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 Mountain Hemlock Forest

Ecological Summary

The North Pacific Mountain Hemlock Forest ecological system forms the matrix forest in the subalpine zones of southeast Alaska to the southern Cascades in Oregon. In the Washington Cascades, it occurs on both windward and less so on the leeward sides of the Cascades Mountains in cold snowy environments. It occurs only on the leeward side of the Olympic Mountains. Elevationally, it occurs between *Abies amabilis - Tsuga heterophylla* forests and North Pacific Maritime Mesic Subalpine Parklands. Eastward, that is drier climatically, North Pacific Mountain Hemlock Forests grade into Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodlands. The lower and upper elevational limits decrease from south to north and from east to west. The climate is generally characterized by short, cool summers, rainy autumns and long, cool, wet winters with heavy snow cover for 5-9 months. Snowpacks are typically over 3m (10 ft) and drip from cloud condensation adds inches to yearly total precipitation (Henderson et al. 1989). The heavy snowpack is ubiquitous, but a summer drought can be experienced in the eastern Cascades. These forests often attain great age due to low fire frequency, but tree stature is strongly affected by local environmental conditions. Substrates are moderately deep soils derived from colluvium, glacial outwash and volcanic ash, which overlie gneiss or schist. Soils are acidic, coarse-textured, and often subirrigated with a substantial organic component, owing to persistently high moisture and low temperatures. Sites are cold and moist, and found on mid to lower slopes, benches and bottoms with typically western and northern aspects.

Tsuga mertensiana (over 5% cover) and *Abies amabilis* are the characteristic dominant tree species over most of the range. *Chamaecyparis nootkatensis* maybe present in higher locations and *Tsuga heterophylla* often occurs at lower elevations in this system but is much less abundant than *Tsuga mertensiana*. *Abies lasiocarpa* is a common associated east of the Cascade Crest where *Picea engelmannii*, *Larix lyallii*, *Larix occidentalis*, *Pinus albicaulis*, or *Pinus monticola* can occur in the canopy. Extensive areas on the leeward side on the mountains generally have more open, diverse tree canopies reflecting different climatic and fire regimes than that on the windward side. In those areas, the Mesic-Wet Spruce Fir Forest and Woodland ecological system EIA would be applied for assessments. Elsewhere on drier sites, *Abies lasiocarpa* and *Pinus contorta* can be the first forests to develop after stand-replacing fire would be classified and mapped as Rocky Mountain Lodgepole Pine Forest unless *Tsuga mertensiana* have significant cover. Deciduous trees are rare in this system.

The undergrowth is often somewhat depauperate because of poor light penetration at the forest floor, but may include a moderately sparse shrub layer composed of *Elliottia pyroliflorus, Rhododendron albiflorum, Menziesia ferruginea, Vaccinium membranaceum*, and *Vaccinium ovalifolium*. Ground covering vines *Rubus lasiococcus* and *Rubus pedatus* are present to common. Shade-tolerant forbs and ferns include, *Clintonia uniflora, Cornus canadensis, Erythronium montanum, Orthilia secunda, Pteridium aquilinum, Streptopus lanceolatus* var. *curvipes (= Streptopus roseus), Valeriana sitchensis*, and *Tiarella trifoliata var. unifoliata*. Colder sites have ericaceous shrubs including *Vaccinium membranaceum, Vaccinium scoparium, Menziesia ferruginea*, and *Rhododendron albiflorum*. Herbaceous species include *Carex* spp., *Luzula glabrata*, and *Chimaphila umbellata*.

Stands are typically old-growth with multi-layered canopies and abundant woody debris. Across the majority of the system distribution, fire very rarely or never occurs while the more summer-dry climatic areas (east Cascades) have occasional high-severity fires with return intervals of 400-600 years. Root rot (*Phellinus weirii)*, bark beetles, and other insects can be locally important disturbances in these higher elevation drier sites (Landfire 2007b). Wind can be a significant factor in portions of the system's range (Henderson et al. 1989).

Overall, infrequent mixed severity fire regimes occurring at greater than 5000 years and stand-replacement fires occur with mean return intervals of about 10,000 years characterize most of this system (fire regime V Landfire 2007a). In east Cascades areas, mean return intervals are 400 to over 1500 yrs (fire regime V Landfire 2007b). In those east Cascade areas, the Mesic-Wet Spruce Fir Forest and Woodland ecological system EIA may better work in assessments. Consequently, old-growth is the most common stand condition. Avalanches and wind events are also common disturbances in this type. Pre-settlement landscape patch structure as estimated by Landfire (2007a) consisted of 1% early seral stage (cohort establishment of Franklin et al. 2002) dominated by shrubs and *Tsuga mertensiana* and *Abies amabilis* tree seedlings. That early stage typically develops into closed canopy forest stands with poor understory development (biomass accumulation/ competitive exclusion of Franklin et al. 2002) and occupied an estimated 5% of the landscape. *Tsuga mertensiana* and *Abies amabilis* trees are less than 21 inches diameter-at-breast height. Another 5% of the landscape consists of young, open canopy of the same trees species developed from mix-severity fire or other standing thinning event (wind, avalanche, pathogens). An estimate 4% of the forests is similar open stands composed of 21 inches dbh and over trees. An estimated 85% of 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) (Landfire 2007a). Figure 1 displays various likely stand conditions and relationship in the system.

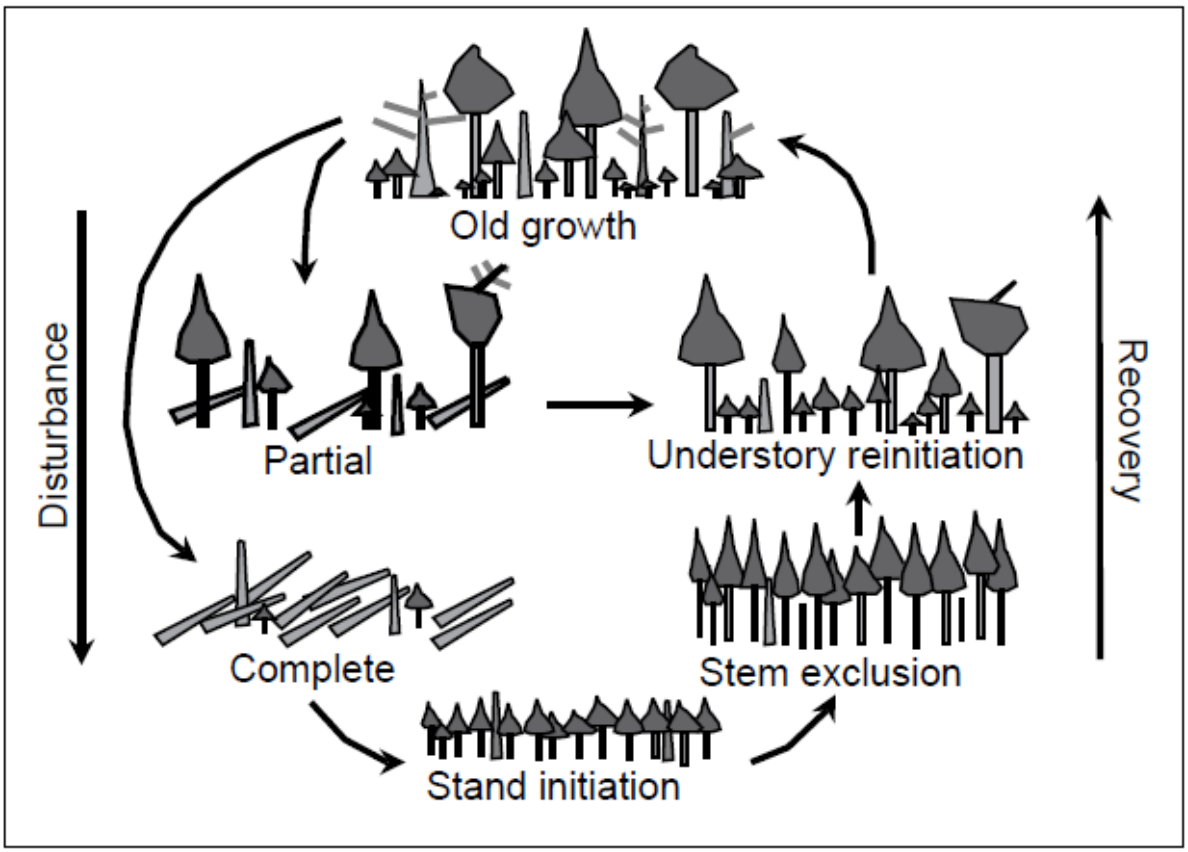

Figure 7—Disturbance and recovery cycles in temperate rain forests of southeast Alaska that occur on wind-protected landscapes where small-scale gap processes predominate.

Table 1. Wind disturbance and other small gap-phase forest dynamics differ from fire replacement forest as illustrated above from Nowacki and Kramer (1998).

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, timber harvest, road building, and tree plantations have all impacted natural disturbance regimes, forest structure, composition, landscape patch diversity, and tree regeneration. 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). They reduce coarse woody debris compared to natural levels, and truncate succession well before late-seral characteristics are expressed. Plantation forestry has changed local tree gene pools, horizontal arrangement of trees and homogenized the diversity of tree sizes. 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.

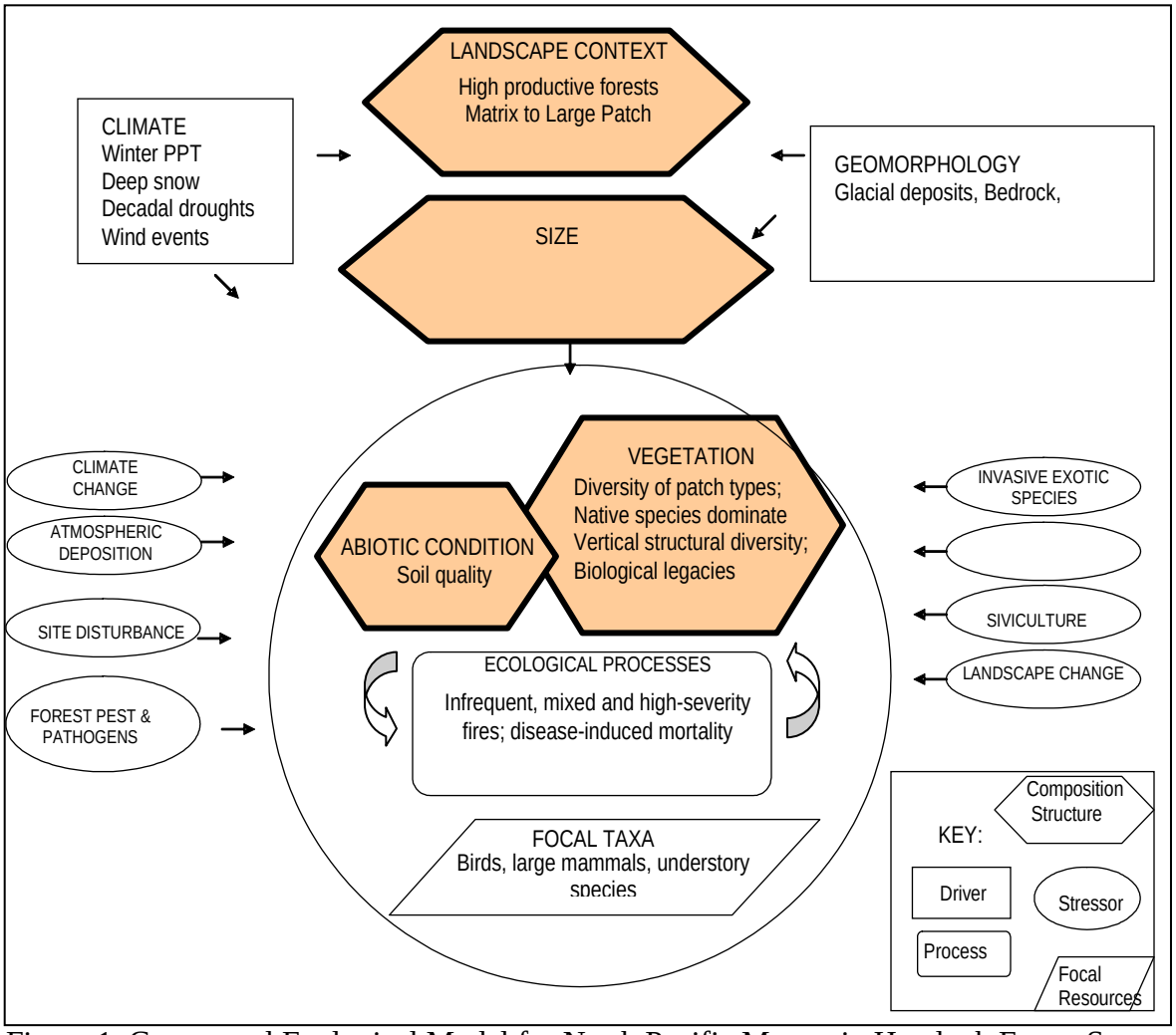

Figure 1. Conceptual Ecological Model for North Pacific Mountain Hemlock Forest System.

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.** 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 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 Mountain Hemlock Forest System 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 2007a)	Mature & Old Growth over 80% (Landfire 2007)	Early seral and/or Stem exclusion and/or mid seral open over 10%; Mature & Old Growth 20-80%		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 at 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)
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, >50 cm (21 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 old 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 old trees have been harvested.	Considering the natural stand development stage, most, if not all, old trees have been harvested. None or rare old 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	Agee (1998) list over 3200 ha as fire patch size.	8000+ ac/3200+ ha (matrix Agee 1998)	800-8000 ac/320-3200 ha	80-800 ac/32-320 ha	< 80 ac/32 ha

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)

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. Northwest Sci.72:24-35.

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., 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.

Henderson, J.A., D.A. Peter, R. Lesher, and D.C. Shaw. 1989. Forested Plant Associations of the Olympic National Forest U.S.D.A. For. Serv. PNW Region. R6-ECOL-TP 001-88. 502 p.

Landfire. 2007a. North Pacific Mountain Hemlock-wet. BPS 0110411 IN: Landfire Biophysical Setting Descriptions.
http://www.landfire.gov/NationalProductDescriptions20.php

Landfire. 2007b. North Pacific Mountain Hemlock-xeric. BPS 0110412 IN: Landfire Biophysical Setting Descriptions.
http://www.landfire.gov/NationalProductDescriptions20.php

Ohlman, J. and K. Waddell. 2002. Regional Patterns of Dead Wood in Forested Habitats of Oregon and Washington IN: Laudenslayer, W. F., Jr.; Shea, P. J.; Valentine, Bradley E.; Weatherspoon, Phillip, C.; Lisle, T. 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.

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.

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

Authorship: Rex Crawford, Washington Natural Heritage Program
February 24, 2011