	n/a	n/a	35
GF	01703	1.0	n/a	n/a	n/a	n/a	40
AF	01905	1.0	10	85	n/a	n/a	30
RF	02006	1.0	n/a	n/a	n/a	n/a	65
SS	09805	1.0	n/a	n/a	n/a	n/a	50
NF	02206	1.0	n/a	n/a	n/a	n/a	40
YC	04205	1.0	16	62	n/a	n/a	59
IC	08105	1.0	5	62	n/a	n/a	78
ES	09305	1.0	1	85	n/a	n/a	40
LP	10805	1.0	1	79	n/a	n/a	40
JP	11605	1.0	n/a	n/a	n/a	n/a	39
SP	11705	1.0	5	75	n/a	n/a	56
WP	11905	1.0	10	75	n/a	n/a	35

PP	12205	1.0	13	75	n/a	n/a	50
DF	20205	1.0	1	75	n/a	n/a	80
RW	21104	1.0	n/a	n/a	n/a	n/a	39
RC	24205	1.0	1	72	n/a	n/a	45
WH	26305	1.0	1	72	n/a	n/a	54
MH	26403	n/a	n/a	n/a	n/a	n/a	45
BM	31206	1.0	n/a	n/a	n/a	n/a	30
RA	35106	1.0	n/a	n/a	n/a	n/a	35
MA	36102	5.0	n/a	n/a	-55	15	43
TO	63102	5.0	n/a	n/a	-55	15	41
GC	63102	5.0	n/a	n/a	-55	15	41
AS	74605	1.0	n/a	n/a	n/a	n/a	45
CW	74705	1.0	n/a	n/a	n/a	n/a	56
WO	81505	1.0	n/a	n/a	n/a	n/a	39
WJ	06405	1.0	n/a	n/a	n/a	n/a	36
LL	07204	1.0	n/a	n/a	n/a	n/a	33
WB	10105	1.0	n/a	n/a	n/a	n/a	40
KP	10305	1.0	12	49	n/a	n/a	46
PY	23104	1.0	n/a	n/a	n/a	n/a	30
DG	35106	1.0	n/a	n/a	n/a	n/a	35
HT	35106	1.0	n/a	n/a	n/a	n/a	35
CH	35106	1.0	n/a	n/a	n/a	n/a	35
WI	31206	1.0	n/a	n/a	n/a	n/a	30
OT	12205	1.0	13	75	n/a	n/a	50

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

Species Code	Location Code				
	609 800	**612**	**708**	**709**	**712**
SF	1.032		1.296		
SS	1.146				
LP	1.114		0.944	0.903	0.944
DF		0.977			0.961
RC	0.941	0.905	1.115		0.973
WH		0.924	1.260	1.087	1.028
WF			1.130		
GF			1.086	0.972	
AF			1.038	0.936	
NF			1.301		
YC			1.493	1.127	
WP			1.081	1.081	
MH			1.106		0.900

RA					0.810
IC					0.821
PP				1.070	0.951
ES				0.857	
SP				1.097	

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

4.5 Crown Competition Factor

The OP 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 use in ORGANON equations is computed using ORGANON crown width equations previously discussed. For FVS equations, crown competition factor for an individual tree is calculated using equation set {4.5.1}. All species coefficients are shown in table 4.5.1.

{4.5.1} CCF Equations

$CCF_t = 0.001803 * (MCW_t)^2$

$HT \leq 4.501$: $MCW_t = HT/4.5 * R_1$

$HT < 4.501$”: $MCW_t = R_1 + (R_2 * DBH) + (R_3 * DBH^2)$

where:

MCW_t	is maximum crown width for an individual tree
CCF_t	is crown competition factor for an individual tree
DBH	is tree diameter at breast height (if DBH is greater than MaxDBH, DBH=MaxDBH)
HT	is tree height
$R_1 – R_3$	are species-specific coefficients shown in table 4.5.1

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

Species Code	Model Coefficients			
	R_1	R_2	R_3	MaxDBH
SF	6.188	1.0069	0	999.99
WF	6.188	1.0069	0	999.99
GF	6.188	1.0069	0	999.99
AF	6.188	1.0069	0	999.99
RF	4.6198	1.8426	-0.01131	81.45
SS	4.6198	1.8426	-0.01131	81.45
NF	6.188	1.0069	0	999.99
YC	4	1.65	0	999.99
IC	4	1.65	0	999.99
ES	4.6198	1.8426	-0.01131	81.45
LP	4.6198	1.8426	-0.01131	81.45
JP	4.6198	1.8426	-0.01131	81.45
SP	4.6198	1.8426	-0.01131	81.45
WP	4.6198	1.8426	-0.01131	81.45
PP	4.6198	1.8426	-0.01131	81.45
DF	4.6198	1.8426	-0.01131	81.45
RW-NWO	4.3586	1.57458	0	76.7
RW-SMC	4.5652	1.4147	0	999.99
RC	4	1.65	0	999.99
WH-NWO	4.3586	1.57458	0	76.7
WH-SMC	4.5652	1.4147	0	999.99
MH-NWO	4.3586	1.57458	0	76.7
MH-SMC	4.5652	1.4147	0	999.99
BM-NWO	4.0953	2.3849	-0.01027	102.53
BM-SMC	4.0953	2.3849	-0.01163	102.53
RA	8	1.53	0	999.99
MA	3.429863	1.35323	0	999.99
TO-NWO	4.0953	2.3849	-0.01027	102.53
TO-SMC	4.0953	2.3849	-0.01163	102.53
GC	3.429863	1.35323	0	999.99
AS-NWO	4.0953	2.3849	-0.01027	102.53
AS-SMC	4.0953	2.3849	-0.01163	102.53
CW-NWO	4.0953	2.3849	-0.01027	102.53

CW-SMC	4.0953	2.3849	-0.01163	102.53
WO	3.078564	1.924221	0	999.99
WJ	4.5652	1.4147	0	999.99
LL	6.188	1.0069	0	999.99
WB	4.6198	1.8426	-0.01131	81.45
KP	4.6198	1.8426	-0.01131	81.45
PY	4.5652	1.4147	0	999.99
DG	2.97939	1.551244	-0.01416	54.77
HT	2.97939	1.551244	-0.01416	54.77
CH	2.97939	1.551244	-0.01416	54.77
WI	2.97939	1.551244	-0.01416	54.77
OT	2.97939	1.551244	-0.01416	54.77

4.6 Small Tree Growth Relationships

Non-valid ORGANON tree records are considered “small trees” for FVS modeling purposes when they are smaller than some threshold diameter. This threshold diameter is set to 3.0” for all species in the OC variant. All valid ORGANON tree records are considered “large trees” for FVS modeling purposes (see section 4.7).

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

4.6.1 Small Tree Height Growth

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

{4.6.1.1} Small Tree Height Growth

$$H5 = D5 / a_1$$

Where:

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

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

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

Species Code	a_1
SF	0.2474
WF	0.2175
GF	0.1797
AF	0.2056
RF	0.2168
SS	0.2168
NF	0.2822
YC	0.2168
IC	0.2815
ES	0.1704
LP	0.1682
JP	0.2168
SP	0.2168
WP	0.2168
PP	0.2369
DF	0.1635
RC	0.1829
WH	0.1727
MH	0.3029
BM	0.2168
RA	0.2168
MA	0.2168
TO	0.2168
GC	0.2168
AS	0.2168
CW	0.2168
WO	0.2168
WJ	0.2168
LL	0.2168
WB	0.2168
KP	0.1682
PY	0.2168
DG	0.2168
HT	0.2168
CH	0.2168
WI	0.2168
OT	0.1635

For redwood, a potential height growth curve is used to estimate small tree height growth. Height growth is computed by subtracting the current predicted height from the predicted height 5 years in the future, as depicted in equation {4.6.1.2}.

{4.6.1.2} $POTHTG = 2.242202 * SI * [1.0 – \exp(-0.010742 * AGE1)]^{0.919076}$

where:

POTHTG	is predicted tree height, used for current and future height growth
SI	is species site index
AGE1	is tree age
	$AGE1 = 1/ -0.010742 * (\ln(1-(HT/2.242202/SI)^{(1/ 0.919076)}))$

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

Height growth estimates from the small-tree model are weighted with the height growth estimates from the large tree model over a range of diameters (X_{min} and X_{max}) in order to smooth the transition between the two models. For example, the closer a tree's *DBH* value is to the minimum diameter (X_{min}), the more the growth estimate will be weighted towards the small-tree growth model. The closer a tree's *DBH* value is to the maximum diameter (X_{max}), the more the growth estimate will be weighted towards the large-tree growth model. If a tree's *DBH* value falls outside of the range given by X_{min} and X_{max}, then the model will use only the small-tree or large-tree growth model in the growth estimate. The weight applied to the growth estimate is calculated using equation {4.6.1.3}, and applied as shown in equation {4.6.1.4}. The range of diameters for each species is shown in table 4.6.1.2.

{4.6.1.3}

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

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

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

{4.6.1.4}

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

Redwood estimated growth = $[(1 - XWT) * ((STGE+LTGE)/2.0)] + [XWT * LTGE]$

where:

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

Table 4.6.1.2 Diameter bounds by species in the OP variant.

Species Code	X_{min}	X_{max}
SF	2.0	4.0
WF	2.0	4.0
GF	2.0	4.0
AF	2.0	4.0
RF	2.0	4.0
SS	2.0	4.0
NF	2.0	4.0
YC	2.0	4.0
IC	2.0	4.0
ES	2.0	4.0
LP	1.0	3.0
JP	2.0	4.0
SP	2.0	4.0
WP	2.0	4.0
PP	2.0	4.0
DF	2.0	4.0
RW	2.0	10.0
RC	2.0	4.0
WH	2.0	4.0

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

4.6.2 Small Tree Diameter Growth

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

{4.6.2.1} Small Tree Diameter Growth

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

where:

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

{4.6.2.2} Small tree Height – Diameter Equation

$DBH = (HT - 4.5) \cdot a_1$

where:

HT is tree height
DBH is tree diameter at breast height

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

Table 4.6.1.1 Coefficients (c_0 – c_9) and equation reference for small-tree diameter increment equations {4.6.1.1} in the OP variant.

Species Code	*DMAX*	Model Coefficients									
		c_0	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9
SF	1.7035	2.9445	0	0	0.0068	0	0	-0.1895	0	-1.4049	-0.0168
WF	1.4964	1.7536	0	0.2928	0.0009	0	-0.0446	-2.0349	0	-1.3839	-0.0033
GF	1.6389	2.3571	0.0052	0	0.0006	0	-0.4269	-1.2219	0	0	-0.0170
AF	1.1961	2.5839	0	0.0410	0.0020	0	-0.0152	-2.2060	0	-0.5915	-0.0009
RF	1.5146	2.4743	0	0	0.0032	0	-0.8934	-2.2709	0	-1.0690	0
SS	3.3957	3.8205	0	0.0523	0.0051	0	-0.4102	-1.6968	0	-1.4001	-0.0109
NF	2.9394	0.3376	0	0	0.0101	0	0	0	0	0	-0.0043
YC	1.5400	-2.0216	0.0063	0	0	0.7175	0	0	0	0	0
IC	1.6825	0.5996	0	0	0.0080	0	0	0	-1.0479	0	0
ES	1.8853	0.0452	0.0080	0	0.0071	0	0	0	0	0	0
LP	1.6535	1.7400	0	0.3718	0.0027	0	-0.1712	-2.1359	0	-0.7266	-0.0074
JP	1.7985	1.8451	0	0	0.0167	0	-1.4737	0	0	-0.4103	-0.0112
SP	2.4740	3.8085	0	0	0.0023	0	-0.4265	-2.0913	0	-1.3932	-0.0093
WP	2.4740	3.8085	0	0	0.0023	0	-0.4265	-2.0913	0	-1.3932	-0.0093
PP	1.7985	1.8451	0	0	0.0167	0	-1.4737	0	0	-0.4103	-0.0112
DF	5.3730	2.4473	0	0	0.0098	0	-0.4290	-0.1710	0	-0.1879	-0.0110
RC	2.7899	1.6815	0	0	0.0068	0	0	0	0	-0.6049	-0.0121
WH	3.4187	2.9527	0	0	0.0066	0	0	-0.4734	0	-0.7394	-0.0207
MH	1.3834	2.6762	0.0024	0	0.0006	0	-0.4309	-1.6205	0	-0.5930	-0.0051
BM	3.0939	-1.2421	0.0124	0	0	0.4161	0	0	0	0	0
RA	3.0939	1.4593	0	0	0.0085	0	-0.6000	0	0	-1.2280	0
MA	2.0110	-1.1900	0.0158	0	0	0.6600	0	0	0	0	0
TO	2.1657	-1.2421	0.0124	0	0	0.7813	0	0	0	0	0
GC	3.0939	-1.2421	0.0124	0	0	0.6382	0	0	0	0	0
AS	2.4751	-1.2421	0.0124	0	0	0.6013	0	0	0	0	0
CW	3.7127	-1.2421	0.0124	0	0	0.6013	0	0	0	0	0
WO	0.9861	-2.1910	0	0	0	0.7191	-3.1321	0	0	0	0
WJ	1.2192	0.3755	0.0120	0	0	0	0	0	0	0	0
LL	0.6234	1.0527	0	0.3580	0.0019	0	0	-0.6008	0	-0.7451	-0.0101

Species Code	DMAX	Model Coefficients									
		c_0	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9
WB	0.8070	2.4949	0	0	0.0049	0	-0.2085	-1.7001	0	-0.7952	-0.0177
KP	0.5859	-0.8085	0	0.5001	0	0	0	0	0	0	-0.0081
PY	0.8601	1.5156	0	0	0.0012	0	0	-0.5478	0	-0.6123	0
DG	1.0032	-3.8345	0	0	0	1.0701	0	0	0	0	0
HT	1.8903	3.5521	0	0	0.0002	0	0	-0.5932	0	-0.5029	-0.0038
CH	2.1657	-1.2421	0.0124	0	0	0.7312	0	0	0	0	0
WI	2.1657	-1.2421	0.0124	0	0	0.6598	0	0	0	0	0
OT	5.3730	2.4473	0	0	0.0098	0	-0.3575	-0.1710	0	-0.1879	-0.0110

For redwood, small tree height growth is predicted first, and then diameter growth. 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. Diameter growth is predicted with the height-diameter equations shown in section 4.1 inverted, so that diameter is a function of height. Diameter growth estimates for redwood are weighted with the diameter growth estimates from the large-tree model when DBH is between 2” and 7”, in a similar manner to the weighting explained in section 4.6.1. By definition, diameter growth is zero for trees less than 4.5 feet tall.

4.7 Large Tree Growth Relationships

For non-valid ORGANON tree records, trees are considered “large trees” for FVS modeling purposes when they are equal to, or larger than, some threshold diameter. This threshold diameter is set to 3.0” for all species in the OP variant. In addition, all valid ORGANON tree records are considered large trees for FVS modeling purposes.

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). Organon based diameter growth equations are constructed similarly, they predict periodic change in diameter squared as well, however they include bark, where FVS does not.

In the OP variant, there are three primary equations that estimate large-tree diameter growth. The non-valid ORGANON tree records use equation {4.7.1.1} for all species except red alder {4.7.1.2} and redwood {4.7.1.3}. Coefficients for these equations are shown in tables 4.7.1.2 and 4.7.1.4. These equations yield a 10-year diameter growth estimate. Equation {4.7.1.3} is used to convert the 10-year estimate to a 5-year estimate.

All valid ORGANON tree records use equation {4.7.1.5}, these were developed by Zumrawi and Hann 1993, Hann and Hanus 2002, Johnson 2002 and Gould, Marshall, and Harrington 2008.

In the OP variant, all non-valid ORGANON tree records are mapped into a species index as shown in table 4.7.1.1. The coefficients for each species for equation 4.7.1.1 will depend on the species index of the subject species.

{4.7.1.1} All species except red alder:

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

where:

DDS	is the square of the diameter growth increment
EL	is stand elevation in hundreds of feet (if species index 14, $EL \leq 30$)
SI	is species site index in feet (if species index =19, $SI = SI_{King}$; if species index =10 do a metric to feet conversion when using a Means site index curve)
ASP	is stand aspect
SL	is stand slope
DBH	is tree diameter at breast height
BAL	is total basal area in trees larger than the subject tree
CR	is crown ratio expressed as a proportion
PCCF	is crown competition factor on the inventory point where the tree is established
RELHT	is tree height divided by average height of the 40 largest diameter trees in the stand bounded to $RELHT \leq 1.5$)
BA	is total stand basal area
b_1	is a location-specific coefficient shown in table 4.7.1.3
b_2-b_{18}	are species-specific coefficients shown in tables 4.7.1.2 and 4.7.1.5

Table 4.7.1.1 Mapped species index for each species for large-tree diameter growth on non-valid ORGANON tree records in the OP variant.

Species Code	Species Index	Species Code	Species Index
SF	1	BM	12
WF	2	RA	
GF	2	MA	14
AF	3	TO	14
RF	4	GC	14
SS	18	AS	14
NF	4	CW	14
YC	15	WO	19
IC	11	WJ	14
ES	11	LL	11
LP	16	WB	11
JP	6	KP	11
SP	5	PY	11
WP	5	DG	14
PP	6	HT	14
DF	7	CH	14
RC	8	WI	14
WH	9	OT	14
MH	10		

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

Coefficient	Species Index								
	1	2	3	4	5	6	7	8	9
b_2	-0.023858	-0.003051	-0.003773	-0.069045	-0.023376	-0.003784	-0.009845	-0.009564	-0.018444
b_3	0	0	0	0.000608	0	0.0000666	0	0	0
b_4	0.541881	0.318254	0.349888	0.684939	0.40401	1.011504	0.495162	0.708166	0.634098
b_5	0.096326	0	0.02216	-0.207659	0	0	0.003263	-0.10602	0.061254
b_6	-0.217205	0	-0.782418	-0.374512	0	0	0.014165	-0.106936	-0.056608
b_7	-0.265612	0	0.319956	0.400223	0	0	-0.340401	-0.30349	0.736143
b_8	0	0	0	0	0	0	0	0	-1.082191

Coefficient	Species Index								
	1	2	3	4	5	6	7	8	9
b_9	0.919402	0.905119	0.993986	0.904253	0.84469	0.73875	0.802905	0.744005	0.641956
b_{10}	1.290568	1.754811	1.522401	4.123101	1.59725	3.454857	1.936912	0.771395	1.471926
b_{11}	0.125823	0	0	-2.68934	0	-1.773805	0	0	0
b_{12}*									
b_{13}	-0.002133	-0.005355	-0.002979	-0.006368	-0.003726	-0.013091	-0.001827	-0.01624	-0.012589
b_{14}	0	0	0	-0.000471	-0.000257	-0.000593	0	0	0
b_{15}	0	-0.000661	0	0	0	0	0	0	0
b_{16}	-0.136818	0	0	0	0	-0.131185	-0.129474	-0.130036	-0.085525
b_{17}	0	0	0	0	0	0	-0.001689	0.003883	0.002385
b_{18}	0	0	-0.000137	0	0	0	0	0	0

*See table 4.7.1.4 for b_{12} values

Table 4.7.1.2 (continued) Coefficients (b_2- b_{18}) for species with a species index 10-19 for equation {4.7.1.1} in the OP variant.

Coefficient	Species Index							
	10	11	12	14	15	16	18	19
b_2	-0.003809	0	-0.012111	-0.075986	0	-0.005414	0.007009	0
b_3	0	0	0	0.001193	0	0	0	0
b_4	0.20804	0.252853	1.965888	0.227307	0.244694	0.391327	0	0.14995
b_5	-0.12613	0	0	-0.86398	0.679903	0.37886	0.100081	0
b_6	-0.104495	0	0	0.085958	-0.023186	0.207853	-0.221095	0
b_7	0.411602	0	0	0	0	-0.06644	-0.169141	0
b_8	0	0	0	0	0	0	0	0
b_9	0.857131	0.879338	1.024186	0.889596	0.81688	0.478504	1.049845	1.66609
b_{10}	1.505513	1.970052	0.459387	1.732535	2.471226	1.905011	1.632468	0
b_{11}	0	0	0	0	0	0	0	0
b_{12}*								
b_{13}	-0.004101	-0.004215	-0.010222	-0.001265	-0.00595	-0.004706	-0.000086	0
b_{14}	-0.000201	0	-0.000757	0	0	0	0	0
b_{15}	0	0	0	0	0	0	0	0
b_{16}	0	0	0	0	0	0	-0.198636	0

b_{17}	0	0	0	0	0	0	-0.002319	-0.00326
b_{18}	0	-0.000173	0	-0.000981	-0.000147	-0.000114	0	-0.00204

*See table 4.7.1.4 for b_{12} values

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

Location Class	Species Index								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	-0.627531	-0.64392	-1.888949	-1.401865	-0.58957	-2.922255	-0.739354	-0.68825	-0.59446
2	0	0	0	-1.127977	-0.909553	0	-0.1992	-0.40559	-0.522658
3	0	0	0	0	0	0	0	0	0

Table 4.7.1.3 (continued) b_1 values by location class for species that have a species index 10 – 19 for equation {4.7.1.1} in the PN variant.

Location Class	Species Index							
	10	**11**	**12**	**14**	**15**	**16**	**18**	**19**
1	-1.052161	-1.310067	-7.753469	-0.107648	-1.277664	-0.524624	2.075598	-1.33299
2	0	-1.432659	-8.279266	-0.098335	-1.178041	-0.803095	2.100904	0
3	0	0	0	0	0	0	0	0

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

	Species Index																
Location Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**14**	**15**	**16**	**18**	**19**
609 – Olympic	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
612 – Siuslaw	1	1	1	2	2	1	2	2	2	1	2	2	2	2	2	2	1
800 – Quinault Indian Res.	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1
708 – BLM Salem	1	1	1	2	2	1	2	2	2	1	2	2	2	2	2	2	1
709 – BLM Eugene	1	1	1	2	2	1	2	2	2	1	2	2	2	2	2	2	1
712 – BLM Coos Bay	1	1	1	2	2	1	2	2	2	1	2	2	2	2	2	2	1

Table 4.7.1.5 b_{12} values by location class for species that have a species index 1 – 9 for equation {4.7.1.1} in the OP variant.

Location Class	Species Index								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	-0.0002641	-0.0003137	-0.0002621	-0.0003996	-0.0000596	-0.0004708	-0.0000896	-0.0000572	-0.0001736
2	0	0	0	0	0	0	-0.0000641	-0.0000862	-0.000104

Table 4.7.1.5 (continued) b_{12} values by location class for species that have a species index 10 – 19 for equation {4.7.1.1} in the OP variant.

	Species Index

Location Class	10	11	12	14	15	16	18	19
1	-0.0002214	-0.0001323	-0.0001737	0	-0.0002536	0	-0.0002123	-0.00154
2	0	0	0	0	0	0	-0.0001361	0

Table 4.7.1.6 Location class by species index and location code in the OP variant.

Location Code	Species Index																
	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	18	19
609 – Olympic	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
612 – Siuslaw	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	2	1
800 – Quinault Indian Res.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
708 – BLM Salem	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	2	1
709 – BLM Eugene	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	2	1
712 – BLM Coos Bay	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	2	1

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

{4.7.1.2} Used for red alder

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

where:

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

{4.7.1.3} Used for redwood

$DI = \exp(-3.502444 + (0.185911 * \ln(DBH)) + (-0.000073 * DBH^2) + (-0.001796 * PBAL) + (-0.42078 * PRD) + (0.589318 * \ln(CR)) + (0.415435 * \ln(SI)) + (-0.000926 * SL) + (-0.002203 * (SL) * \cos(ASP)))$

where:

DI is 10-year outside bark diameter growth increment
SI is species site index
ASP is stand aspect
SL is stand slope

CR is crown ratio expressed as a proportion
DBH is tree diameter at breast height
PBAL is point basal area in trees larger than the subject tree
PRD is relative density of the inventory point (point Zeide SDI / point SDI max)

For all species, equation {4.7.1.4} is used to convert the 10-year diameter growth estimate to a 5-year diameter growth estimate.

{4.7.1.4} ln(*DDS)* = ln(exp(*DDS)* / 2.0)

For all valid ORGANON tree records, equation {4.7.1.5} predicts the change in square of the 5-year diameter outside bark. An adjustment factor {4.7.1.6} is then applied to the final diameter growth value.

{4.7.1.5} Used for all valid ORGANON tree records:

ln*(DDS*)=X0 + X1*LOG(DBH+K1) + X2*DBH**K2 + X3*LOG((CR+0.2)/1.2) + X4*LOG(SITE) + X5*((BAL**K3)/LOG(DBH+K4)) + X6*SQRT(BA)

{4.7.1.6} Modifier to 5-year diameter growth

MOD=(1.0-EXP(-(25.0*CR)**2))*ADJ

DG=EXP(ln(DDS))*MOD

where:

DDS is the square of the 5-year diameter outside bark growth increment
DG is 5-year diameter growth outside bark
SI is site index
CR is crown ratio expressed as a proportion
DBH is tree diameter at breast height
BA is total stand basal area
BAL is total basal area in trees larger than the subject tree
X_0- X_6, K_1- K_4,
ADJ are species-specific coefficients shown in table 4.7.1.5

Table 4.7.1.5 Coefficients (X_0- X_6, K_1- K_4,) for equation {4.7.1.5-4.7.1.6} in the OP variant.

Species	X0	X1	X2	X3	X4	X5	X6	K1	K2	K3	K4	ADJ
DF	-4.69624	0.339513	-0.00042826	1.19952	1.15612	-0.0000446	-0.0237	1	2	2	5	0.701101
GF	-2.34619	0.59464	-0.00097609	1.12712	0.555333	-0.0000291	-0.04708	1	2	2	5	0.8722
WH	-4.49867	0.362369	-0.00153907	1.1557	1.12154	-0.0000201	-0.04174	1	2	2	5	0.7163

Species	X0	X1	X2	X3	X4	X5	X6	K1	K2	K3	K4	ADJ
RC	-11.4546	0.784134	-0.02613779	0.701748	2.057236	-0.004154	0	5	1	1	2.7	0.8
PY	-9.15836	1	-0.02613779	1.166885	0	0	-0.02	4000	4	1	2.7	0.8
MD	-8.84532	1.5	-0.00000035	0.512256	0.418129	-0.003553	-0.03213	110	2	1	2.7	0.7928
BL	-3.4145	1	-0.050	0	0.324349	0	-0.09895	10	1	1	2.7	0.8
WO	-7.81268	1.405617	-0.06031059	0.64286	1.037687	0	-0.0787	5	1	1	2.7	1
RA	-4.39082	1	-0.09450571	1.06867	0.685908	-0.005863	0	5	1	1	2.7	0.8
PD	-8.08353	1	-0.00000035	0.311766	0	0	-0.07308	4000	4	1	2.7	0.8
WI	-8.08353	1	-0.00000035	0.311766	0	0	-0.07308	4000	4	1	2.7	0.8

4.7.2 Large Tree Height Growth

For all species except redwood, height growth estimates for non-valid ORGANON tree records in the OP variant are based on site index curves. Species differences in height growth are accounted for by entering the appropriate curve with the species specific site index value.

In the OP variant, each non-valid ORGANON tree record is mapped into a species index as shown in table 4.7.2.1. The coefficients and equations used for each species will depend on the species index of the subject species.

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

Species Code	Species Index
SF	1
WF	2
GF	2
AF	3
RF	4
SS	15

Species Code	Species Index
BM	6
RA	12
MA	6
TO	6
GC	6
AS	6

Species Code	Species Index
NF	5
YC	6
IC	7
ES	3
LP	8
JP	7
SP	9
WP	9
PP	7
DF	14
RW	
RC	15
WH	10
MH	11

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

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

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

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

where:

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

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

Species Code	a_0	a_1	Maximum Age
SF	43.9957174	4.3396271	200
WF	43.9957174	4.3396271	200
GF	43.9957174	4.3396271	200
AF	39.6317079	4.3149844	200
RF	39.6317079	4.3149844	200
SS	16.2223589	6.3657425	200
NF	39.6317079	4.3149844	200
YC	62.7139427	3.2412923	200

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

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

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

{4.7.2.3} $HTG = 0.1$

{4.7.2.4} $HTG = 0.5 * DG$

{4.7.2.5} $HTG = POTHTG * HTGMOD$

where:

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

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

{4.7.2.6} $POTHTG = 0.1$

where:

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

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

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

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

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

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

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

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

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

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

$$H = [(SI - 4.5) * (1 - \exp(-X * A^{\wedge}b_1))] / [1 - \exp(-Y * 50^{\wedge}b_1)] + 4.5$$
$$X = (SI * TERM) + (b4 * TERM^{\wedge}2) + b5$$

TERM = A * b2* exp (A * b3)
Y = (SI * TERM2) + (b4* TERM2^2) + b5
TERM2 = 50 * b2 * exp (50 * b3)

{4.7.2.11} Used for species index 5: noble fir

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

{4.7.2.12} Used for species index 6: Alaska cedar, bigleaf maple, Pacific madrone, tanoak, giant chinquapin, quaking aspen, black cottonwood, western juniper, whitebark pine, knobcone pine, Pacific yew, Pacific dogwood, hawthorn, bitter cherry, willow, other

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

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

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

{4.7.2.14} Used for species index 8: lodgepole pine

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

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

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

{4.7.2.16} Used for species index 10: western hemlock

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

{4.7.2.17} Used for species index 11: mountain hemlock

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

{4.7.2.18} Used for species index 12: red alder

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

{4.7.2.19} Used for species index 13: subalpine larch

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

{4.7.2.20} Used for species index 14: Douglas-fir

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

{4.7.2.21} Used for species index 15: Sitka spruce, western redcedar

$$H = 4.5 + \exp[b_0 + b_1 * \ln(A) + b_2 * (\ln(A))^3 + b_3 * (\ln(A))^5 + b_4 * (\ln(A))^{30}] + ((SI - 4.5) + b_{11}) * [\exp[b_5 + b_6 * \ln(A) + b_7 * (\ln(A))^2 + b_8 * (\ln(A))^5 + b_9 * (\ln(A))^{16} + b_{10} * (\ln(A))^{36}]$$

where:

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

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

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

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

Coefficient	Species Index						
	9	10	11	12	13	14	15
b_0	-4.62536	-1.7307	22.8741	59.5864	0	-0.954038	-0.2050542
b_1	1.346399	0.1394	0.950234	0.7953	1.46897	0.109757	1.449615
b_2	-135.3545	-0.0616	-0.002065	0.00194	0.0092466	0.0558178	-0.01780992
b_3	0	0.0137	0	-0.00074	-2.40E-04	0.00792236	6.51975E-05
b_4	0	0.00192	1.365566	0.9198	1.11E-06	-0.000733819	-1.09559E-23
b_5	0	0.00007	2.045963	0	-0.12528	0.000197693	-5.611879
b_6	0	0	0	0	0.039636	0	2.418604
b_7	0	0	0	0	-4.28E-04	0	-0.259311
b_8	0	0	0	0	1.70E-06	0	0.000135145
b_9	0	0	0	0	73.57	0	-1.70114E-12
b_{10}	0	0	0	0	-0.12528	0	7.9642E-27
b_{11}	0	0	0	0	0.039636	0	-86.43
b_{12}	0	0	0	0	-4.28E-04	0	0
b_{13}	0	0	0	0	1.70E-06	0	0

For all species, modifiers are applied to the height growth based upon a tree's crown ratio (equation {4.7.2.24}), and relative height and shade tolerance (equation {4.7.2.25}). Equation {4.7.2.26} uses the Generalized Chapman – Richard's function (Donnelly et. al, 1992) to calculate a height-growth modifier. Final height growth is calculated using equation {4.7.2.5} as a product of the modifier and potential height growth. The final height growth is then adjusted to the length of the cycle.

{4.7.2.24} *HGMDCR* = (100 * (*CR* / 100)^3) * exp(-5 * (*CR* / 100)) bounded *HGMDCR* ≤ 1.0

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

{4.7.2.26} *HTGMOD* = (0.25 * *HGMDCR*) + (0.75 * *HGMDRH*) bounded 0.0 ≤ *HTGMOD* ≤ 2.0

*if *HTGMOD* ≤ 0.0, then *HTGMOD* = 0.1

where:

POTHTG	is potential height growth
H10	is estimated height of the tree in ten years
HT	is height of the tree at the beginning of the cycle
BA	is stand basal area
DBH1	is diameter of the tree at the beginning of the cycle
DBH2	is estimated diameter of the tree at the end of the cycle
HGMDCR	is a height growth modifier based on crown ratio
HGMDRH	is a height growth modifier based on relative height and shade tolerance

HTGMOD is a weighted height growth modifier
CR is crown ratio expressed as a percent
RELHT is tree height divided by average height of the 40 largest diameter trees in the stand
$b_1 - b_4$ are species-specific coefficients shown in table 4.7.2.4

Table 4.7.2.4 Coefficients ($b_1 - b_4$) for equation 4.7.2.25 in the OP variant.

Species Code	Coefficients			
	b_1	**b_2**	**b_3**	**b_4**
SF	0.15	1.1	16	-1.2
WF	0.15	1.1	16	-1.2
GF	0.15	1.1	16	-1.2
AF	0.2	1.1	20	-1.1
RF	0.15	1.1	16	-1.2
SS	0.15	1.1	16	-1.2
NF	0.1	1.1	15	-1.45
YC	0.15	1.1	16	-1.2
IC	0.2	1.1	20	-1.1
ES	0.15	1.1	16	-1.2
LP	0.01	1.1	12	-1.6
JP	0.05	1.1	13	-1.6
SP	0.1	1.1	15	-1.45
WP	0.15	1.1	15	-1.45
PP	0.05	1.1	13	-1.6
DF	0.1	1.1	15	-1.45
RC	0.2	1.1	20	-1.1
WH	0.2	1.1	20	-1.1
MH	0.2	1.1	20	-1.1
BM	0.2	1.1	20	-1.1
RA	0.05	1.1	13	-1.6
MA	0.05	1.1	13	-1.6
TO	0.1	1.1	15	-1.45
GC	0.1	1.1	15	-1.45
AS	0.01	1.1	12	-1.6
CW	0.01	1.1	12	-1.6
WO	0.1	1.1	15	-1.45
WJ	0.05	1.1	13	-1.6
LL	0.01	1.1	12	-1.6
WB	0.1	1.1	15	0.1
KP	0.01	1.1	12	-1.6
PY	0.2	1.1	20	-1.1
DG	0.2	1.1	20	-1.1
HT	0.01	1.1	12	-1.6

Species Code	Coefficients			
	b_1	b_2	b_3	b_4
CH	0.05	1.1	13	-1.6
WI	0.01	1.1	12	-1.6
OT	0.1	1.1	15	-1.45

One check is done after computing height growth to limit the maximum height for a given diameter. This check is to make sure that current height plus height growth does not exceed the maximum height for the given diameter. The maximum height for a given diameter is calculated using equation {4.7.2.27}. Species-specific coefficients for this equation are shown in Table 4.7.2.2.

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

where:

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

Equation {4.7.2.28} is used to predict 10-year height increment for redwood and equation {4.7.2.29} is used to convert this estimate to 5-year height increment. The final height growth is then adjusted to the length of the cycle.

{4.7.2.28} $HTG = \exp(1.412947 + (-0.000204 * DBH^2) + (0.31971 * \ln(DBH)) + (0.394005 * \ln(SI)) + (-(0.399888 * (\ln(DG10)) + (-0.451708 * \ln(HT))$

{4.7.2.29} $HTG = HTG * 0.5$

where:

HTG is 10-year height growth increment
DBH is diameter at breast height
SI is species site index
DG10 is 10-year outside bark diameter growth increment
HT is total tree height

A height growth bounding function is used to ensure tree heights do not exceed the height maximum of redwood. The bounding function is applied using the following concepts. For a tree with height less than the lower height-bounding limit, the height growth modifier is set to 1.0. For a tree with a height greater than or equal to the lower height-bounding limit and less than the upper height-bounding limit, a height growth modifier is computed using equation {4.7.2.30}. For a tree with a height greater than the upper height-bounding limit, the height growth modifier is set to 0.1. The lower bounding limit was determined from the height growth fitting data and the upper bounding limit was determined from literature. The final height increment estimate is multiplied by the bounding function, equation {4.7.2.31}.

{4.7.2.30} $HGBND = 1.0 - ((HT - HTLO) / (HTHI - HTLO))$

{4.7.2.31} $HTG = HTG * HGBND$

where:

HGBND	is height growth bounding modifier, limited to 0.1 $\le$ *HGBND* $\le$ 1.0
HT	is total tree height (ft)
HTLO	is the lower height-bounding limit (217 ft)
HTHI	is the upper height-bounding limit (380 ft)

Valid ORGANON tree records use ORGANON based height growth equations {4.7.2.32} – {4.7.2.34} which all yield a 5-year height growth estimate. Equations {4.7.2.32} and {4.7.2.33} are used for the major conifer species (DF, GF/WF, and WH). These equations predict potential height growth based on dominant height from the Flewelling western hemlock and Bruce's (1981) Douglas-fir and grand fir site index curves, based on the tree's growth effective age. The estimate is then modified. Other valid ORGANON tree records (RC, PY, MA, BM, WO, RA, DG, WI) use equation {4.7.2.34} which is based on ORGANON height-diamater equations.

{4.7.2.32} Used for DF and GF/WF

HG=PHTGRO*MODIFER*CRADJ

where:

PHTGRO= SI*EXP(B1*((GEAGE+GP+X1)**B2-X2**B2)) - HT

X1=13.25-SI/20.0

X2=63.25-SI/20.0

B1=ALOG(4.5/SI)/(X1**B2-X2**B2)

B2=-0.447762-0.894427*SI/100.0+0.793548*(SI/100.0)**2 -0.171666*(SI/100.0)**3

GEAGE=XX1**(1.0/B2)-X1 if XX1 is less than 0, GEAGE=500

XX1=ALOG(HT/SI)/B1+X2**B2

MODIFER=P8*((P1*EXP(P2*TCCH))+((EXP(P3*TCCH**P4))-(EXP(P3*TCCH**P4))*EXP((-P5*(1.0-CR)**P6)*EXP(P7*TCCH**0.5)))

CRADJ=(1.0-EXP(-(25.0*CR)**2))

HG	is predicted 5-year height growth
HT	is height of the tree
SI	is site index (Bruce)

B_0 – B_2, P_1 – P_8 are coefficients in table 4.7.2.3

{4.7.2.33} Used for WH

HG=PHTGRO*MODIFER*CRADJ

where:

PHTGRO= HTOP*3.2808 - HT

X=AGE-1

if X less than XK,

HTOP = H1 + SI_2*X +(1-B1)*SI_2*XK/(C+1) * (((XK-X)/XK)**(C+1)-1)

if X not less than XK,

HTOP = YK+ALPHA*(1-EXP(-BETA*Z)), with Z=X-XK

XK = 128.326*EXP(-2.54871)*PSI)

B1 = 0.2+0.8/(1.0+EXP(5.33208+-9.00622*PSI))

C =1.0+1.2*PSI

ALPHA = 52.7948*PSI

H1 = 1.3+(B1*PSI)/2.0

YK = H1+PSI*XK*(1.0-(1.0-B1)/(C+1.0))

BETA = PSI/ALPHA

X = (SI-32.25953)/10.0

If SI is less than or equal to 32.25

PSI
=0.75+X*(0.299720+X*(0.116875+X*(0.074866)+X*(0.032348+X*(0.006984+X*0.000339
)))))

If SI is greater than 32.25

PSI=0.75+X*(0.290737+X*(0.129665+X*(-0.058777)+X*(-0.000669+X*(0.006003+

X*-0.001060)))))

MODIFER=P8*((P1*EXP(P2*TCCH))+((EXP(P3*TCCH**P4))-(EXP(P3*TCCH**P4))*EXP((-P5*(1.0-CR)**P6)*EXP(P7*TCCH**0.5)))

CRADJ=(1.0-EXP(-(25.0*CR)**2))

HG is predicted 5-year height growth
HT is height of the tree
SI is site index (Flewelling)
$B_0 – B_2$, $P_1 – P_8$ are coefficients in table 4.7.2.3

{4.7.2.34} Used for non-major species

HG= HT*((PRDHT2/ PRDHT1)-1)

where:

PRDHT1=4.5+EXP(X1+X2*DBH**X3)

PRDHT2=4.5+EXP(X1+X2*(DBH+DG)**X3)

HG is predicted 5-year height growth
HT is height of the tree
DBH is diameter of tree

DG is predicted 5-year diameter growth for the tree
$X_1 – X_3$ are coefficients shown in table 4.1.2

Table 4.7.2.3 Coefficients ($P_1 – P_8$) for the DF, WH and GF/WF height-growth equations {4.7.2.32-4.7.2.34} in OP variant

species	P1	P2	P3	P4	P5	P6	P7	P8
DF	0.65525888	-0.006322913	-0.039409636	0.5	0.597617316	2.0	0.631643636	1.010018427
GF/WF	1.0	-0.0328142	-0.0127851	1.0	6.1978	2.0	0	1.01
WH	1.0	-0.0384415	-0.0144139	0.5	1.04409	2.0	0	1.03

5.0 Mortality Model

If there are valid ORGANON tree records in the tree list for a cycle, then all trees get mortality estimates using equations developed for ORGANON (Hann et al 2003, Hann and Hanus 2001 or Gould and Harrington 2008) with surrogate assignments for non-valid ORGANON tree records as shown in section 1.1. If all tree records for the projection cycle are non-valid ORGANON tree records, then all trees get mortality estimates using equations developed for the FVS PN variant.

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

{5.0.1} Mortality Equations:

$RA=1-[((1-(1/(1+exp(-Z))))^{0.2})*CRADJ]$

In SMC and NWO for GF, WF, SF, AF, NF, LL:

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

In SMC and NWO for WH, RC, YC, IC, MH:

$Z= d_0 + d_1*DBH+ d_2*DBH**2+ d_3*CR+ d_4*(SI\_2+4.5)+ d_5*BAL$

In SMC and NWO for WO:

$Z= d_0 + d_1*DBH + d_2*DBH^2+ d_3*CR + d_4*(XSITE1+4.5) + d_5*ALOG(BAL+5.0)$

In SMC for DF, RF, SS, ES, LP, JP, SP, WP, PP, WB, KP:

$Z= d_0 + d_1*DBH^2+ d_3*CR^{.25}+ d_4*(XSITE1+4.5)+ d_5*BAL$

In NWO for DF and all other and SMC any species not specified above:

$Z= d_0 + d_1*DBH+ d_2* DBH^2+ d_3*CR+ d_4*(XSITE1\_1+4.5)+B5*BAL$

where:

RA	is the estimated annual mortality rate
DBH	is tree diameter at breast height
BAL	is total basal area in trees larger
CR	is crown ratio
CRADJ	crown adjustment $=1.0-exp(-(25.0*CR)^2)$
XSITE1	Douglas-fir site index
XSITE2	Ponderosa Pine site index
d_{0-7}	are species-specific coefficients shown in table 5.0.1 for NWO
d_{0-7}	are species-specific coefficients shown in table 5.0.2 for SMC

The annual mortality rates are adjusted for the length of cycle using a compound interest formula (Hamilton 1976), and then applied to each tree record.

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

where:

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

Table 5.0.1 Coefficients used in the individual tree mortality equation {5.0.1} in the OP variant (NWO .version)

Species	d0	d1	d2	d3	d4	d5	d6
SF	-7.60159	-0.20052	0	0	0.044133	0.000638	1
WF	-7.60159	-0.20052	0	0	0.044133	0.000638	1
GF	-7.60159	-0.20052	0	0	0.044133	0.000638	1
AF	-7.60159	-0.20052	0	0	0.044133	0.000638	1
RF	-4.13142	-1.13736	0	-0.82331	0.030775	0.00991	1
SS	-4.13142	-1.13736	0	-0.82331	0.030775	0.00991	1
NF	-7.60159	-0.20052	0	0	0.044133	0.000638	1
YC	-0.76161	-0.52937	0	-4.74019	0.011959	0.007564	1
IC	-0.76161	-0.52937	0	-4.74019	0.011959	0.007564	1
ES	-4.13142	-1.13736	0	-0.82331	0.030775	0.00991	1
LP	-4.13142	-1.13736	0	-0.82331	0.030775	0.00991	1
JP	-4.13142	-1.13736	0	-0.82331	0.030775	0.00991	1
SP	-4.13142	-1.13736	0	-0.82331	0.030775	0.00991	1
WP	-4.13142	-1.13736	0	-0.82331	0.030775	0.00991	1
PP	-4.13142	-1.13736	0	-0.82331	0.030775	0.00991	1
DF	-4.13142	-1.13736	0	-0.82331	0.030775	0.00991	1
RW	-0.76161	-0.52937	0	-4.74019	0.011959	0.007564	1
RC	-0.76161	-0.52937	0	-4.74019	0.011959	0.007564	1
WH	-0.76161	-0.52937	0	-4.74019	0.011959	0.007564	1
MH	-0.76161	-0.52937	0	-4.74019	0.011959	0.007564	1
BM	-2.97682	0	0	-6.22325	0	0	1
RA	-2	-0.5	0.015	-3	0.015	0.01	1
MA	-6.0896	-0.24562	0	-3.20827	0.033348	0.013571	1
TO	-2.97682	0	0	-6.22325	0	0	1
GC	-6.0896	-0.24562	0	-3.20827	0.033348	0.013571	1
AS	-2.97682	0	0	-6.22325	0	0	1
CW	-2.97682	0	0	-6.22325	0	0	1
WO	-6.00031	-0.10491	0	-0.99542	0.009127	0.871157	1
WJ	-4.07278	-0.17643	0	-1.72945	0	0.012526	1
LL	-7.60159	-0.20052	0	0	0.044133	0.000638	1
WB	-4.13142	-1.13736	0	-0.82331	0.030775	0.00991	1
KP	-4.13142	-1.13736	0	-0.82331	0.030775	0.00991	1

PY	-4.07278	-0.17643	0	-1.72945	0	0.012526	1
DG	-3.02035	0	0	-8.46788	0.013966	0.009462	1
HT	-3.02035	0	0	-8.46788	0.013966	0.009462	1
CH	-3.02035	0	0	-8.46788	0.013966	0.009462	1
WI	-1.38629	0	0	0	0	0	1
OT	-3.02035	0	0	-8.46788	0.013966	0.009462	1

Table 5.0.2 Coefficients used in the individual tree mortality equation {5.0.1} in the OP variant (SMC .version)

Species	d0	d1	d2	d3	d4	d5	d6
SF	-7.60159	-0.20052	0	0	0.044133	0.000638	1
WF	-7.60159	-0.20052	0	0	0.044133	0.000638	1
GF	-7.60159	-0.20052	0	0	0.044133	0.000638	1
AF	-7.60159	-0.20052	0	0	0.044133	0.000638	1
RF	-3.12162	-0.44724	0	-2.48387	0.018431	0.013539	1
SS	-3.12162	-0.44724	0	-2.48387	0.018431	0.013539	1
NF	-7.60159	-0.20052	0	0	0.044133	0.000638	1
YC	-0.76161	-0.52937	0	-4.74019	0.011959	0.007564	1
IC	-0.76161	-0.52937	0	-4.74019	0.011959	0.007564	1
ES	-3.12162	-0.44724	0	-2.48387	0.018431	0.013539	1
LP	-3.12162	-0.44724	0	-2.48387	0.018431	0.013539	1
JP	-3.12162	-0.44724	0	-2.48387	0.018431	0.013539	1
SP	-3.12162	-0.44724	0	-2.48387	0.018431	0.013539	1
WP	-3.12162	-0.44724	0	-2.48387	0.018431	0.013539	1
PP	-3.12162	-0.44724	0	-2.48387	0.018431	0.013539	1
DF	-3.12162	-0.44724	0	-2.48387	0.018431	0.013539	1
RW	-0.76161	-0.52937	0	-4.74019	0.011959	0.007564	1
RC	-0.76161	-0.52937	0	-4.74019	0.011959	0.007564	1
WH	-0.76161	-0.52937	0	-4.74019	0.011959	0.007564	1
MH	-0.76161	-0.52937	0	-4.74019	0.011959	0.007564	1
BM	-2.97682	0	0	-6.22325	0	0	1
RA	-2	-0.5	0.015	-3	0.015	0.01	1
MA	-6.0896	-0.24562	0	-3.20827	0.033348	0.013571	1
TO	-2.97682	0	0	-6.22325	0	0	1
GC	-6.0896	-0.24562	0	-3.20827	0.033348	0.013571	1
AS	-2.97682	0	0	-6.22325	0	0	1
CW	-2.97682	0	0	-6.22325	0	0	1
WO	-6.00031	-0.10491	0	-0.99542	0.009127	0.871157	1
WJ	-4.07278	-0.17643	0	-1.72945	0	0.012526	1
LL	-7.60159	-0.20052	0	0	0.044133	0.000638	1
WB	-3.12162	-0.44724	0	-2.48387	0.018431	0.013539	1
KP	-3.12162	-0.44724	0	-2.48387	0.018431	0.013539	1

PY	-4.07278	-0.17643	0	-1.72945	0	0.012526	1
DG	-3.02035	0	0	-8.46788	0.013966	0.009462	1
HT	-3.02035	0	0	-8.46788	0.013966	0.009462	1
CH	-3.02035	0	0	-8.46788	0.013966	0.009462	1
WI	-1.38629	0	0	0	0	0	1
OT	-3.02035	0	0	-8.46788	0.013966	0.009462	1

If all tree records for the projection cycle are non-valid ORGANON tree records, then the OP variant uses logic from the PN variant. The large tree equations except for Oregon white oak, were developed by Hann et al 2003 and Hann and Hanus 2001. The small tree equations were developed by Gould and Harrington 2013. The equation for redwood was developed by Castle 2021.

The annual mortality rate estimates, *RA*, predicts individual tree mortality based on trees size, stand density and other tree and stand attributes. The equations used to calculate the annual mortality rate are shown in equations {5.0.3} – {5.0.6}.

{5.0.3} Hann Mortality Equations:

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

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

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

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

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

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

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

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

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

HT < 4.5: $DBHA = DBH+HT* a_1$

HT ≥ 4.5: $DBHA = DBH+4.5* a_1$

{5.0.6} Redwood mortality equation

$RA = [1/(1+\exp(2.901447+ 0.578694*DBH - 0.001793*PBAL)))]$

where:

RA	is the estimated annual mortality rate (bound to minimum value of 0.001)
DBH	is tree diameter at breast height
BA	is total stand basal area
BAL	is total basal area in trees larger
RELHT	is tree height divided by average height of the 40 largest diameter trees in the stand

CR	is crown ratio
CRADJ	*crown adjustment =1.0-exp(-(25.0*CR)²)*
XSITE1	*Douglas-fir site index*
XSITE2	*Western hemlock site index*
PBAL	is basal area of trees larger than the subject tree on the inventory point
MCLASS	Mortality class based on shade tolerance table 5.0.1
HT	is tree height
d_{0-5}	are species-specific coefficients shown in table 5.0.1
a_i	is a species-specific coefficient from table 4.6.1.1

Table 5.0.3 values used in the individual tree mortality equation {5.0.3 - 5.0.5} in the OP variant.

Species Code	Coefficients							
	group	d_0	d_1	d_2	d_3	d_4	d_5	MCLASS
SF	2	-7.60159	-0.20052	0	0	0.044133	0.000638	1
WF	2	-7.60159	-0.20052	0	0	0.044133	0.000638	1.5
GF	2	-7.60159	-0.20052	0	0	0.044133	0.000638	1.5
AF	2	-7.60159	-0.20052	0	0	0.044133	0.000638	1.5
RF	2	-7.60159	-0.20052	0	0	0.044133	0.000638	1.5
SS	2	-7.60159	-0.20052	0	0	0.044133	0.000638	1.5
NF	2	-7.60159	-0.20052	0	0	0.044133	0.000638	2.25
YC	4	-1.92269	-0.13608	0.00248	-3.17812	0	0.004684	1.5
IC	4	-1.92269	-0.13608	0.00248	-3.17812	0	0.004684	2.25
ES	2	-7.60159	-0.20052	0	0	0.044133	0.000638	1.5
LP	4	-1.05	-0.19436	0.003803	-3.5573	0.003972	0.005574	3.375
JP	4	-1.05	-0.19436	0.003803	-3.5573	0.003972	0.005574	3.375
SP	4	-1.05	-0.19436	0.003803	-3.5573	0.003972	0.005574	2.25
WP	4	-1.05	-0.19436	0.003803	-3.5573	0.003972	0.005574	2.25
PP	4	-1.05	-0.19436	0.003803	-3.5573	0.003972	0.005574	3.375
DF	1	-4.13142	-1.13736	0	-0.82331	0.030775	0.00991	2.25
RC	3	-0.76161	-0.52937	0	-4.74019	0.011959	0.007564	1
WH	3	-0.76161	-0.52937	0	-4.74019	0.011959	0.007564	1
MH	3	-0.76161	-0.52937	0	-4.74019	0.011959	0.007564	1
BM	4	-2.97682	0	0	-6.22325	0	0	1
RA	4	-2	-0.5	0.015	-3	0.015	0.01	3.375
WA	4	-2	-0.5	0.015	-3	0.015	0.01	2.25
PB	4	-2	-0.5	0.015	-3	0.015	0.01	3.375

Species Code	Coefficients							
	group	d_0	d_1	d_2	d_3	d_4	d_5	MCLASS
GC	4	-4.13175	-0.0577	0	0	0.004861	0.009981	2.25
AS	4	-2	-0.5	0.015	-3	0.015	0.01	5.062
CW	4	-2	-0.5	0.015	-3	0.015	0.01	5.062
WO	5	0	0	0	0	0	0	5.062
WJ	4	-1.05	-0.19436	0.003803	-3.5573	0.003972	0.005574	5.062
LL	4	-1.05	-0.19436	0.003803	-3.5573	0.003972	0.005574	3.375
WB	4	-1.05	-0.19436	0.003803	-3.5573	0.003972	0.005574	3.375
KP	4	-1.05	-0.19436	0.003803	-3.5573	0.003972	0.005574	5.062
PY	4	-4.07278	-0.17643	0	-1.72945	0	0.012526	1
DG	4	-3.02035	0	0	-8.46788	0.013966	0.009462	1
HT	4	-3.02035	0	0	-8.46788	0.013966	0.009462	2.25
CH	4	-3.02035	0	0	-8.46788	0.013966	0.009462	2.25
WI	4	-2	-0.5	0.015	-3	0.015	0.01	5.062
--	1	-4.13142	-1.13736	0	-0.82331	0.030775	0.00991	1
OT	1	-4.13412	-1.13736	0	-0.82331	0.030775	0.00991	5.062

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

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

where:

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

6.0 Regeneration

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

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

Table 6.0.1 Regeneration parameters by species in the OP variant.

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

Species Code	Sprouting Species	Minimum Bud Width (in)	Minimum Tree Height (ft)	Maximum Tree Height (ft)
LL	No	0.3	1.5	20.0
WB	No	0.4	1.0	20.0
KP	No	0.4	1.0	20.0
PY	Yes	0.2	1.0	20.0
DG	Yes	0.2	1.0	20.0
HT	Yes	0.2	1.0	20.0
CH	Yes	0.2	1.0	20.0
WI	Yes	0.2	1.0	20.0
OT	No	0.2	1.0	20.0

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

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

{6.0.1} For stump sprouting hardwood species

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

{6.0.2} For root suckering hardwood species

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

{6.0.3} $TPA_s = TPA_i * PS$

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

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

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

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 OP variant.

Species Code	Sprouting Probability	Number of Sprout Records	Source
RW	{6.0.4}	{6.0.2}	Neal 1967 Boe 1975 Griffith 1992
BM	0.9	{6.0.2}	Roy 1955 Tappenier et al. 1996 Ag. Handbook 654
RA	{6.0.5}	{6.0.2}	Harrington 1984 Uchytil 1989
MA	0.9	{6.0.2}	McDonald et al. 1983 McDonald and Tappenier 1990
TO	0.9	{6.0.2}	Harrington et al. 1992 Wilkinson et al. 1997 Fryer 2008
GC	0.9	{6.0.2}	Harrington et al. 1992 Wilkinson et al. 1997 Fryer 2008
AS	{6.0.6}	1	Keyser 2001
CW	0.9	{6.0.2}	Gom and Rood 2000 Steinberg 2001
WO	0.9	{6.0.1}	Roy 1955 Gucker 2007
PY	0.4	1	Minore 1996 Ag. Handbook 654
DG	0.9	{6.0.1}	Gucker 2005
HT	No info available--default to 0.7	1	n/a
CH	0.9	{6.0.2}	Mueggler 1965 Leedge and Hickey 1971 Morgan and Neuenschwander 1988
WI	0.9	1	Ag. Handbook 654

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

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

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

7.0 Volume

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

Table 7.0.1 Volume merchantability standards for the OP variant.

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

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

Common Name	**Location Code**	**Equation Number**	**Model Name**
Pacific silver fir	609, 612, 800	616BEHW011	Behre's Hyperbola
Pacific silver fir	708, 709, 712	B00BEHW011	Behre's Hyperbola
white fir	609, 612, 800	616BEHW015	Behre's Hyperbola
white fir	708, 709, 712	B00BEHW015	Behre's Hyperbola
grand fir	609, 612, 800	616BEHW017	Behre's Hyperbola
grand fir	708, 709, 712	B00BEHW017	Behre's Hyperbola
subalpine fir	609, 612, 800	616BEHW019	Behre's Hyperbola
subalpine fir	708, 709, 712	B00BEHW015	Behre's Hyperbola

Common Name	Location Code	Equation Number	Model Name
California red fir	609, 612, 800	616BEHW020	Behre's Hyperbola
California red fir	708, 709, 712	B00BEHW021	Behre's Hyperbola
Sitka spruce	609, 800	F03FW2W263	Flewelling's 2-Point Profile Model
Sitka spruce	612	616BEHW098	Behre's Hyperbola
Sitka spruce	708, 709, 712	B00BEHW098	Behre's Hyperbola
noble fir	609, 612, 800	616BEHW022	Behre's Hyperbola
noble fir	708, 709, 712	B00BEHW022	Behre's Hyperbola
Alaska cedar	609, 612, 800	616BEHW042	Behre's Hyperbola
Alaska cedar	708, 709, 712	B00BEHW042	Behre's Hyperbola
incense cedar	609, 612, 800	616BEHW081	Behre's Hyperbola
incense cedar	708, 709, 712	B00BEHW081	Behre's Hyperbola
Engelmann spruce	609, 612, 800	616BEHW093	Behre's Hyperbola
Engelmann spruce	708, 709, 712	B00BEHW093	Behre's Hyperbola
lodgepole pine	609, 612, 800	616BEHW108	Behre's Hyperbola
lodgepole pine	708, 709, 712	B00BEHW108	Behre's Hyperbola
Jeffrey pine	609, 612, 800	616BEHW116	Behre's Hyperbola
Jeffrey pine	708, 709, 712	B00BEHW116	Behre's Hyperbola
sugar pine	609, 612, 800	616BEHW117	Behre's Hyperbola
sugar pine	708, 709, 712	B00BEHW117	Behre's Hyperbola
western white pine	609, 612, 800	616BEHW119	Behre's Hyperbola

Common Name	Location Code	Equation Number	Model Name
western white pine	708, 709, 712	B00BEHW119	Behre's Hyperbola
ponderosa pine	609, 612, 800	616BEHW122	Behre's Hyperbola
ponderosa pine	708, 709, 712	B00BEHW122	Behre's Hyperbola
Douglas-fir	609, 800	F03FW2W202	Flewelling's 2-Point Profile Model
Douglas-fir	612	F00FW2W202	Flewelling's 2-Point Profile Model
Douglas-fir	708, 709	B01BEHW202	Behre's Hyperbola
Douglas-fir	712	B02BEHW202	Behre's Hyperbola
redwood	609, 612, 800	616BEHW211	Behre's Hyperbola
redwood	708, 709, 712	B00BEHW211	Behre's Hyperbola
western redcedar	609, 612, 800	616BEHW242	Behre's Hyperbola
western redcedar	708, 709, 712	B00BEHW242	Behre's Hyperbola
western hemlock	612	F03FW2W263	Flewelling's 2-Point Profile Model
western hemlock	609, 800	F00FW2W263	Flewelling's 2-Point Profile Model
western hemlock	708, 709, 712	B00BEHW263	Behre's Hyperbola
mountain hemlock	609, 612, 800	616BEHW264	Behre's Hyperbola
mountain hemlock	708, 709, 712	B00BEHW260	Behre's Hyperbola
bigleaf maple	609, 612, 800	616BEHW312	Behre's Hyperbola
bigleaf maple	708, 709, 712	B00BEHW312	Behre's Hyperbola
red alder	609, 612, 800	616BEHW351	Behre's Hyperbola
red alder	708, 709, 712	B00BEHW351	Behre's Hyperbola

Common Name	Location Code	Equation Number	Model Name
Pacific madrone	609, 612, 800	616BEHW361	Behre's Hyperbola
Pacific madrone	708, 709, 712	B00BEHW361	Behre's Hyperbola
tanoak	609, 612, 800	616BEHW631	Behre's Hyperbola
tanoak	708, 709, 712	B00BEHW631	Behre's Hyperbola
giant chinquapin	609, 612, 800	616BEHW431	Behre's Hyperbola
giant chinquapin	708, 709, 712	B00BEHW431	Behre's Hyperbola
quaking aspen	609, 612, 800	616BEHW746	Behre's Hyperbola
quaking aspen	708, 709, 712	B00BEHW999	Behre's Hyperbola
black cottonwood	609, 612, 800	616BEHW747	Behre's Hyperbola
black cottonwood	708, 709, 712	B00BEHW747	Behre's Hyperbola
Oregon white oak	609, 612, 800	616BEHW815	Behre's Hyperbola
Oregon white oak	708, 709, 712	B00BEHW800	Behre's Hyperbola
western juniper	609, 612, 800	616BEHW064	Behre's Hyperbola
western juniper	708, 709, 712	B00BEHW242	Behre's Hyperbola
subalpine larch	609, 612, 800	616BEHW072	Behre's Hyperbola
subalpine larch	708, 709, 712	B00BEHW073	Behre's Hyperbola
whitebark pine	609, 612, 800	616BEHW101	Behre's Hyperbola
whitebark pine	708, 709, 712	B00BEHW119	Behre's Hyperbola
knobcone pine	609, 612, 800	616BEHW103	Behre's Hyperbola
knobcone pine	708, 709, 712	B00BEHW108	Behre's Hyperbola

Common Name	Location Code	Equation Number	Model Name
Pacific yew	609, 612, 800	616BEHW231	Behre's Hyperbola
Pacific yew	708, 709, 712	B00BEHW231	Behre's Hyperbola
Pacific dogwood	609, 612, 800	616BEHW492	Behre's Hyperbola
Pacific dogwood	708, 709, 712	B00BEHW999	Behre's Hyperbola
hawthorn	609, 612, 800	616BEHW500	Behre's Hyperbola
hawthorn	708, 709, 712	B00BEHW999	Behre's Hyperbola
bitter cherry	609, 612, 800	616BEHW768	Behre's Hyperbola
bitter cherry	708, 709, 712	B00BEHW999	Behre's Hyperbola
willow	609, 612, 800	616BEHW920	Behre's Hyperbola
willow	708, 709, 712	B00BEHW999	Behre's Hyperbola
other	609, 612, 800	616BEHW999	Behre's Hyperbola
other	708, 709, 712	B00BEHW999	Behre's Hyperbola

Table 7.0.3 Citations by Volume Model in the OP variant

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

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

Species Code	Behr's Hyperbola Equation Number	Form Class				
		0<DBH<11	11<=DBH<21	21<=DBH<31	31<=DBH<41	DBH>=41
Olympic NF (609)						
SF	616BEHW011	97	97	91	90	90
WF	616BEHW015	97	97	93	91	91

Species Code	Behr’s Hyperbola Equation Number	Form Class				
		0<DBH<11	11<=DBH<21	21<=DBH<31	31<=DBH<41	DBH>=41
GF	616BEHW017	86	86	83	82	82
AF	616BEHW019	97	97	97	95	95
RF	616BEHW020	83	83	80	80	79
SS*	616BEHW098	89	89	86	84	84
NF	616BEHW022	88	88	84	82	82
YC	616BEHW042	99	99	88	87	86
IC	616BEHW081	81	81	72	71	70
ES	616BEHW093	90	90	86	85	85
LP	616BEHW108	96	96	96	93	93
JP	616BEHW116	92	92	82	80	79
SP	616BEHW117	79	79	76	76	75
WP	616BEHW119	95	95	91	90	90
PP	616BEHW122	89	89	82	80	80
DF*	616BEHW202	82	82	79	78	78
RW	616BEHW211	82	82	79	78	78
RC	616BEHW242	93	93	87	86	86
WH*	616BEHW263	96	96	93	91	91
MH	616BEHW264	98	98	95	94	93
BM	616BEHW312	86	86	84	82	82
RA	616BEHW351	84	84	81	80	79
MA	616BEHW361	79	79	76	76	75
TO	616BEHW631	79	79	76	74	74
GC	616BEHW431	87	87	81	79	79
AS	616BEHW746	85	85	81	80	79
CW	616BEHW747	82	82	80	79	79
WO	616BEHW815	95	95	82	82	82
WJ	616BEHW064	81	81	81	81	74
LL	616BEHW072	92	92	92	92	92
WB	616BEHW101	96	96	96	96	96
KP	616BEHW103	96	96	89	87	86
PY	616BEHW231	76	76	69	65	65
DG	616BEHW492	95	95	86	82	82
HT	616BEHW500	95	95	95	95	95
CH	616BEHW768	86	86	86	84	84
WI	616BEHW920	92	92	92	92	92

Species Code	Behr's Hyperbola Equation Number	Form Class				
		0<DBH<11	11<=DBH<21	21<=DBH<31	31<=DBH<41	DBH>=41
OT	616BEHW999	84	84	80	79	78
Siuslaw NF (612)						
SF	616BEHW011	95	95	89	88	88
WF	616BEHW015	97	97	93	91	91
GF	616BEHW017	86	86	83	82	82
AF	616BEHW019	96	96	93	91	91
RF	616BEHW020	83	83	80	80	79
SS	616BEHW098	89	89	86	84	84
NF	616BEHW022	88	88	84	82	82
YC	616BEHW042	88	88	79	77	76
IC	616BEHW081	81	81	72	71	70
ES	616BEHW093	90	90	86	85	85
LP	616BEHW108	98	98	93	90	90
JP	616BEHW116	92	92	82	80	79
SP	616BEHW117	79	79	76	76	75
WP	616BEHW119	93	93	89	88	88
PP	616BEHW122	89	89	82	80	80
DF	616BEHW202	73	73	71	70	70
RW	616BEHW211	82	82	79	78	78
RC	616BEHW242	68	68	63	63	62
WH	616BEHW263	75	75	72	71	71
MH	616BEHW264	89	89	83	82	81
BM	616BEHW312	86	86	84	82	82
RA	616BEHW351	84	84	81	80	79
MA	616BEHW361	79	79	76	76	75
TO	616BEHW631	79	79	76	74	74
GC	616BEHW431	87	87	81	79	79
AS	616BEHW746	85	85	81	80	79
CW	616BEHW747	82	82	80	79	79
WO	616BEHW815	95	95	82	82	82
WJ	616BEHW064	81	81	81	81	74
LL	616BEHW072	92	92	92	92	92
WB	616BEHW101	96	96	96	96	96
KP	616BEHW103	96	96	89	87	86
PY	616BEHW231	76	76	69	65	65

Species Code	Behr's Hyperbola Equation Number	Form Class				
		0<DBH<11	11<=DBH<21	21<=DBH<31	31<=DBH<41	DBH>=41
DG	616BEHW492	95	95	86	82	82
HT	616BEHW500	95	95	95	95	95
CH	616BEHW768	86	86	86	84	84
WI	616BEHW920	92	92	92	92	92
OT	616BEHW999	84	84	80	79	78

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

BLM Locations:		**708**	**709**	**712**
SF	B00BEHW011	84	82	80
WF	B00BEHW015	86	78	84
GF	B00BEHW017	84	82	86
AF	B00BEHW015	82	78	80
RF	B00BEHW021	75	78	75
SS	B00BEHW098	80	78	80
NF	B00BEHW022	84	78	78
YC	B00BEHW042	73	78	70
IC	B00BEHW081	73	70	70
ES	B00BEHW093	77	78	72
LP	B00BEHW108	68	78	80
JP	B00BEHW116	75	78	75
SP	B00BEHW117	75	72	76
WP	B00BEHW119	76	78	80
PP	B00BEHW122	82	70	80
DF	B01BEHW202	80	78	74
RW	B00BEHW211	75	78	75
RC	B00BEHW242	76	72	70
WH	B00BEHW260	88	80	84
MH	B00BEHW260	72	78	72
BM	B00BEHW312	84	78	82
RA	B00BEHW351	88	80	82
MA	B00BEHW361	70	78	82
TO	B00BEHW631	70	78	70
GC	B00BEHW431	75	80	82
AS	B00BEHW999	75	78	75
CW	B00BEHW747	74	82	74
WO	B00BEHW800	70	78	70

BLM Locations:		708	709	712
WJ	B00BEHW242	60	78	60
LL	B00BEHW073	75	78	75
WB	B00BEHW119	82	78	82
KP	B00BEHW108	82	78	82
PY	B00BEHW231	60	78	82
DG	B00BEHW999	70	78	70
HT	B00BEHW999	70	78	70
CH	B00BEHW999	75	78	86
WI	B00BEHW999	75	78	75
OT	B00BEHW999	74	78	74

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 OP variant, refer to the updated FFE-FVS model documentation (Rebain, comp. 2010) available on the FVS website.

9.0 Insect and Disease Extensions

The FVS Insect and Pathogen model for dwarf mistletoe has been developed for the base variant of the OP variant through the participation and contribution of various organizations led by Forest Health Protection. This model is currently maintained by the Forest Management Service Center and regional Forest Health Protection specialists. Additional details regarding this 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 B: Plant Association Codes

Table 11.2.1 Plant association codes recognized in the PN variant.

FVS Sequence Number = Plant Association Species Type	Alpha Code	Site Species	Site Index*	Max. SDI*	Source*	Reference
1 = PSME/HODI-ROGY Douglas-fir/oceanspray-baldhip rose	CDS221	DF	54	750	C	R6 E TP-036-92 p. 37
2 = PSME/GASH Douglas-fir/salal	CDS255	DF	62	955	C	R6 E TP-036-92 p. 93
3 = PSME/ARUV Douglas-fir/kinnikinnick	CDS651	DF	33	600	C	R6 E TP-036-92 p. 91
4 = ABLA2/LULA Subalpine fir/subalpine lupine	CEF321	AF	50	367	H	R6 E TP-255-86 p. 93
5 = ABLA2/RHAL-OLY Subalpine fir/white rhododendron (Olympic)	CES212	AF	65	535	H	R6 E TP-036-92 p. 85
6 = ABLA2/VAME-OLY Subalpine fir/big huckleberry (Olympic)	CES321	AF	91	955	H	R6 E TP-255-86 p. 358
7 = ABLA2/JUCO4 Subalpine fir/common juniper	CES621	AF	31	560	C	R6 E TP-255-86 p. 365
8 = ABAM/OXOR-OLY Silver fir/oxalis (Olympic)	CFF111	SF	150	1050	C	R6 E TP-036-92 p. 87
9 = ABAM/ACTR-TIUN Silver fir/vanillaleaf-foamflower	CFF211	DF	84	950	C	R6 E TP-255-86 p. 352
10 = ABAM/XETE Silver fir/beargrass	CFF311	SF	83	1093	H	R6 E TP-036-92 p. 83
11 = ABAM/POMU Silver fir/swordfern	CFF611	SF	145	995	C	R6 E TP-255-86 p. 339
12 = ABAM/POMU-OXOR Silver fir/swordfern-oxalis	CFF612	SF	154	845	C	R6 E TP-036-92 p. 81
13 = ABAM/Dep. Silver fir/depauperate	CFF911	DF	84	861	H	R6 E TP-255-86 p. 268
14 = ABAM/GASH/OXOR Silver fir/salal/oxalis	CFS156	SF	149	1015	C	R6 E TP-255-86 p. 275
15 = ABAM/VAME/XETE-OLY Silver fir/big huckleberry/beargrass (Olympic)	CFS211	SF	83	1050	C	R6 E TP-036-92 p. 25
16 = ABAM/VAAL-OLY Silver fir/Alaska huckleberry (Olympic)	CFS212	SF	127	1090	C	R6 E TP-279-87 p. 55
17 = ABAM/VAAL/ERMO Silver fir/Alaska huckleberry/avalanche lily	CFS213	SF	108	835	C	R6 E TP-279-87 p. 57
18 = ABAM/VAAL/XETE Silver fir/Alaska huckleberry/beargrass	CFS214	DF	84	1090	C	R6 E Tp-279-87 p. 49
19 = ABAM/VAAL/TIUN Silver fir/Alaska huckleberry/foamflower	CFS215	SF	101	1101	H	R6 E TP-004-88 p. 59
20 = ABAM/VAAL/OXOR Silver fir/Alaska huckleberry/oxalis	CFS217	SF	136	1055	C	R6 E TP-006-88 p. 45
21 = ABAM/VAAL/CLUN Silver fir/Alaska huckleberry/queen's cup	CFS218	SF	111	1080	C	R6 E TP-255-86 p. 262
22 = ABAM/VAAL/LIBO2 Silver fir/Alaska huckleberry/twinflower	CFS219	SF	115	955	C	R6 E TP-255-86 p. 238
23 = ABAM/OPHO-OLY Silver fir/devil's club (Olympic)	CFS311	SF	118	920	C	R6 E TP-036-92 p. 33

FVS Sequence Number = Plant Association Species Type	Alpha Code	Site Species	Site Index*	Max. SDI*	Source*	Reference
24 = ABAM/RHMA-OLY Silver fir/rhododendron (Olympic)	CFS611	SF	107	996	H	R6 E TP-036-92 p. 27
25 = ABAM/RHMA-VAAL Silver fir/rhododendron-Alaska huckleberry	CFS612	SF	96	470	C	R6 E TP-255-86 p. 253
26 = TSHE/OXOR-OLY Western hemlock/oxalis (Olympic)	CHF112	WH	104	780	C	R6 E TP-036-92 p. 35
27 = TSHE/OXOR-COAST Western hemlock/Oregon oxalis (Coast)	CHF121	WH	110	960	C	R6 E TP-036-92 p. 29
28 = TSHE/POMU-COAST Western hemlock/swordfern (Coast)	CHF122	WH	114	925	C	R6 E TP-255-86 p. 244
29 = TSHE/POMU-OXOR-OLY Western hemlock/swordfern-oxalis (Olympic)	CHF131	WH	94	950	C	R6 E TP-255-86 p. 305
30 = TSHE/POMU-TITR Western hemlock/swordfern-foamflower	CHF132	DF	116	1010	C	R6 AG 3-1-73 p. 34
31 = TSHE/ACTR-OLY Western hemlock/vanillaleaf (Olympic)	CHF211	DF	108	1040	C	R6 E TP-279-87 p. 29
32 = TSHE/XETE-OLY Western hemlock/beargrass (Olympic)	CHF511	WH	50	696	H	R6 E TP-279-87 p. 41
33 = TSHE/Dep. Western hemlock/depauperate	CHF911	WH	105	1165	H	R6 E TP-279-87 p. 43
34 = TSHE/LYAM-OLY Western hemlock/skunkcabbage (Olympic)	CHM111	RA	52	760	C	R6 E TP-279-87 p. 39
35 = TSHE/BENE-COAST Western hemlock/dwarf Oregon grape (Coast)	CHS121	DF	118	985	C	R6 E TP-279-87 p. 33
36 = TSHE/BENE-GASH-COAST Western hemlock/dwarf Oregon grape-salal (Coast)	CHS122	WH	114	820	C	R6 E TP-279-87 p. 35
37 = TSHE/GASH-COAST Western hemlock/salal (Coast)	CHS123	WH	112	1210	C	R6 E TP-279-87 p. 45
38 = TSHE/GASH-OLY Western hemlock/salal (Olympic)	CHS131	WH	78	1050	C	R6 AG 3-1-73 p. 36
39 = TSHE/GASH/XETE Western hemlock/salal/beargrass	CHS132	DF	67	880	C	R6 E TP-255-86 p. 250
40 = TSHE/GASH-VAOV2 Western hemlock/salal-evergreen huckleberry	CHS133	DF	98	1606	H	R6 E TP-036-92 p. 79
41 = TSHE/GASH-HODI Western hemlock/salal-oceanspray	CHS134	DF	78	810	C	R6 AG 3-1-73 p. 35
42 = TSHE/GASH/OXOR Western hemlock/salal/oxalis	CHS136	WH	84	895	C	R6 E TP-255-86 p. 259
43 = TSHE/GASH/POMU Western hemlock/salal/swordfern	CHS137	DF	108	975	C	R6 E TP-255-86 p.230
44 = TSHE/BENE-OLY Western hemlock/Oregongrape(Olympic)	CHS138	DF	71	1095	C	R6 E TP-255-86 p. 230
45 = TSHE/BENE/POMU-OLY Western hemlock/Oregongrape/swordfern (Olympic)	CHS139	DF	119	955	C	R6 E TP-036-92 p. 121
46 = TSHE/ACCI-GASH-COAST Western hemlock/vine maple-salal (Coast)	CHS221	DF	122	825	C	R6 E TP-036-92 p. 119
47 = TSHE/ACCI/POMU-COAST Western hemlock/vine maple/swordfern (Coast)	CHS222	DF	128	875	C	R6 E TP-255-86 p. 378
48 = TSHE/RHMA-BENE-COAST Western hemlock/rhododendron-dwarf OR grape (Coast)	CHS321	WH	98	1107	H	R6 E TP-255-86 p. 383

FVS Sequence Number = Plant Association Species Type	Alpha Code	Site Species	Site Index*	Max. SDI*	Source*	Reference
49 = TSHE/RHMA-GASH-COAST Western hemlock/rhododendron-salal	CHS322	DF	114	840	C	R6 E TP-036-92 p. 107
50 = TSHE/RHMA/POMU-COAST Western hemlock/rhododendron/swordfern (Coast)	CHS323	WH	84	945	C	R6 E TP-036-92 p. 109
51 = TSHE/RHMA/VAOV2-COAST W.hemlock/rhododendron-evergreen huckleberry(Coast)	CHS324	WH	80	865	C	R6 AG 3-1-73 p. 28
52 = TSHE/RHMA-OLY Western hemlock/rhododendron (Olympic)	CHS331	WH	56	1145	C	R6 E TP-036-92 p. 117
53 = TSHE/RHMA/XETE-OLY Western hemlock/rhododendron/beargrass (Olympic)	CHS332	DF	56	610	C	R6 E TP-036-92 p. 111
54 = TSHE/RHMA-BENE-OLY Western hemlock/rhododendron-Oregongrape (Olympic)	CHS333	DF	80	1065	C	R6 E TP-036-92 p. 113
55 = TSHE/RHMA-GASH-OLY Western hemlock/rhododendron-salal (Olympic)	CHS334	DF	66	810	C	R6 E TP-036-92 p. 115
56 = TSHE/RHMA/POMU-OLY Western hemlock/rhododendron/swordfern (Olympic)	CHS335	DF	88	845	C	R6 E TP-036-92 p. 97
57 = TSHE/RUSP-COAST Western hemlock/salmonberry (Coast)	CHS421	WH	110	675	C	R6 E TP-036-92 p. 99
58 = TSHE/RUSP-ACCI-COAST Western hemlock/salmonberry-vine maple (Coast)	CHS422	WH	94	660	C	R6 E TP-036-92 p. 101
59 = TSHE/RUSP-GASH-COAST Western hemlock/salmonberry-salal (Coast)	CHS423	DF	119	600	C	R6 E TP-279-87 p. 27
60 = TSHE/OPHO-OLY Western hemlock/devil's club (Olympic)	CHS512	DF	134	485	C	R6 E TP-255-86 p. 372
61 = TSHE/OPHO-COAST Western hemlock/devil's club (Coast)	CHS521	WH	114	375	C	R6 E TP-255-86 p. 377
62 = TSHE/VAOV2-COAST Western hemlock/evergreen huckleberry (Coast)	CHS610	WH	118	935	C	R6 E TP-036-92 p. 103
63 = TSHE/VAAL Western hemlock/Alaska huckleberry	CHS621	WH	98	1025	C	R6 E TP-036-92 p. 105
64 = TSHE/VAAL/XETE Western hemlock/Alaska huckleberry/beargrass	CHS622	DF	70	610	C	R6 E TP-036-92 p. 51
65 = TSHE/VAAL/OXOR-OLY Western hemlock/Alaska huckleberry/oxalis (Olympic)	CHS623	WH	94	570	C	R6 E TP-036-92 p. 53
66 = TSHE/VAAL-GASH-OLY Western hemlock/Alaska huckleberry-salal (Olympic)	CHS624	WH	92	915	C	R6 E TP-255-86 p. 298
67 = TSME/VAAL/ERMO Mountain hemlock/Alaska huckleberry/avalanche lily	CMS242	MH	14	1021	H	R6 E TP-036-92 p. 59
68 = PISI/POMU-OXOR Sitka spruce/swordfern-oxalis	CSF111	SS	120	930	C	R6 E TP-255-86 p. 279
69 = PISI/POMU-COAST Sitka spruce/swordfern (Coast)	CSF121	SS	115	930	C	R6 E TP-279-87 p. 47
70 = PISI/OXOR-COAST Sitka spruce/Oregon oxalis	CSF321	SS	120	930	C	R6 E TP-036-92 p. 49

FVS Sequence Number = Plant Association Species Type	Alpha Code	Site Species	Site Index*	Max. SDI*	Source*	Reference
71 = PISI/MEFE-VAPA-COAST Sitka spruce/fool's huckleberry-red huckleb (Coast)	CSS221	SS	125	1000	C	R6 E TP-036-92 p. 45
72 = PISI/GASH-COAST Sitka spruce/salal (Coast)	CSS321	SS	117	615	C	R6 E TP-036-92 p. 47
73 = PISI/RUSP-COAST Sitka spruce/salmonberry (Coast)	CSS521	SS	123	545	C	R6 E TP-036-92 p. 73
74 = PISI/RUSP-GASH-COAST Sitka spruce/salmonberry-salal (Coast)	CSS522	SS	111	535	C	R6 E TP-255-86 p. 320
75 = PISI/OPHO-COAST Sitka spruce/devil's club (Coast)	CSS621	SS	121	1000	C	R6 E TP-036-92 p. 71

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