This document is part of a collection of [Ecological Integrity Assessments] addressing 67 of Washington's 99 [Ecological Systems]. These documents were prepared by the Washington Natural Heritage Program with funding provided by the Washington Department of Fish and Wildlife.

Ecological Integrity Assessment: North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest and North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest

Ecological Summary

These forest ecological systems combine to form the matrix vegetation in the lower montane, foothills and lowlands of western British Columbia, western Washington and much of western Oregon except in rainshadows. In Washington, the North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest (hereafter referred to as Dry-Mesic) appears as the forest matrix in a landscape mosaic with the North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest system (hereafter referred to as Mesic-Wet) that occurs in mesic-wet environments. Landfire considers Mesic-Wet (Model 0110390**)** the matrix in Washington with large patches of Dry-Mesic forests (Model 0110370) and the opposite matrix:large patch relationship in Oregon. These two systems are combined for the EIA although differences will be emphasized when appropriate.

The Dry-Mesic system occurs as lowland forests on dry to mesic sites. The Mesic-Wet forest system is a significant component of the lowland and low montane forests of western Washington, except on extremely dry sites and in the hypermaritime zone near the outer coast. These forests are best represented on lower mountain slopes with high precipitation, long frost-free periods, and low to moderate fire frequencies. The associated climate is relatively mild and moist to wet. Mean annual precipitation is mostly 90-254 cm (35-100 inches) falling mostly as winter rain. Elevation ranges from sea level to 610 m (2000 feet). Snowfall is rare in lower elevations but occurs more regularly with increasing elevation but rarely establishes a snow pack. Topography ranges from relatively flat glacial till plains to steep mountainous terrain. Dry-Mesic fores are on soils are generally well-drained and are mesic to dry for much of the year. Mesic-Wet forest soils are moist to somewhat wet (but not saturated) for much of the year and are well-drained to somewhat poorly drained.

The Dry-Mesic system is characterized by giant *Pseudotsuga menziesii* forests with *Tsuga heterophylla* or *Thuja plicata* co-dominant or occasional in the understory. Other tree species such as *Abies grandis, Acer macrophyllum, Thuja plicata, Acer macrophyllum, Abies grandis,* and *Pinus monticola* appear less abundantly but sometimes can be significant canopy components. *Tsuga heterophylla* is generally the dominant regenerating tree species and is typically lacking from young stands, especially in the Puget Lowlands. Late seral stands typically have an abundance of large coniferous trees, a multi-layered canopy structure, biological legacies of large snags, and many large logs on the ground. Early seral stands typically have smaller trees, single-storied canopies, may be dominated by conifers, broadleaf trees, or both and most cases have biological legacies of previous stands. The understory may contain *Gaultheria shallon, Mahonia nervosa, Rhododendron macrophyllum, Acer circinatum, Achlys triphylla*, *Vaccinium ovatum*, and *Linnaea borealis. Polystichum munitum* may also be present but less than 30-40% total cover. Mosses are often a major ground cover. Lichens are abundant in the canopy of old stands.

Mesic-Wet forest overstory canopy is dominated by *Pseudotsuga menziesii*, *Tsuga heterophylla*, and/or *Thuja plicata*. *Abies grandis* often can be codominant. *Acer macrophyllum* and *Alnus rubra* (the latter primarily where there has been historic logging disturbance) are commonly found as canopy or subcanopy codominants, especially at lower elevations. In a natural landscape, small patches can be dominated by these same broadleaf trees for several decades after a severe fire. Late seral stands typically have an abundance of large coniferous trees, a multi-layered canopy structure, large snags, and many large logs on the ground. Early seral stands typically have smaller trees, single-storied canopies, and may be dominated by conifers, broadleaf trees, or both. Young stands may lack *Tsuga heterophylla* or *Thuja plicata*, especially in the Puget Lowland. *Tsuga heterophylla* is generally the dominant regenerating tree species. *Polystichum munitum* (over 30-40% cover), *Oxalis oregana*, *Rubus spectabilis*, and *Oplopanax horridus* typify the poor to well-developed understory layers. *Gaultheria shallon, Mahonia nervosa, Rhododendron macrophyllum*, and *Vaccinium ovatum* are often present but are generally not as abundant as the aforementioned indicators. *Acer circinatum* is a very common codominant as a tall shrub. Mosses are often a major ground cover. Lichens are abundant in the canopy of old stands.

Fire is the major natural disturbance, thus these systems are less common to absent on the windward side of the Olympic Mountains and Willapa Hills, where fire is rare. Fire intervals vary from < 100 years in driest climatic areas to several hundred years in wetter climates. Stand replacing fire occasionally occur but areas supporting the Dry-Mesic system are more commonly moderate-severity fires. Bark beetles and fungi are significant causes of mortality that typically operate on a small scale the Dry-Mesic system. Landslides occur in some areas. Generally characterized as large, stand-replacing fires, historical (pre-1880), fires were high-severity or, less commonly, moderate-severity, with natural return intervals of a few hundred to several hundred years. More frequent moderate-severity fires would generally not burn these moister microsites. Landfire (2007) modeled the Dry-Mesic as a fire regime III system with 75% in late-seral structure (60% closed), 20% mid-seral (15% closed) and 5% early seral in pre-settlement condition. In the Mesic-Wet system, wind may be an equally important natural disturbance as fire. Typical Mesic-Wet system soils supporting a *Polystichum* understory would be deep, fine- to moderately coarse-textured, and for sites with an *Oplopanax* understory, soils typically have an impermeable layer at a moderate depth. Both types of soils are well-watered from upslope or hyperheic sources and seeps. Approximately three-quarters of fire in Dry-Mesic forest systems are mixed severity with a fire interval of 100 to 150 years. The remaining fires are high severity every 300-500 years. Mesic-Wet forests are nearly all high severity fires with a fire interval of 400 to 800 years (Landfire 2007). Landfire (2007) modeled the Dry-Mesic as a fire regime V system with 75% in late-seral structure (70% closed), 20% mid-seral (15% closed) and 5% early seral in pre-settlement condition.

In a landscape analysis of the central Cascades in Washington, Thomson, Weller and Severtsen (2003) concluded that the pre-settlement mean forest patch sizes are 1-5 square miles (average of

4.3 square miles for the 25-square mile analysis windows and 6.9 square miles for the 100-square mile windows). Agee (1998) reckoned that over 385 sq. miles (10,000 ha) was the historic fire size in these systems. Pre-settlement patch structure as estimated by Landfire (2007) consisted of 5% of the landscape in early seral stage (cohort establishment of Franklin et al. (2002) dominated by shrubs or rarely herbaceous plants. That stage typically develops into closed canopy forest stands with poor understory development (biomass accumulation/ competitive exclusion of Franklin et al. 2002). Those patches occupied an estimated 15% of the landscape, typically with *Pseudotsuga menziesii* sometimes with *Tsuga heterophylla* as the dominant trees, although *Acer macrophyllum* or *Alnus rubra* can dominate patches in Mesic-Wet forest systems. Trees are less than 20 inches diameter-at-breast height, 12-inches on average. Another 5% of the landscape consists of young, open canopy forest stands that have experienced or developed from mix-severity fire (usually conifer-dominated) or in more mesic to wet areas, windthrows, root-rot or die back by *Alnus rubra* after 80 or so years. Another 5% of Mesic-Wet forest system areas are display open canopy, mature to old-growth structure (largest trees over 20 inches dbh) following windthrow or root-rot opening of the canopy. An estimate 15% of the Dry-Mesic forests is in the similar structural condition that developed following mix-severity fire but with less *Tsuga heterophylla* or other shade-tolerant species in the upper canopy. An estimated 60% of Dry-Mesic and 70% of Mesic-Wet forest patches would be closed canopy mature to old-growth stands with high vertical structural diversity (Maturation to Pioneer loss stage of Franklin et al. 2002).

Stressors

The stressors described below are those primarily associated with the loss of extent and degradation of the ecological integrity of existing occurrences. The stressors are the cause of the system shifting away from its natural range of variability. In other words, type, intensity, and duration of these stressors is what moves a system's ecological integrity rank away from the expected, natural condition (e.g. A rank) toward degraded integrity ranks (i.e. B, C, or D).

Since European settlement, development, timber harvest, road building, fire suppression, tree plantations and introduced diseases have all impacted natural disturbance regimes, forest structure, composition, landscape patch diversity, and tree regeneration. Development has fragmented the landscape changing fire regime and connectivity of this small patch system particularly in lowlands. Timber harvest operations change canopy structural complexity and abundance of large woody debris of individual stands and has altered whole landscape patch pattern, age and structural complexity (Van Pelt 2007). Plantation forestry has changed local tree gene pools, horizontal arrangement of trees and homogenized the diversity of tree sizes. Other effects include loss of early seral shrub species, advanced stand development, increased stand density, and increased tree mortality. Older logged areas can support dense, stagnating second growth with root rot (Arno 2000). Ohlman and Waddel (2002) speculated that snag abundance more likely reflect recent disturbance and forest succession, whereas down wood amounts more are strongly reflect long-term stand history and site productivity.

Conceptual Ecological Model

The general relationships among the key ecological attributes associated with this system are presented in Figure 1.

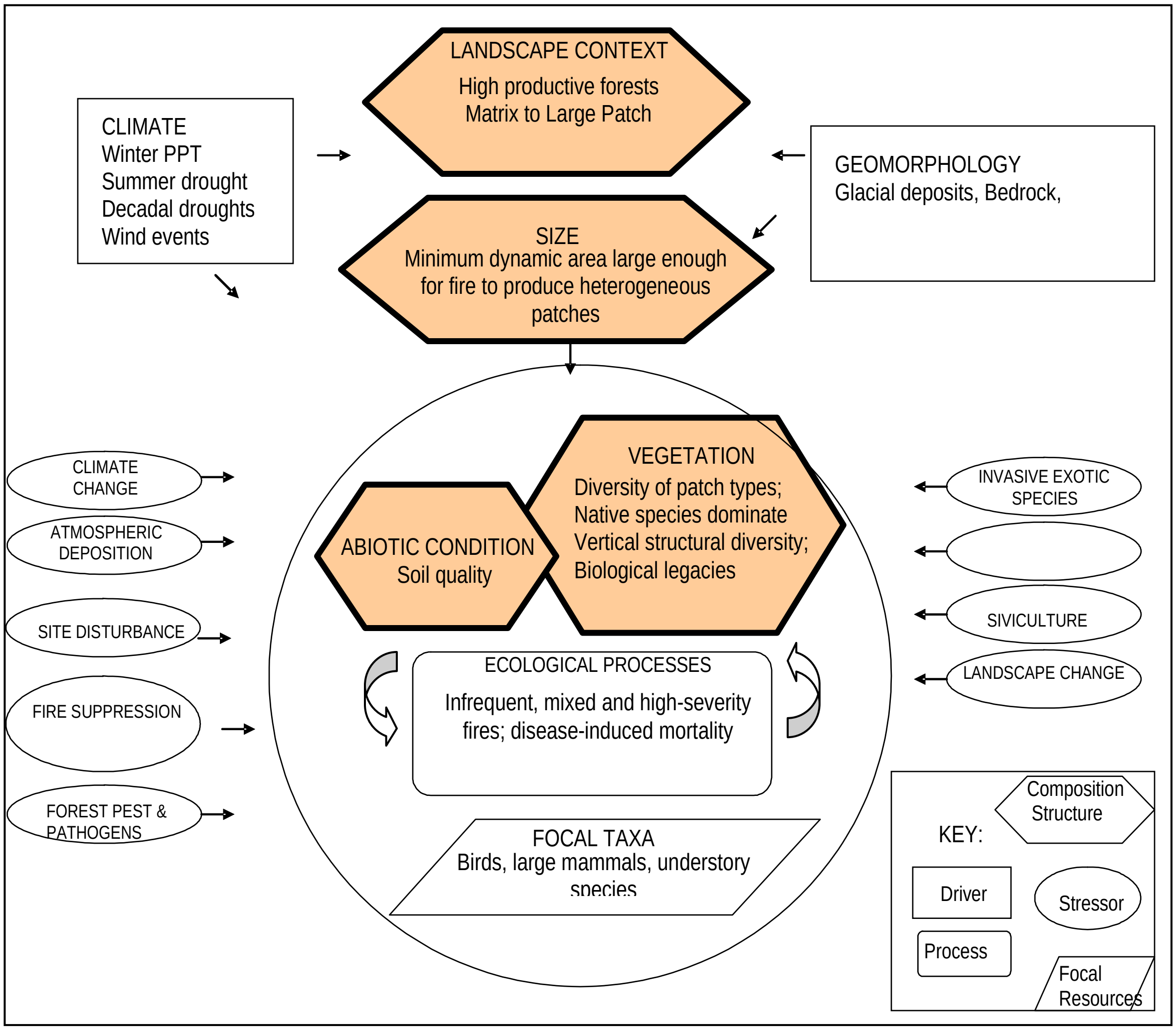

Figure 1. Conceptual Ecological Model for North Pacific Maritime Douglas-fir - Western Hemlock Forest Systems.

Ecological Integrity Assessments

The assessment of ecological integrity can be done at three levels of intensity depending on the purpose and design of the data collection effort. The three-level approach is intended to provide increasing accuracy of ecological integrity assessment, recognizing that not all conservation and management decisions need equal levels of accuracy. The three-level approach also allows users to choose their assessment based in part on the level of classification that is available or targeted. If classification is limited to the level of forests vs. wetlands vs. grasslands, the use of remote sensing metrics may be sufficient. If very specific, fine-scale forest, wetland, and grassland types are the classification target then one has the flexibility to decide to use any of the three levels, depending on the need of the assessment. In other words, there is no presumption that a fine-level of classification requires a fine-level of ecological integrity assessment.

Because the purpose is the same for all three levels of assessment (to measure the status of ecological integrity of a site) it is important that the Level 1 assessment use the same kinds of metrics and major attributes as used at Levels 2 and 3. Level 1 assessments rely almost entirely on Geographic Information Systems (GIS) and remote sensing data to obtain information about landscape integrity and the distribution and abundance of ecological types in the landscape or watershed. Level 2 assessments use relatively rapid field-based metrics that are a combination of qualitative and narrative-based rating with quantitative or semi-quantitative ratings. Field observations are required for many metrics, and observations will typically require professional expertise and judgment. Level 3 assessments require more rigorous, intensive field-based methods and metrics that provide higher-resolution information on the integrity of occurrences. They often use quantitative, plot-based protocols coupled with a sampling design to provide data for detailed metrics.

Although the three levels can be integrated into a monitoring framework, each level is developed as a stand-alone method for assessing ecological integrity. **When conducting an ecological integrity assessment, one need only complete a single level that is appropriate to the study at hand.** Typically only one level may be needed, desirable, or cost effective. But for this reason it is very important that each level provide a comparable approach to assessing integrity, else the ratings and ranks will not achieve comparable information if multiple levels are used.

Level 1 EIA

A generalized Level 1 EIA is provided in Rocchio and Crawford (2009). Please refer to that document for the list of metrics applicable to this ecological system.

Level 2 EIA

The following tables display the metrics chosen to measure most of the key ecological attributes in the conceptual ecological model above. The EIA is used to assess the ecological condition of an assessment area, which may be the same as the element occurrence or a subset of that occurrence based on abrupt changes in condition or on artificial boundaries such as management areas**. Unless otherwise noted, metric ratings apply to both Level 2 and Level 3 EIAs. The difference between the two is that a Level 3 EIA will use more intensive and precise methods to determine metric ratings (see section 5.0).** To calculate ranks, each metric is ranked in the field according the ranking categories listed below. Then, the rank and point total for each metric is entered into the EIA Scorecard (see Table 5) and multiplied by the weight factor associated with each metric resulting in a metric 'score'. Metric scores within a key ecological attribute are then summed to arrive at a score (or rank). These are then tallied in the same way to arrive at an overall ecological integrity score.

Table 1. North Pacific Maritime (Mesic-Wet and Dry-Mesic) Douglas-fir – Western Hemlock Forests Level 2 EIA

Metric	Justification	Rank			
		A (5 pts.)	**B (4 pts.)**	**C (3 pts.)**	**D (1 pts.)**
Rank Factor: LANDSCAPE CONTEXT					
Key Ecological Attribute: *Edge Effects*					
Edge Length	The intactness of the edge can be important to biotic and abiotic aspects of the site.	75 – 100% of edge is bordered by natural communities	50 – 74% of edge is bordered by natural communities	25 – 49% of edge is bordered by natural communities	< 25% of edge is bordered by natural communities
Edge Width		Average width of edge is at least 100 m.	Average width of edge is at least 75-100 m.	Average width of edge is at least 25-75 m.	Average width of edge is <25 m.
Edge Condition		>95% cover native vegetation, <5% cover of non-native plants, intact soils	75–95% cover of native vegetation, 5–25% cover of non-native plants, intact or moderately disrupted soils	25–50% cover of non-native plants, moderate or extensive soil disruption	>50% cover of non-native plants, barren ground, highly compacted or otherwise disrupted soils
Key Ecological Attribute: *Landscape Structure*					
Connectivity **(within 1 km)**	Intact areas have a continuous corridor of natural or semi-natural vegetation between assessment areas	Intact: Embedded in 90-100% natural habitat; connectivity is expected to be high.	Variegated: Embedded in 60-90% natural or semi-habitat; habitat connectivity is generally high, but lower for species sensitive to habitat modification;	Fragmented: Embedded in 20-60% natural or semi-natural habitat; connectivity is generally low, but varies with mobility of species and arrangement on landscape.	Relictual: Embedded in < 20% natural or semi-natural habitat; connectivity is essentially absent
Landscape Condition Model Index	The intensity and types of land uses in the surrounding landscape can affect ecological integrity.	Landscape Condition Model Index >0.8		Landscape Condition Model Index 0.79 – 0.65	Landscape Condition Model Index < 0.65
Patch Diversity Origin (within 1 km)	Patch diversity reflects natural dynamics of mixed or high severity fire and gap replacement processes	Over 90% of forest patches of natural origin or result of natural processes	75-90% of forest patches of natural origin or result of natural processes	50-74% of forest patches of natural origin or result of natural processes	Less than 50% of forest patches of natural origin or result of natural processes
Old Growth Proportion **(within 1 km)**	Patch diversity reflects natural dynamics of mixed or high severity fire and gap replacement processes (Landfire 2007)	Mature & Old Growth over 74% (Landfire 2007)	Early seral and/or Stem exclusion and/or mid seral open 25-70; Mature & Old Growth 20-75		Mature & Old Growth <20% (Raphael 1995)

Rank Factor: CONDITION					
Key Ecological Attribute: *Vegetation*					
Natural Tree regeneration	Natural forests are composed of largely spontaneously growing sets of native plants.	All trees originated from natural regeneration of native tree species	Evidence that some of trees were planted but most trees are native originating from natural regeneration		Evidence that half to 10% of trees established as natural regeneration (partial or failed plantation with natural regeneration)
Large Tree Age	Age is not a structural feature but is included because some of the biological diversity of old growth requires a long time to colonize and accumulate after stand-replacement disturbance (Pabst 2005).	Large trees >140 yr. old (Van Pelt 2007)	Large trees 60-100 yr. old (Van Pelt 2007)		Large trees (<60 yr. old (Van Pelt 2007)
Relative Cover Native Understory Plant Species	Native species in shrub and herbaceous layers; non-natives increase with human impacts.	Native species in shrub and herbaceous layers; relative >95% and dominate all physiognomic layers;	Cover of native species in shrub and herbaceous layers; relative 80-95%	Cover of Native species in shrub and herbaceous layers relative 50 to 79%. Nonnative may be co-dominant with native species	Cover of Native species in shrub and herbaceous layers < relative 50%. Nonnative species dominate understory with minor native component.
Absolute Cover of Exotic Invasive Understory Species	Invasive species can inflict a wide range of ecological impacts. *Digitalis purpurea Geranium robertianum, Ilex* sp., *Rubus armeniacus*	None or minimal (<1%) present.	Invasive species present, but sporadic (<5% cover).	Invasive species prevalent (5–30% absolute cover).	Invasive species abundant (>30% absolute cover).
Relative Cover of Native Increaser Species	Some stressors such as soil disturbance can shift or homogenize native composition toward species tolerant of stressors, such as *Rubus ursinus, Urtica dioeca*	Absent or incidental	<10% cover	10-20% cover	>20% cover

Key Ecological Attribute: *Structure*					
Coarse Woody Debris (upland)	Coarse woody debris (CWD), cubic meters/ha, is an important structural feature that provides necessary habitat for many forest taxa and is characteristic and vital part of the forest (Franklin and Spies 1984; Pabst 2005; Faber-Langendoen 2007)	Considering the natural stand development stage, a wide size-class diversity of downed coarse woody debris (logs), with several or more logs exceeding 50 cm dbh / ha, and logs in various stages of decay.	Considering the natural stand development stage, a moderately wide size-class diversity of downed coarse woody debris (logs), with a few logs exceeding 50 cm dbh / ha, and logs in various stages of decay.		Considering the natural stand development stage, a low size-class diversity of downed coarse woody debris (logs) with logs and snags absent to rarely exceeding 50 cm dbh / ha, and logs in mostly early stages of decay (if present).
Large Snags	Large snags, >50 cm (19 in) & >15 m (49 ft) tall, are a characteristic and vital part of the forest (Franklin and Spies 1984; Pabst 2005)	Considering the natural stand development stage, large snags common or frequently observed (unless in natural, late stem exclusion stage)	Considering the natural stand development stage, large snags occasionally observed to present		Considering the natural stand development stage, large snags absent.
Large Live Trees	Large trees, >100 cm (39 in) dbh, are a characteristic and vital part of the forest (Franklin and Spies 1984; Pabst 2005) arbitrary thresholds	Considering the natural stand development stage, there are only a few if any cut stumps;	Considering the natural stand development stage, there are many more large trees than large cut stumps; Some (10-30%) of the large trees have been harvested	Considering the natural stand development stage, there are around as many large trees as large cut stumps; Many (over 50%) of the large trees have been harvested	Considering the natural stand development stage, most, if not all, old trees have been harvested. None or rare large trees present
Key Ecological Attribute: *Physicochemical*					

Soil Surface Condition	Soil disturbance can result in compaction, erosion thereby negatively affecting many ecological processes (Napper et al 2009)	**Soil-disturbance Class 0** Undisturbed • No evidence of past equipment. • No depressions or wheel tracks. • Forest-floor layers are present and intact. • No soil displacement evident. • No management-generated soil erosion. • No management-created soil compaction. • No management-created platy soils.	**Soil-Disturbance Class 1** • Wheel tracks or depressions evident, but faint and shallow. • Forest-floor layers are present and intact. • Surface soil has not been displaced. • Soil burn severity from prescribed fires is low (slight charring of vegetation, discontinuous) • Soil compaction is shallow (0 to 4 inches). • Soil structure is changed from undisturbed conditions to platy or massive albeit discontinuous.	**Soil Disturbance Class 2** • Wheel tracks or depressions are evident and moderately deep. • Forest-floor layers are partially missing. • Surface soil partially intact and maybe mixed with subsoil. • Soil burn severity from prescribed fires is moderate (black ash evident and water repellency may be increased compared to preburn condition) • Soil compaction is moderately deep (up to 12 inches). • Soil structure is changed from undisturbed conditions and may be platy or massive.	**Soil Disturbance Class 3** • Wheel tracks or depressions are evident and deep. • Forest-floor layers are missing. • Surface soil is removed through gouging or piling. • Surface soil is displaced. • Soil burn severity from prescribed fires is high (white orreddish ash, all litter completely consumed, and soil structureless). • Soil compaction is persistent and deep (greater than 12 inches) • Soil structure is changed from undisturbed and is platy or massive throughout.
Rank Factor: SIZE					
Key Ecological Attribute: *Size*					
Relative Size	Indicates the proportion lost due to stressors.	Site is at or minimally reduced from natural extent (>95% remains)	Occurrence is only modestly reduced from its original natural extent (80-95% remains)	Occurrence is substantially reduced from its original natural extent (50-80% remains)	Occurrence is severely reduced from its original natural extent (<50% remains)
Absolute Size	In a landscape analysis of the central Cascades in Washington, Thomson, Weller and Severtsen (2003) concluded that the pre-settlement mean forest patch sizes are 1-5 square miles. Agee (1998) list over 10,000 ha as fire patch size.	24,7000+ ac/10,000+ ha (matrix Agee 1998) (>5000 ac/2000 ha for large patch Chappell 2000)	24,700-3200 ac/10,000-1300 ha (1500-5000 ac/600-2000 ha for large patch Chappell 2000)	3200-640 ac/1300-260 ha (160-1500 ac/64-600 ha for large patch Chappell 2000)	< 640 ac/260 ha (Thomson et al 2003) (<160 ac/64 ha for large patch Chappell 2000)

Level 3 EIA
Level 3 metrics would include more quantitative measures of the metrics listed above. In addition, further consideration might be given to:

- Stand structure and composition measurements (Franklin et al. 2002)
- Macrolichens species composition and abundance indicator of air pollution and management (Peterson and McCune 2001; Geiser and Neitlich 2007).
- Weighted Old Growth Habitat Index (Pabst 2005)
- Fire Regime Condition Class standard landscape worksheet method (FRCC 2010)

Triggers or Management Assessment Points
Ecological triggers or conditions under which management activities need to be reassessed are shown in the table below. Since the Ecological Integrity rankings are based on hypothesized thresholds, they are used to indicate where triggers might occur. Specific details about how these triggers translate for each metric can be found by referencing the values or descriptions for the appropriate rank provided in the Table above.

Table 2. Triggers for Level 2 & 3 EIA

Key Ecological Attribute or Metric	Trigger	Action
Any metric (except Connectivity)	▪ C rank ▪ Shift from A to B rank ▪ negative trend within the B rating (Level 3)	Level 2 triggers: conduct Level 3 assessment; make appropriate short-term management changes to ensure no further degradation Level 3 triggers: make appropriate management adjustments to ensure no additional degradation occurs. Continue monitoring using Level 3.
Any Key Ecological Attribute	▪ any metric has a C rank ▪ > ½ of all metrics are ranked B ▪ negative trend within the B rating (Level 3)	Level 2 triggers: conduct Level 3 assessment; make appropriate short-term management changes to ensure no further degradation Level 3 triggers: make appropriate management adjustments to ensure no additional degradation occurs. Continue monitoring using Level 3.

Protocol for Integrating Metric Ranks
If desired, the user may wish to integrate the ratings of the individual metrics and produce an overall score for the three rank factor categories: (1) Landscape Context; (2) Condition; and (3) Size. These rank factor rankings can then be combined into an Overall Ecological Integrity Rank. This enables one to report scores or ranks from the various hierarchical scales of the assessment depending on which best meets the user's

objectives. Please see Table 5 in Rocchio and Crawford (2009) for specifics about the protocol for integrating or 'rolling-up' metric ratings.

Supporting documents for the EIAs can be found at:
http://www1.dnr.wa.gov/nhp/refdesk/communities/eia.html

Documentation about Ecological Systems can be found at:
http://www1.dnr.wa.gov/nhp/refdesk/communities/ecol_systems.html

References

Agee, J. 1998. Landscape ecology of western forest fire regimes. Nortwest Sci.72:24-35.

Chappell, C. 2000. Douglas fir – western hemlock –western redcedar Forests Appendix 11 Willamette Valley – Puget Trough – Georgia Basin Ecoregion Terrestrial Ecological System EO Specs and EO Rank Specs. *In* Floberg, J., M. Goering, G. Wilhere, C. MacDonald, C. Chappell, C. Rumsey, Z. Ferdana, A. Holt, P. Skidmore, T. Horsman, E. Alverson, C. Tanner, M. Bryer, P. Iachetti, A. Harcombe, B. McDonald, T. Cook, M. Summers, D. Rolph. 2004. Willamette Valley-Puget Trough-Georgia Basin Ecoregional Assessment, Volume One: Report. Prepared by The Nature Conservancy with support from the Nature Conservancy of Canada, Washington Department of Fish and Wildlife, Washington Department of Natural Resources (Natural Heritage and Nearshore Habitat programs), Oregon State Natural Heritage Information Center and the British Columbia Conservation Data Centre.

FRCC. 2008. Interagency Fire Regime Condition Class (FRCC) Guidebook *Version 1.3.0.* www.landfire.gov.

FRCC. 2010. FRCC Software Application User's Guide (version 3.0.3.0). www.frcc.gov.

Franklin, J.F., F.C. Hall, W.F. Laudenslayer, Jr., C. Maser, J. Nunan, J. Poppino, C.J. Ralph, T.A Spies. 1986. Interim definitions for old-growth Douglas-fir and mixed-conifer forests in the Pacific Northwest and California. Res. Note PNW-447. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 7 p.

Faber-Langendoen, D. 2007. A Temperate Upland Forest (Cool Temperate Forest, Warm Temperate Forest) Rapid Assessment and Scorecard for the U.S. Army Corp of Engineers. NatureServe. Arlington, VA

Franklin, J. F., and T. A. Spies. 1984. Characteristics of old-growth Douglas-fir forests. Pages 328-334 *in* Proceedings, Soc. of American Foresters national convention, Oct. 16-20, 1983. Soc. of American Foresters, Washington, D.C.

Franklin, J.F., T.A. Spies, R. Van Pelt, A.B. Carey, D.A. Thornburgh, D.R. Berg, D.B. Lindenmayer, M.E. Harmon, W.S. Keeton, D.C. Shaw, K. Bible and J. Chen. 2002.

Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir as an example. Forest Ecology and Management 155: 399–423.

Franklin, J.F., T.A. Spies, R. Van Pelt, A.B. 2005 Definition and inventory of old forests on DNR-managed state lands. Section I, Washington Dept. Natural Resources, Olympia WA.

Geiser, L.H., and Neitlich, P.N., 2007. Air pollution and climate gradients in western Oregon and Washington indicated by epiphytic macrolichens: Environmental Pollution, v. 145, p. 203-218.

Gray, A.N., V.J Monleon, T.A. Spies. 2009. Characteristics of remnant old-growth forests in the northern Coast Range of Oregon and comparison to surrounding landscapes. Gen. Tech. Rep. PNW-GTR-790. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 45 p.

Landfire. 2007. Biophysical Setting Model 0110370: North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest. Rapid Assessment Biophysical Settings Model Descriptions.

Landfire. 2007. Biophysical Setting Model 0110390: North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest. Rapid Assessment Biophysical Settings Model Descriptions.

Ohlman, J. and K. Waddell. 2002. Regional Patterns of Dead Wood in Forested Habitats of Oregon and Washington IN: Laudenslayer, William F., Jr.; Shea, Patrick J.; Valentine, Bradley E.; Weatherspoon, C. Phillip; Lisle, Thomas E., technical coordinators. Proceedings of the symposium on the ecology and management of dead wood in western forests. 1999 November 2-4; Reno, NV. Gen. Tech. Rep. PSW-GTR-181. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 949 p.

Napper, C., S. Howes, and D. Page-Dumroese. 2009. *The soil disturbance field guide.* U.S. For. Serv. 0819 1815-SDTC. 112p.

Parks, C. G., S. R. Radosevich, B. A. Endress, B. J. Naylor, D. Anzinger, L. J. Rew, B. D. Maxwell, K. A. Dwire. 2005. Natural and land-use history of the Northwest mountain ecoregions (USA) in relation to patterns of plant invasions. Perspectives in Plant Ecology, Evolution and Systematics 7 (2005) 137–158

Pabst, R. 2005. Methodology for developing the old-growth index. Appendix 1. In: Franklin, J.F.; Spies, T.; Van Pelt, R. Definition and inventory of oldgrowth forests on DNR-managed state lands. Olympia, WA: Washington State Department of Natural Resources.

Peterson, E.B. and McCune, B. 2001. Diversity and succession of epiphytic macrolichen communities in low-elevation managed conifer forests in Western Oregon. Journal of Vegetation Science 12: 511-524.

Rocchio, F.J. and R.C. Crawford. 2009. Monitoring Desired Ecological Conditions on Washington State Wildlife Areas Using an Ecological Integrity Assessment Framework. Washington Natural Heritage Program, Washington Department of Natural Resources, Olympia, WA.

Thomson, J.L., C. Weller, and B. Severtsen. 2003. Cascades Crest Forests: Forest Loss, Habitat Fragmentation and Wildness. The Wilderness Society. 46p.

Wendel, R., and D. Zabowski. 2010. Fire History within the lower Elwah Watershed, Olympic national Park. Northwest Science 84(1):88-97.

Van Pelt, R. 2007. Identifying Old trees and Forests in Eastern Washington. Wa. Dept Natural Resources, Olympia Wa. 169p.

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