Monitoring Desired Ecological Conditions on Washington State Wildlife Areas Using an Ecological Integrity Assessment Framework

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1.0 Introduction

In order to make informed management decisions aimed at maintaining or protecting ecological integrity, credible data on how human activities affect the chemical, physical, and biological integrity of ecological systems needs to be collected (EPA 2002). Indicator-based (ecological endpoints) approaches to assessing and reporting on ecological integrity (Harwell et al. 1999, Young and Sanzone 2002, EPA 2002) are now being used by numerous organizations to assist with regulatory decisions (Mack 2004, USACE 2003, 2005, 2006), to set mitigation performance standards (Mack 2004, Faber-Langendoen et al. 2006, 2008), and to set conservation priorities (Faber-Langendoen et al. 2009a).

Assessing the current ecological condition of an ecosystem requires developing indicators of the structure, composition, and function of an ecosystem as compared to reference or benchmark examples of those ecosystems operating within the bounds of natural or historic disturbance regimes (Lindenmayer and Franklin 2002, Young and Sanzone 2002). Given the complexity of ecological systems, concerns over cost-effectiveness and statistical rigor, and the loss of adequate reference sites, the selection and development of indicators can be challenging (Brewer and Menzel 2009). There is a need for a method which provides guidance on the range of options for assessing ecological integrity, scaled both in terms of the scale of ecosystem type that is being assessed, and the level of information required to conduct the assessment. NatureServe and the Natural Heritage Network have recently developed such an approach called the Ecological Integrity Assessment (Faber-Langendoen et al. 2006, 2008, 2009a, 2009b) and are now implementing it for a variety of small- and large-scale projects (Lemly and Rocchio *In Preparation*, Faber-Langendoen et al. 2009b, Tierney et al. 2009, Vance et al. *In Progress* WNHP *In Progress*).

The Ecological Integrity Assessment method (EIA) aims to measure the current ecological integrity of a site through a standardized and repeatable assessment of current ecological conditions associated with the structure, composition, and ecological processes of a particular ecological system. These conditions are then compared to those associated with sites operating within the bounds of their natural range of variation. Ratings or scores for individual metrics and overall ecological integrity are presented in a clear and transparent scorecard matrix. The purpose of assigning an index of ecological integrity is to provide a succinct assessment of the current status of the composition, structure and function of occurrences of a particular ecosystem type and to give a general sense of conservation value, management effects, restoration success, etc. As such, the EIA can be used to address a number of objectives, including to: assess ecological integrity on a fixed, objective scale; compare ecological integrity of various occurrences of the same ecological systems; to determine the best examples and support selection of sites for conservation priority; inform decisions on monitoring individual ecological attributes of a particular occurrences; and to provide an aggregated index of integrity to interpret monitoring data, including tracking the status of ecological integrity over time.

The general framework of the EIA can be tailored by regional and local ecologist to more specifically address the complexity of individual ecosystem types using the following approach: (1) develop a conceptual model with key ecological attributes and associated indicators; (2) use a three level approach to identify a suite of metrics, including Level 1 (remote sensing), Level 2 (rapid ground-based), and Level 3 (intensive ground-based) metrics (EPA 2006); (3) identify ratings and thresholds for each metric based on deviation from the "natural range of variation" benchmarks for each metric relative to each type; (4) provide a scorecard matrix by which the metrics are rated and integrated into an overall assessment of the ecological integrity of each type. The EIA aims to standardize expert opinion and existing data up front so that a single, qualified ecologist could apply the EIA in a rapid manner to get an estimate of a site's ecological integrity. The EIA can improve an understanding of current ecological conditions which can lead to more effective and efficient use of available resources for ecosystem protection, management, and restoration efforts. The flexibility in scale, detail, and level of effort associated with the three-level approach around which the EIA is developed provides a foundation upon which a multi-scaled approach to monitoring and assessment can be systematically implemented.

The Washington Department of Fish and Wildlife serves Washington's citizens by protecting, restoring, and enhancing fish and wildlife on private and public lands, such as those support by the Bonneville Power Administration (BPA). Recognizing that EIAs are essential tools for monitoring and evaluating these resources, the Washington Department of Fish and Wildlife contracted with the Washington Natural Heritage Program to adapt the EIA method (Faber-Langendoen et al. 2009a) as an approach for developing standards and a monitoring protocol for measuring desired ecological conditions on State Wildlife Areas. This document presents a framework in which the EIA can be used to achieve those objectives.

The remainder of this report will (1) describe the Ecological Integrity Assessment method; (2) provide an overview of how the EIA could be used within the context of a multi-scaled monitoring program; (3) present initial EIA models for a selection of the Ecological Systems which occur on WDFW lands; and (4) provide guidance on measurement protocols for individual metrics.

2.0 Overview of Ecological Integrity Assessments

The EIA is a multi-metric index designed to document degradation of key biotic and abiotic attributes along a continuum from reference to degraded. The EIA approach to assessing ecological integrity is similar to the Index of Biotic Integrity (IBI) approach. The original IBI interpreted stream integrity from twelve metrics that reflected the health, reproduction, composition and abundance of fish species (Karr and Chu 1999). Each metric was rated by comparing measured values with values expected under relatively unimpaired (reference standard) conditions, and the ratings were aggregated into a total score. The EIA builds upon this foundation and assesses the integrity of ecosystems by developing suites of indicators or metrics comprising key biological, physical and functional attributes of those ecosystems (Harwell et al. 1999, Andreasen et al. 2001, Parrish et al. 2003). The EIA uses a scorecard matrix to communicate the results of the assessment. A rating or score for individual metrics, as well as an overall index of ecological integrity are presented in the scorecard.

Ecological Integrity Assessments are developed using the following steps; we:

1) outline a general conceptual model that identifies the major ecological attributes, provide a narrative description of declining integrity levels based on changes to those ecological attributes, and introduce the metrics-based approach to measure those attributes and assess their levels of degradation.
2) use ecological classifications at multiple classification scales to guide the development of the conceptual models, allowing improved refinement of assessing attributes, as needed.
3) use a three level assessment approach – (i) remote sensing, (ii) rapid ground-based, and (iii) intensive ground-based metrics – to guide development of metrics. The 3-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.
4) identify ratings and thresholds for each metric based on "normal' or "natural range of variation" benchmarks.
5) provide a scorecard matrix by which the metrics are rated and integrated into an overall index of ecological integrity.

This section describes each of these components associated with EIA development. **Most of this discussion is summarized and adapted from Faber-Langendoen et al. (2009a).** For additional background and details concerning EIA development, please consult that document as well as Faber-Langendoen et al. (2006, 2008).

A general note of caution: ecosystems are far too complex to be fully represented by a suite of key ecological attributes, indicators, and metrics. As such, our efforts to assess ecological integrity are approximations of our current understanding of any ecosystem which means the metrics, indices and scorecards presented in this report must be flexible enough to allow change over time as our knowledge grows.

2.1 Definitions

2.1.1 Ecological Integrity

The concept of ecological integrity, as used within the context of the EIA method, builds on the related concepts of biological integrity and ecological health, and is a broad and useful endpoint for ecological assessment and reporting (Harwell et al. 1999). Ecological integrity, as used for the EIA, is defined as "an assessment of the structure, composition, and function of an ecosystem as compared to reference ecosystems operating within the bounds of natural or historic disturbance regimes" (adapted from Karr and Dudley 1981, Lindenmayer and Franklin 2002, Young and Sanzone 2002, Parrish et al. 2003). To have ecological integrity, an ecosystem should be relatively unimpaired across a range of ecological attributes and spatial and temporal scales (De Leo and Levin 1997, Karr 1994). Impairment is defined as deviation from the natural range of variation as described by the ecological condition of reference or benchmark sites. The notion of naturalness (or its inverse, impairment) depends on an understanding of how the presence and impact of human activity relates to natural ecological patterns and processes (Kapos et al. 2002). Identification of reference or benchmark conditions based on natural or historic ranges of variation, although challenging, can provide a basis for interpretation of ecological integrity (Swetnam et al. 1999). These concepts require greater specificity to become a useful guide for conducting ecological integrity assessments which is described in more detail in Sections 2.6-2.8.

2.1.2 Ecological Condition

Ecological condition represents the current state of a resource compared to reference standards or benchmarks for physical, chemical, and biological characteristics.

2.1.3 Desired Ecological Condition

Management objectives, societal values, and other factors determine the desired ecological conditions of any particular site or ecosystem. Specifically, desired ecological conditions can be defined as the detailed, measureable descriptions of what a resource will look like after social, economic, and ecological management goals have been achieved (IEMTF 1995). Desired ecological conditions are the long-term goals a natural resource manager is targeting and can be used as performance standards or measures of success for management actions (NPS 2009). For this project, the Washington Department of Fish and Wildlife (WDFW) has identified a portion of the ecological integrity scale (see Section 2.6), specifically the A and B integrity rankings, as comprising desired ecological conditions for each of the Ecological Systems that are addressed in this report. Thus, any metric, key ecological attribute, or overall ecological integrity rating that has an A or B ranking would be considered to be within desired ecological conditions. Correspondingly, C and D ratings would indicate that a variable is outside desired conditions and that management action is required to reverse these conditions.

2.1.4 Best Attainable Condition

Best attainable condition is a subset of both ecological integrity and desired ecological conditions. In other words, the ecological potential or best attainable condition of any given site can vary depending on factors outside the control of the manager setting desired ecological conditions. For example, best attainable condition may be constrained by the landscape an ecological system is embedded within or by past land use which has occurred and left lasting impacts. A specific example might be a riparian ecological system that occurs immediately downstream of a dam. Unless managers of the dam are willing to conduct flood releases that would mimic the natural timing, duration, and frequency of flooding associated with that riparian type, achieving desired ecological conditions may not be feasible for that particular occurrence. Given those constraints, the particular ecological conditions that are possible at this site are referred to as best attainable condition. Best attainable conditions are determined on a case-by-case basis through an integrated assessment of both site- and landscape scale ecological conditions and stressors. This can be accomplished using the three-level approach of the EIA (Section 2.5).

2.1.5 Triggers

Triggers, also known as management assessment points, are points along a continuum of values associated with a metric or attribute where managers are encouraged to initiate closer examination of current management and ecological conditions in order to avoid crossing an undesirable threshold (Bennetts et al. 2007; Carter and Bennetts 2007). Within the context of the EIA framework presented here (see Section 3.0), triggers or management assessment points will be most applicable when using a Level 2 EIA since these are rapid assessments designed to provide a snapshot of current ecological condition. If a trigger point is detected by the Level 2 EIA, then a more detail assessment (e.g. Level 3 EIA; see Sections 2.5 and 3.0) is warranted in order to provide a more accurate assessment of status and trends as well as the type of preventive management actions that need to be taken to avoid crossing an ecological threshold into an undesirable state of ecological condition.

2.2 Importance of Ecological Classification

2.2.1 Classification and Natural Range of Variation

Classification is a necessary component to both using and developing an EIA as it constrains natural variability and thus helps clarify whether differences in ecological condition are due to natural or anthropogenic causes. To successfully develop indicators of ecological integrity, an understanding of the structure, composition, and processes that govern the wide variety of ecosystem types is needed. Ecological classifications help ecologists to better cope with natural variability within and among types so that differences between occurrences with good integrity and poor integrity can be more clearly recognized. In other words, classification helps us differentiate between signals (indicators of degradation) from noise (natural variability). Classifications are also important in establishing "ecological equivalency" which is especially important for establishing restoration targets and benchmarks. There are a variety of classification schemes and ecoregional frameworks for structuring ecological integrity assessments. The EIA presented here are based on the International Vegetation Classification and Ecological Systems classification.

2.2.2 The International Vegetation Classification and Ecological Systems Classification

The International Vegetation Classification (IVC) covers all vegetation from around the world. In the United States, its national application is the U.S. National Vegetation Classification (NVC), supported by the Federal Geographic Data Committee (FGDC 2008), NatureServe (Faber-Langendoen et al. 2009c), and the Ecological Society of America (Jennings et al. 2009), with other partners. The IVC and NVC were developed to classify both wetlands and uplands, and identify types based on vegetation composition and structure and associated ecological factors.

The NVC meets several important needs for conservation and resource management. It provides:

- a multi-level, ecologically based framework that allow users to address conservation and management concerns at scales relevant to their work.
- characterization of ecosystem patterns across the entire landscape or watershed, both upland and wetland.
- information on the relative rarity of types. Each association has been assessed for conservation status (extinction risk).
- relationships to other classification systems are explicitly linked to the NVC types
- a federal standard for all federal agencies, facilitating sharing of information on ecosystem types (FGDC 2008).

A related classification approach, the Ecological Systems classification (Comer et al. 2003), can be used in conjunction with the IVC and NVC. Ecological systems provide a spatial-ecologic perspective on the relation of associations and alliances (fine-scale NVC types), integrating vegetation with natural dynamics, soils, hydrology, landscape setting, and other ecological processes. They can also provide a mapping application of the NVC, much as soil associations help portray the spatial-ecologic relations among soil series in a soil taxonomic hierarchy. Ecological systems types facilitate mapping at meso-scales (1:24,000 – 1:100,000; Comer and Schulz 2007) and a comprehensive ecological systems map exists for Washington State (www.landscope.org). Ecological systems are somewhat comparable to the Group level of the revised NVC hierarchy, and can be linked to higher levels of the NVC hierarchy, including macrogroups and formations. Ecological systems meet several important needs for conservation, management and restoration, because they provide:

- an integrated biotic and abiotic approach that is effective at constraining both biotic and abiotic variability within one classification unit.
- comprehensive maps of all ecological system types are becoming available.
- explicit links to the USNVC, facilitating crosswalks of both mapping and classifications.

Both the NVC and Ecological Systems classifications can be used in conjunction to sort out the ecological variability that may affect ecological integrity. **For this project, Ecological Systems are used as the foundation from which EIAs will be developed. It is recommended that the *Draft Field Guide to Washington's Ecological Systems* (Rocchio and Crawford 2008) be used to identify the ecological system in question to ensure that the correct EIA is used.** However, if finer-scale classification units are needed for WDFW's monitoring objectives, NVC types are recommended.

2.2.3 Integration of Classification and Ecological Integrity Assessment

The purpose of intersecting the various classifications approaches with that of the EIA methods is that as the level of assessment intensifies we may find (but not always) that a greater (or lesser) level of ecosystem classification detail is needed. Finer classes allow for greater specificity in developing conceptual models of the natural variability and stressors of an ecological system and the thresholds that relate to impacts of stressors. On the other hand, coarser classes allow the development of metrics that are more likely to be applicable across classes since the specificity of these metrics is limited by scale. Because the Ecological Systems classification remains comparable to coarser or finer-scale levels of the NVC, the flexibility to tailor EIAs to NVC types remains an option if WDFW finds a need for monitoring such types in the future. However, there are some metrics which are broadly applicable across any classification scale. For example, the percent cover of native species is a metric that is likely useful for any classification type, whether coarse or fine-scale. Likewise, some metrics are very specific regardless of scale, such as the Floristic Quality Index which requires detailed knowledge of the floristics of any classification unit. Thus, consideration of both the level of metric resolution and the scale of classification that is desired is taken into account in order to accurately develop the metric. In summary, the EIA is both practical and flexible for a range of assessment types spanning broad to local scale and from extensive to intensive detail and effort.

2.3 Conceptual Ecological Models

A conceptual model helps guide the selection of indicators, organized across a standard set of ecological attributes and factors (e.g., Harwell et al. 1999, Young and Sanzone 2002, Parrish et al. 2003). With a specific Ecological System type in mind, a conceptual model describing linkages between key ecosystem attributes and known stressors is developed and used for identifying and interpreting metrics with high ecological and management relevance (Noon 2003; Faber-Langendoen et al. 2009a). The first component to the conceptual model is identifying the key ecological attributes associated with the overall structure, composition and ecological processes which are considered primary drivers or have a very important functional role in maintaining the integrity of the ecological system. In other words, the conceptual models identify the key ecological drivers that are most valuable to measure for assessing ecological integrity. The models can be narrative or a graph. Next, the primary stressors impacting the ecological system are identified and incorporated into the conceptual model. With stressors incorporated, the conceptual model is then used to describe the predicted relationships between ecological components and their potential stressors.

2.4 Ecological Indicators and Metrics

2.4.1 Use of Indicators and Metrics in This Report

The conceptual model provides guidance as to which specific indicators and metrics will be useful for distinguishing a highly impacted, degraded or depauperate state from a relatively unimpaired, intact and functioning state. The difference between indicators and metrics is subtle yet important to distinguish. **Indicators** provide the specificity needed to assess the key ecological attributes. Example indicators for vegetation include structure, composition, diversity, life history, tolerance, alien taxa and examples for hydrology include water depth or flooding duration. **Metrics** are measureable expressions of an indicator. For example, metrics for the alien plant taxa indicator might include percent alien species richness, relative alien cover, or number of invasive alien species.

For this report, metrics are the focus. Any use of indicators is for conceptual organization of metrics but indicators are not included in the EIA Scorecards and thus are not ranked or scored in the EIA method. However, if this would be useful for monitoring, indicators could be added into the framework.

2.4.2 Selecting Metrics

The selection of metrics is focused on those that can detect changes in a key ecological attributes due to a response that attribute to stressors. In other words, not all measures of various characteristics in an ecosystem are useful for measuring ecological integrity. Metrics that can be used to measure a key ecological attribute and is sensitive to changes from stressors are referred to here as "**condition metrics**." Stressors themselves can also be measured, but information from these metrics provides only an indirect measure of ecological condition – we will need to infer that changes in the stressor correspond to changes in the condition of the system. Such metrics are referred to as "**stressor metrics.**" It is preferable to use condition metrics separate from stressors metrics, in order to independently assess the effects of stressors on condition at a site to guide interpretation and possible correlations between ecological integrity and stressors (e.g. stressor checklists; Section 2.9). However, when measuring condition is challenging or not cost-effective a stressor metric may be substituted. However, if a stressor index is used to test, verify, or validate the EIA model then it is important to remove stressor metrics from the analysis (Section 2.10). Table 1 shows how metrics relate to the key ecological attributes identified in the conceptual ecological model, which are themselves organized by rank factors. Stressor checklists are also shown within the context of this model (Table 1).

Metrics are identified using a variety of expert-driven processes and through a series of data-driven calibration tests. The scientific literature is searched to identify existing and vetted metrics that could be useful for measuring ecological integrity. Some of the metrics presented in this report were derived from a national effort to select metrics for rapid assessment and monitoring of ecological integrity of wetlands (Faber-Langendoen et al. 2006; Faber-Langendoen et al. 2008). Many of these metrics are also applicable to some upland ecological systems. A variety of existing rapid assessment and monitoring materials, particularly the California Rapid Assessment Manual (Collins et al. 2006, 2007), the Ohio Rapid Assessment Manual (Mack 2001), indicators of rangeland health (Pellant et al. 2005), Natural Resources Conservation Service ecological site descriptions, etc, were referenced for suitable metrics. From these resources, as well metrics identified by the Washington Natural Heritage Program, a list of potential metrics was compiled then filtered through the following criteria to determine which would be most useful for use in the EIA (Andreasen et al. 2001, Kapos et al. 2002, Kurtz et al. 2001):

a) useful at multiple spatial scales;

b) inclusive across ecological attributes of composition, structure and function;
c) grounded in natural history and ecologically relevant;
d) practically relevant to managers, decision-makers, and the public, not just scientists;
e) flexible,
f) feasible, to implement and measure, with relevant target or threshold settings; and
g) responsive, including to changes from stressors.

Table 1. Conceptual Ecological Model for a wetland. Stressors are described using checklists (see Section 2.9).

Rank Factor	Key Ecological Attribute	Metric
LANDSCAPE CONTEXT	**Landscape Structure**	Landscape Connectivity
		Buffer Index
		Surrounding Land Use Index
	Landscape Stressors	Landscape Stressors Checklist
SIZE	**Size**	Patch Size Condition
		Patch Size
CONDITION	**Vegetation**	Vegetation Structure
		Organic Matter Accumulation
		Vegetation Composition
		Relative Cover of Native Plant Species
	Vegetation Stressors	Vegetation Stressors Checklist
	Soils/Physiochemical	Physical Patch Types
		Water Quality
		Soil Surface Condition
	Soil Stressors	Soil Stressors Checklist
	Hydrology	Water Source
		Hydroperiod
		Hydrologic Connectivity
	Hydrology Stressors	Hydrology Stressors Checklist

2.5 The Three Level Approach to Metric Development

The selection of metrics to assess ecological integrity can be done at three levels of intensity depending on the purpose and design of the data collection effort (Brooks et al. 2004, Tiner 2004, EPA 2006). This "three-level approach" to assessments, summarized in Table 2, allows the flexibility to develop data for many sites that cannot readily be visited or intensively studied, permits more widespread assessment, while still allowing for detailed monitoring data at selected sites. 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 Remote 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 (Mack 2006, EPA 2006, Faber-Langendoen et al. 2009a). Level 1 metrics are usually developed from readily available, processed imagery or existing GIS coverages. Limited ground-truthing may be a component of some assessments.1

Level 2 Rapid 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 (Fennessy et al. 2007).

Level 3 Intensive Assessments require more rigorous, intensive field-based methods and metrics that provide higher-resolution information on the integrity of occurrences within a site. They often use quantitative, plot-based protocols coupled with a sampling design to provide data for detailed metrics (Barbour et al. 1996, Blocksom et al. 2002). Often indices of biological condition such as the Floristic Quality Index or Vegetation Index of Biotic Integrity (Rocchio 2007a, 2007b, DeKeyser et al. 2003, Mack 2004, Miller et al. 2006) are solely used as the Level 3 assessment since vegetation has been found to be an effective integrator of condition of many ecological attributes (Mack 2004). However, quantitative metrics for soils, hydrology, birds, fish, amphibians, invertebrates, and other major ecological attributes can be used. These attributes are typically more time-consuming and costly to measure, but their response may differ enough from that of the vegetation that they provide additional valuable information on ecological integrity.

Although the three levels are integrated, 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. It is also possible to use the three levels together. One might first assign a Level 1 rating or rank to all occurrences, then choose

[1] It should be pointed out that although remote sensing metrics are usually thought of as "coarser" or less accurate than field-based rapid or intensive metrics, this is not always the case. Some information available from imagery may be very accurate and more intensive than can be gathered in the field. Such information may also be more time-demanding and expensive.

Table 2. Summary of Three-level approach to conducting ecological integrity assessments (adapted from Brooks et al. 2004, USEPA 2006).

Level 1 – Remote Assessment	Level 2 – Rapid Assessment	Level 3 – Intensive Assessment
General description: Landscape condition assessment	**General description:** Rapid site condition assessment	**General description:** Detailed site condition assessment
Evaluates: Condition of individual areas/occurrences using remote sensing indicators	**Evaluates:** Condition of individual areas/occurrences using relatively simple field indicators	**Evaluates:** Condition of individual areas/occurrences using relatively detailed quantitative field indicators

Based on:
• GIS and remote sensing data
• Layers typically include:
  – Land cover / use
  – Other ecological types
	Can be based on:
	• Stressor metrics (e.g., ditching, road crossings, and pollutant inputs); and
	• Condition metrics (e.g., hydrologic regime, species composition)
		Can be based on:
		• Indicators that have been calibrated to measure responses of the ecological system to disturbances (e.g., indices of biotic or ecological integrity)

Potential uses: • Identifies priority sites • Identifies status and trends of acreages across the landscape • Identifies condition of ecological types across the landscape • Informs targeted restoration and monitoring	**Potential uses:** • Promotes integrated scorecard reporting • Informs monitoring for implementation of restoration or management projects • Supports landscape / watershed planning • Support s general conservation and management planning	**Potential uses:** • Promotes integrated scorecard reporting • Identifies status and trends of specific occurrences or indicators • Informs monitoring for restoration, mitigation, and management projects
Example metrics: -Landscape Development Index - Land Use Map - Road Density - Impervious Surface	**Example metrics:** - Landscape Connectivity - Vegetation Structure - Invasive Exotic Plant Species - Forest Floor Condition	**Example metrics:** - Landscape Connectivity - Structural Stage Index - Invasive Exotic Plant Species - Floristic Quality Index (mean C) - Vegetation Index of Biotic Integrity - Soil Calcium:Aluminum Ratio

or prioritize among them to conduct a Level 2 EIA, and finally, focus on a few of those with a Level 3 assessment. The process should lead to an increasing accuracy of assessment. Where information is available for all three levels across multiple sites, it is desirable to calibrate the levels, to ensure that there is an increase in accuracy of the assessment as one goes from Level 1 to 3. To ensure that the three-level approach is consistent in how ecological integrity is assessed among levels, a standard framework or conceptual model for choosing metrics is used (as shown in Table 1). Using this model, a similar set of metrics are chosen across the three levels, organized by the standard set of ecological attributes and factors - landscape context, size, condition (vegetation, hydrology, soils). This approach facilitates working between levels for a specific assessment. For example, if the goal is simply to estimate ecological integrity as accurately as possible, given limitation on time and resources, it maybe that landscape context and size are measured using level 1 metrics, soils and hydrology using level 2 metrics, and vegetation using level 3 metrics.

2.6 Definitions of the Ecological Integrity Ranking Scale

As noted previously, ecological integrity can be defined the natural range of variability associated with the structure, composition, and function of an ecosystem exposed to minimal human-induced impacts. Impairment is defined as deviation from the natural range of variation as described by the ecological condition of reference or benchmark sites. A critical aspect of linking ecological integrity to reference sites is to distinguish natural ranges of variation from variation caused by a variety of negative anthropogenic impacts *i.e.,* those impacts that directly or indirectly degrade occurrences of an ecosystem. In other words, an understanding of how the presence and impact of human activity relates to natural ecological patterns and processes is needed to define ratings of individual metrics according to their deviation from the natural range of variation (Kapos et al. 2002). Ideally, measurements of each metric are collected from sites exposed to various degrees of human-induced disturbance ranging from those possessing minimal impact to those highly degraded by human activity, providing an ecological dose-response curve from which to assess the relationship between each metric and human disturbance. This process allows each metric to be quantitatively described along a continuum of human disturbance and provides a means of assessing the deviation of condition from its natural range of variation (Karr and Chu 1999). Each metric is then individually scored on a comparable scale then combined to produce an overall index score.

Regardless of which metric is being measured a standard ecological integrity ranking scale is used to score each measurement. A report-card style scale is used and metrics, key ecological attributes or overall ecological integrity is ranked from “excellent” to “degraded” or A”, “B”, “C” or “D” (Table 3). In order to make such rankings operational, the general ranking definitions need to be more specifically described. A suite of attributes that are assumed to be important to assessing various grades of ecological integrity are used to describe, in more detail, the overall condition each of these rankings are intended to reflect (Table 4). These descriptions provide guidance when developing specific metric rankings (Section 2.8). The helps ensure that all metrics, regardless of the actual unit of measurement of the field value, is ranked or scored on a comparable scale.

Table 3.Basic Ecological Integrity Ranks

Ecological Integrity Rank	Description
A	Excellent estimated ecological integrity
B	Good estimated ecological integrity
C	Fair estimated ecological integrity
D	Poor estimated ecological integrity

Table 4. Ecological Integrity Rank Definitions (Faber-Langendoen et al. 2009a)

Rank Value	Description
A	Occurrence is believed to be, on a global or range-wide scale, among the highest quality examples with respect to major ecological attributes functioning within the bounds of natural disturbance regimes. Characteristics include: the landscape context contains natural habitats that are essentially unfragmented (reflective of intact ecological processes) and with little to no stressors; the size is very large or much larger than the minimum dynamic area ; vegetation structure and composition, soil status, and hydrological function are well within natural ranges of variation, exotics (non-natives) are essentially absent or have negligible negative impact; and, a comprehensive set of key plant and animal indicators are present.
B	Occurrence is not among the highest quality examples, but nevertheless exhibits favorable characteristics with respect to major ecological attributes functioning within the bounds of natural disturbance regimes. Characteristics include: the landscape context contains largely natural habitats that are minimally fragmented with few stressors; the size is large or above the minimum dynamic area, the vegetation structure and composition, soils, and hydrology are functioning within natural ranges of variation; invasives and exotics (non-natives) are present in only minor amounts, or have or minor negative impact; and many key plant and animal indicators are present.
C	Occurrence has a number of unfavorable characteristics with respect to the major ecological attributes, natural disturbance regimes. Characteristics include: the landscape context contains natural habitat that is moderately fragmented, with several stressors; the size is small or below, but near the minimum dynamic area; the vegetation structure and composition, soils, and hydrology are altered somewhat outside their natural range of variation; invasives and exotics (non-natives) may be a sizeable minority of the species abundance, or have moderately negative impacts; and many key plant and animal indicators are absent. Some management is needed to maintain or restore[2] these major ecological attributes.
D	Occurrence has severely altered characteristics (but still meets minimum criteria for the type), with respect to the major ecological attributes. Characteristics include: the landscape context contains little natural habitat and is very fragmented; size is very small or well below the minimum dynamic area; the vegetation structure and composition, soils, and hydrology are severely altered well beyond their natural range of variation; invasives or exotics (non-natives) exert a strong negative impact, and most, if not all, key plant and animal indicators are absent. There may be little long-term conservation value without restoration, and such restoration may be difficult or uncertain.[3]

[2] Ecological restoration is: "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. Restoration attempts to return an ecosystem to its historic trajectory" (SER 2004).

[3] D-ranked types present a number of challenges. First, with respect to classification, a degraded type may bear little resemblance to examples in better condition. Whether a degraded type has "crossed the line" ("transformed" in the words of SER 2004) into a semi-natural or cultural type is a matter of classification criteria. These criteria specify whether sufficient diagnostic criteria of a type remain, bases on composition, structure, and habitat.

2.7 Natural Range of Variation and Reference Conditions

As noted above, the Ecological Integrity Rankings in the EIA are based or benchmarked in the concept of natural range of variability (NRV). In other words, the NRV provides a baseline from which biotic or abiotic variables can be assessed to determine whether ecological integrity has been degraded at a site. Thus, defining and describing the NRV for each ecological system is extremely important to maintaining consistency in how each metric is ranked within and among ecological systems. The conceptual ecological models associated with each ecological system in Section 4.0 essentially summarize the key ecological factors associated with how the system functions within the bounds of the NRV. The specific values or description of the NRV for each of the key ecological attributes are represented by the "A" ranks for each metric.

The concept of the natural range of variability (NRV) is based on the temporal and spatial range of climatic, edaphic, topographic, and biogeographic conditions under which contemporary ecosystems evolved (Morgan et al. 1994; Quigley and Arbelbide 1997). Whitlock (1992) suggest modern vegetation patterns in the Pacific Northwest began about 5,000 – 1,500 years before present although notes that climate and vegetation response is constantly shifting. Thus, the NRV is not considered to be static for any given variable but rather a range of responses to climatic fluctuations which have occurred over the past few thousand years.

Another consideration for describing the NRV is the degree to which anthropogenic impacts have altered natural ecosystems. There is disagreement over whether disturbances resulting from Native Americans' interaction with the landscape occurred over spatial and temporal scales in which native flora and fauna were able to adapt (see Vale 1998 and Denevan 1992). The hypothesis offered by Vale (1998), which notes that Native American impacts were not ubiquitous across the landscape, is accepted for this project. Furthermore, where Native American impacts did occur (i.e. intentional burning of ecosystems), it is accepted here that they occurred over spatial and temporal scales in which native biota were able to adapt and thus are included within the NRV (Quigley and Arbelbide 1997; Wilhelm and Masters 1996). European settlement is presumed to have introduced a myriad of land uses and impacts that, because of their intensity, frequency, and duration were novel changes to the ecological template upon which most contemporary ecosystems evolved.

The description of the NRV is based on historical evidence and current status of natural variation. The current status of NRV is best measured by collecting data from sites with minimal human-induced stress. These conditions, also referred to as the **reference standard condition**, represent one end of a continuum ranging from sites with minimal or no exposure to human-induced disturbance to those in a highly degraded condition due to such impacts (Stoddard et al. 2006). This continuum is also called the **reference condition** and characterizes the full range of common circumstances – from seemingly 'pristine' or benchmark sites to highly degraded sites – so that metrics may be developed and applied that adequately characterize that full range of conditions on the landscape. Sampling ecological conditions associated with the entire spectrum of human-induced stress allows the construction of multi-metric indices as well as a framework for interpreting changes in ecological condition (Davies and Jackson 2006). This requires collection of data from sites exposed to varying types and intensities of human disturbance in order to characterize how metrics respond to increasing human-induced stress. Historical information can also be used to define what ecological conditions were like prior to major human alterations. Only through such sampling and incorporation of historical information can the full range of metric values be sufficiently analyzed and interpreted to provide for rigorous and repeatable ecological integrity assessment ranks.

2.8 Development of Metric Rankings

Each metric is rated according to deviation from its natural range of variability based on an understanding of how each metric responds to increasing human disturbance. The further a metric deviates from its natural range of variability the lower rating (the same applies to the overall index of ecological integrity). The EIA uses four rating categories to describe the status of each metric relative to its natural variability (Section 2.6). There are two important thresholds associated with these ranks. **The B-C threshold indicates the level below which conditions are not considered acceptable for sustaining ecological integrity. This threshold is also the basis for defining Desired Ecological Conditions for this project.** The C-D threshold indicates a level below which system integrity has been drastically compromised and restoration is very difficult and/or very costly.

What is natural or historical may be difficult to define for many cases, given our inability to document this range of variation over sufficient spatial and temporal scales and the relative extent of human disturbance over time. However, through reflections on historical data, and analysis of data gathered from with the full range of reference sites, we can often distinguish the effects of intensive human uses and begin to describe an expected natural range of variation for ecological attributes that maintain the occurrence over the long-term.

For this project, existing information (e.g. literature, existing data sets, best professional judgment, etc.) was used to make some initial hypotheses about specific semi-quantitative values as they relate to the standardized metric rating descriptions developed by NatureServe (Table 4). Minimally, this process incorporates expert opinion and existing data into a standardized format so that a qualified ecologist could apply the EIA in a rapid and standardized manner to get an estimate of a site's ecological integrity. Ideally, the next phase in EIA development would be to field test and validate these initial hypotheses by determining their ability to discriminate between sites exposed to varying degrees of human-induced stress through collection of field data (see Section 2.10).

2.9 Stressor Checklist

As noted above, the measurement of stressors independently from that of ecological condition provides a means for assessing the possible correlations between ecological integrity and specific stressors. Such correlations might help in guiding management recommendations, restoration actions, and conservation measures at a variety of spatial scales. NatureServe has developed a simple method for documenting the type, scope, and severity of stressors associated with each

Rank Factor (Faber-Langendoen et al. 2009a, Master et al. 2009). The stressor checklists are not presented in this document but their use, alongside the EIA Scorecards, are recommended when using the EIA Framework.

2.10 Field Testing and Validating the EIA Model

The development of an ecological assessment tool can be categorized into three major phases: initial development, field testing, and validation (Wakeley and Smith 2001, Collins et al. 2008):

(1) **Initial Development:** The overall framework or model of the assessment is designed and describes the overall purpose and method of the assessment. Conceptual models are used to identify the key ecological attributes and metrics useful for measuring ecological integrity. Natural variability and the response of each metric to human-induced disturbance is described and used to establish ranking thresholds. These tasks are accomplished through an intensive literature review, expert consultation, and use of best professional judgment. A protocol for rating each of the attributes or sites is developed.

(2) **Field Testing (Verification):** Determines whether the ecological attributes and metrics identified during initial development adequately describe ecological integrity. In addition, this exercise may reveal other useful attributes and metrics which hadn't been previously identified. The sensitivity of the metrics to changes in ecological condition is checked as well as the repeatability of metric scores in wetlands of similar condition. The consistency of metric scores between different users is also assessed. Details concerning EIA instructions and field forms are informed by field testing. All necessary changes are made to ensure the assessment adequately describes and discerns different states of ecological condition and that the results of the assessment are repeatable among different users.

(3) **Validation:** The accuracy or reliability of the EIA is tested by comparing it to an independent measure of integrity (e.g., vegetation index of biotic integrity). The EIA Scorecards are recalibrated to ensure that the best possible fit is achieved with the independent measure. This may include reassessing the metrics included in the EIAs, altering metric rating criteria, or simply changing the weights associated with each metric to more accurately reflect their influence on the overall scores.

The process of EIA development described thus far in this report is focused on initial development. Although these initial models could be immediately applied toward a monitoring framework, it is recommended that EIA development continue with field testing and validation. This allows for increased confidence in the sensitivity, accuracy, and precision of the EIA to measure ecological integrity.

Field testing is accomplished by sampling sites across a human disturbance gradient (from relatively intact to highly impacted) for each ecological system. These sample sites are referred to as **reference sites** (or **reference set**) and represent the range of variability that occurs in an ecological system as a result of natural processes as well as anthropogenic alterations. Data collected from reference sites establish a basis for defining what constitutes the natural range of variability and how each metric responds to human-induced stress. **Reference standard sites** are the subset of reference sites that are the least altered (or minimally disturbed) in the least altered landscapes (Stoddard et al. 2006). In other words, these are the sites currently functioning with their NRV and would typically have "A" (excellent) ratings for individual metrics and categories. In order to determine the level of anthropogenic alteration and thus ensure that the entire range of reference sites is sample, the level of human disturbance at each site can be rated using NatureServe's stressor checklist (Master et al. 2009), a human disturbance index (Rocchio 2007a), and/or a Landscape Stressor Model (Comer and Hak 2009).

Data from the reference set are then used to conduct the analyses associated with the field testing phase described above. To conduct validation, an independent measure of ecological integrity must be collected at each of the reference sites. The three-level approach to EIA development also lends itself to the validation phase. For example, sites where a Level 3 index of vegetation or ecological integrity had been measured could be used to calibrate a Level 1 remote-sensing assessment (Mack 2006; Mita et al. 2007, Lemly and Rocchio 2009). Level 3 could also be used in a similar manner to validate a Level 2 EIA. This process of validation results in relatively consistent information about ecological integrity being provided at the three levels of assessment, with improved interpretations as the level of intensity goes up.

2.11 Applying the EIA for Monitoring and Assessment

Below are general guidelines as to how a Level 2 or 3 EIA would be implemented (adapted from Collins et al. 2006). A comprehensive field operating manual has not yet been produced but additional details regarding the steps below can be found in Collins et al. (2006), Rocchio (2007a, 2007b), Faber-Langendoen et al. (2008a).

Step 1: Assemble background information about the management and history of the site.
Step 2: Classify the site using *Draft Field Guide to Washington's Ecological Systems* (Rocchio and Crawford 2008) to ensure that the correct EIA is used.
Step 3: Determine the extent and size of the ecological system.
Step 4: Determine the boundary and estimate the size of the assessment area (if it is not the same as the ecological system occurrence) and allocate observation points or plots, if plots or points are to be used.
Step 5: Establish the landscape context boundary for the occurrence
Step 6: Verify the appropriate season and other timing aspects of field assessment.
Step 7: Consult metric protocols to ensure they are measured systematically (see Section 5.0)
Step 8: Conduct the office assessment of stressors, landscape context and on-site conditions of the assessment area.
Step 9: Conduct the field assessment of stressors and on-site conditions of the assessment area.
Step 10: Complete assessment scores and QA/QC Procedures.
Step 11: Upload results into BIOTICS Database or other regional and statewide information systems.

2.12 Communication and Reporting: The EIA Scorecard

Andreasen et al. (2001) outline six characteristics that a practical index of ecological integrity should be composed of:

- Multi-scaled
- Grounded in natural history
- Relevant and helpful (to the public and decision-makers, not just scientists)
- Flexible
- Measurable
- Comprehensive (for composition, structure and function).

The EIA is scalable -both in terms of its applicability to multi-scaled classification systems as well as the three-level approach used for the EAI assessment. Metric rankings are firmly anchored in the natural history of ecosystem types and using the conceptual model as a framework ensures that the metrics are comprehensive and helpful to a wide audience. The EIA uses a transparent and simple tabular format to report scores or ranks from the various hierarchical scales of the assessment depending on which best meets the user's objectives. For example, the user may not wish to roll-up metric ranks into aggregated ranks of integrity. Or, 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. All of these characteristics make the EIA a practical, transparent, and easily communicable approach to assessing ecological integrity.

The metrics are integrated into a rank factor ranking by plugging each metric score into a simple, weight-based algorithm. These algorithms are constructed based on expert scientific judgment regarding the interaction and corresponding influence of these metrics on ecological integrity (e.g., as done by NatureServe 2002, Parrish et al. 2003).

There are a number of approaches that could be used to aggregate the metric ranks into aggregate rankings. The approach used in this report is a simple **non-interaction point-based approach**. Each metric within a rank factor is assigned a weight, based on its perceived importance. Rankings for each metric are converted to a point value for that rank (A = 5 points, B = 4, C=3, D=1). The points are then multiplied by the weight to get a score for the metric. The scores (weighted points) for all metrics within a rank factor are summed and divided by the sum of the weights to get a rank factor score. The rank factor scores are summed and divided by the total number of factors to get an overall score, which is converted to an Index of Ecological Integrity.

Table 5. Ecological Integrity Assessment Scorecard Example for a Level 2 Assessment.

KEY ECOLOGICAL ATTRIBUTES (KEA) **Metric**	**Assigned Metric Rating**	**Assigned Metric Points**	**Weight (W)**	**Metric Score (M)**	**KEA Score (M/W)**	**KEA Rank**	**Ecological Integrity Score**	**Ecological Integrity Rank (EO rank)**
LANDSCAPE CONTEXT					4.3	B		
Buffer Length	A	5	1	5				
Buffer Width	B	4	1	4				
Buffer Condition	B	4	1	4				
Connectivity	B	4	1	4				
			∑=4	∑=17				
SIZE					4.3	B		
Relative Size	A	5	0.5	2.5				
Absolute Size	B	4	1	4				
			∑=1.5	∑=6.5				
VEGETATION (BIOTA)					3.4	C		
Cover of Native Plants	C	3	1	3				
Cover of Invasive Species	C	3	0.5	1.5				
Cover of Native Increasers	B	4	1	4				
Species Composition	B	4	1	4				
Regeneration of Woody Species	C	3	1	3				
Canopy Structure	C	3	1	3				
Organic Matter Accumulation	B	4	0.5	2				
			∑=6	∑=20.5				
HYDROLOGY					4.0	B		
Water Source	C	3	1	3				
Channel Stability	B	4	1	4				
Hydrologic Connectivity	A	5	1	5				
			∑=3	∑=12				
SOILS (PHYSICOCHEMISTRY)					4.0	B		
Physical Patch Types	B	4	0.5	2				
Water Quality	B	4	1	4				
Soil Surface Condition	B	4	1	4				
			∑=2.5	∑=10				
					∑=20			
RATING **A**=4.5-5.0, **B** = 3.5-4.4, **C**=2.5-3.4, **D**=1.0-2.4							4	B

3.0 Using Ecological Integrity Assessments as a Monitoring Framework for Washington State Wildlife Areas

A monitoring framework designed to track the status and trends of ecological systems across a large spatial scale (e.g. a large or multiple State Wildlife Areas) might be best organized around a hierarchical, multi-scale approach to monitoring and assessment. Because the EIA is scalable in terms of its applicability to multi-scaled classification systems and the scale and intensity of application, it is suited to serve as a foundation for a monitoring framework designed to accommodate site-scale and landscape objectives. For example, a Level 1 EIA might be used as a means of prioritizing sites for field visits where a Level 2 or Level 3 assessment is completed. Prioritization could be based on which sites may be at risk of moving away from desired ecological conditions (as determined by Level 1 metric rankings). Level 2 could serve a similar purpose but with increased accuracy and detail about sites in need of a Level 3 EIA.

This section provides an overview of how the EIA Framework might be used to implement a standardized monitoring framework of ecological systems occurring on Washington State Wildlife Areas.

3.1 Desired Ecological Conditions

As mentioned in Section 2.1.3, the Washington Department of Fish and Wildlife (WDFW) has identified a portion of the ecological integrity ranking scale (see Section 2.6), specifically the A and B integrity rankings, as comprising desired ecological conditions for each of the ecological systems that are addressed in this report. Thus, any metric, key ecological attribute, or overall ecological integrity rating that has an A or B rating would be considered to be within desired ecological conditions. Correspondingly, C and D ratings would indicate that a variable is outside desired conditions and that management action is required to reverse these results.

Whether or not a metric, key ecological attribute or site is functioning within desired ecological condition will guide how the EIA Monitoring Framework is implemented. To make this more operational, additional concepts such as triggers (Section 2.1.5) and best attainable condition (Section 2.1.4) are also incorporated. Collectively, desired ecological condition, best attainable condition, and triggers provide guidance toward decision making within the context of the monitoring framework. This is further described below within the context of each EIA Level.

3.2 Integration of Level 1, 2, and 3 Assessments into a Monitoring Framework

3.2.1 Level 1 Assessment

A Level 1 EIA is a comprehensive generic approach that is applicable to all natural ecosystems and is based primarily on metrics derived from remote sensing imagery (see Section 4.1). A Level 1 EIA could be used as a means of prioritizing sites for field visits, where a Level 2 or

Level 3 assessment is completed. Level 1 EIAs can also be used as a measure of integrity whenever a field visit cannot be completed. Because the objective of all three EIA levels is the same (i.e. 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.

A very basic Level 1 EIA might include an overall assessment of landscape integrity using a Landscape Condition Model (LCM; Comer and Hak 2009). The LCM is similar to the Landscape Development Intensity Index (Brown and Vivas 2005), human footprint model (Leu et al. 2008), and anthropogenic stress model (Danz et al. 2009) all which have been used for similar purposes elsewhere. The LCM integrates various GIS land use layers (roads, land cover, water diversions, groundwater wells, dams, mines, etc.) at a 30-90 m or 1 km pixel scale. These layers are the basis for various stressor-based metrics. The metrics are weighted according to their perceived impact on ecological integrity, into a distance-based, decay function to determine what effect these stressors have on landscape integrity. The result is that each grid-cell (30 m or more) is assigned a stressor "score". The product is a landscape or watershed map depicting areas according to their potential "integrity." We can segment the index into four rank classes, from Excellent (slightly impacted) to Poor (highly impacted) (Figure 1). This landscape model is valuable in its own right for landscape scale planning, site selection, etc.

An example of how to implement a Level 1 assessment is as follows: Locations are chosen within State Wildlife Areas. These locations may be a subset or all examples of an ecosystem type that is of interest identified to specified level of ecosystem classification. Points or polygons are established for each of these locations, and these are overlain on the Landscape Condition Model. A landscape context area is defined around the occurrence (Figure 1). The landscape condition model provides the data for the "landscape condition model" metric, based on the average score of the pixels within the landscape context. Connectivity and Size can be readily assessed as well. Together these metrics provide a simple means of characterizing the ecological integrity of an occurrence of any ecological system.

The results from this analysis can be used in multiple ways:

- To provide a cost efficient way of estimating ecological integrity of every ecosystem which occurs on State Wildlife Areas. This alone could be used for guiding management decisions.
- To prioritize where Level 2 or 3 EIA should be conducted. The ecological integrity rank of each occurrence, relative to desired ecological conditions, best attainable conditions or triggers, could be used as the criteria for needing to conducting Level 2/3 assessments
- To integrate the status and trends of extent and condition of an ecological system to monitor long-term changes of ecological systems on State Wildlife Areas.

A Level 1 assessment can also help determine best attainable conditions of any particular occurrence or site. For example, the best attainable condition of occurrence embedded in a landscape or part of an occurrence with poor integrity might be constrained to an ecological state outside desired ecological conditions. In other words, due to the surrounding landscape, it might not be possible for WDFW to restore or manage the site toward desired ecological conditions.

For such a scenario, best attainable condition would describe (using ecological integrity ranks) the ecological conditions that could be feasibly managed for.

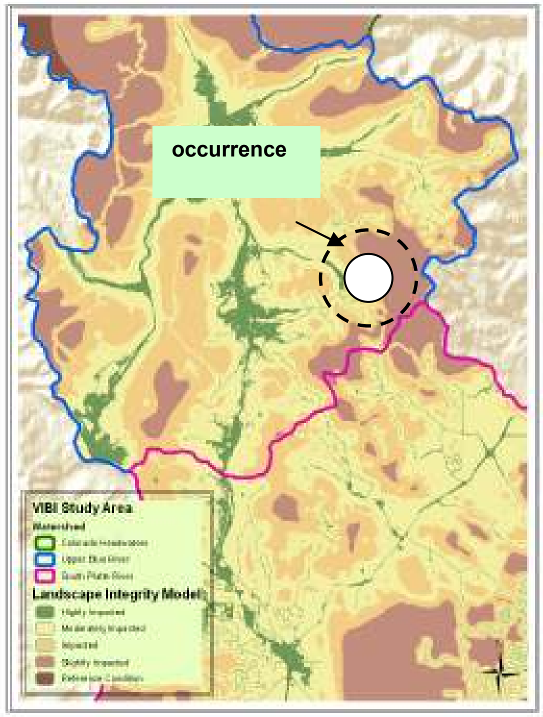

Figure 1. Demonstration of Level 1 Assessment based on a Landscape Condition Model. Values for landscape context metrics and condition metrics for an occurrence can be derived from this approach. (from Rocchio 2007a).

3.2.2 Level 2 Assessment

Level 2 EIAs are used for relatively rapid (~2 hours per small patch up to full day for matrix types) site assessments. The Level 2 EIA can be considered the 'workhorse' within the context of a hierarchical monitoring framework as it provides a compromise between efficiency of application and assessment accuracy. Although it would be more costly and time consuming to apply the Level 2 EIA to each ecological system occurrence on State Wildlife Areas, the Level 2 assessment could be a very useful method for implementing a probability-based approach to monitoring. Probability-based monitoring designs such as the Generalized Random Tessellation Stratified (GRTS) survey design create a spatially balanced random sample of points (Stevens & Olsen 1999). Using a Level 2 EIA to determine ecological integrity of these sites results in a rigorous estimate of overall ecological integrity for the targeted ecological systems. This information can be used to determine if, on average, a particular ecological system is functioning within or outside desired ecological conditions as it appears on State Wildlife Areas. Those systems functioning near or outside the threshold of desired ecological conditions would require Level 3 assessments to obtain more detailed information about current ecological conditions.

Of course, Level 2 EIA could also be used at any particular site to determine its current ecological integrity and, thus, determine whether it is functioning within desired ecological conditions. If the site is near (i.e. a trigger has occurred) or outside the desired ecological conditions then a Level 3 assessment would be warranted for that specific location.

A probability-based Level 2 assessment could also be useful for identifying sensitive or vulnerable ecological systems on State Wildlife Areas through the development of ecological system ‘profiles’. These profiles would include: (1) total extent on and off a particular State Wildlife Area; (2) changes in extent with time; and (3) overall ecological integrity of a system throughout extent of the profile. The current and historical extent would be determined using comprehensive maps such as NatureServe’s Ecological Systems map. The profile could then be used to prioritize management actions for ecological systems on State Wildlife Areas. For example, depending on the type, abundance, and overall ecological integrity of each ecological system, they can be categorized into “action” categories, thereby providing a systematic means of prioritizing protection, restoration, and enhancement actions.

Finally, the Level 2 assessment should be used to test and calibrate a Level 1 EIA. This is accomplished by correlating Level 1 with Level 2 ecological integrity ranks from multiple occurrences, ideally spanning the full range of ecological conditions.

3.2.3 Level 3 Assessment

Level 3 assessments are intended for more intensive sampling objectives such as detailed assessment of ecological integrity or quantitative site-scale monitoring. Level 3 assessments are also time-consuming, costly and may required extended commitments. They are most valuable where it is important to assess in detail the status and trends of a particularly important site. The Level 3 assessment is essentially an intensification of the metrics collected for Level 2 EIAs through use of a more rigorous sampling design to collective quantitative data.

Within a multi-scaled monitoring framework, Level 3 assessments will typically be used only when a Level 2 assessment has indicated that a specific ecological system type or occurrences is near (i.e. a trigger has occurred) or outside desired ecological conditions. The Level 3 assessment will confirm the results of the Level 2 assessment and provide additional detail about specific conditions for each key ecological attribute. The Level 3 EIA can also be used to set and monitor attainment of specific performance measures for restoration or management actions.

Finally, the Level 3 assessment should be used to test and calibrate a Level 2 (or Level 1) EIA using the same approach described above.

3.2.4 Integrated Monitoring Framework

The following flowchart is intended to summarize how the integration of Levels 1, 2, and 3 EIAs can be used for a multi-scale monitoring framework.

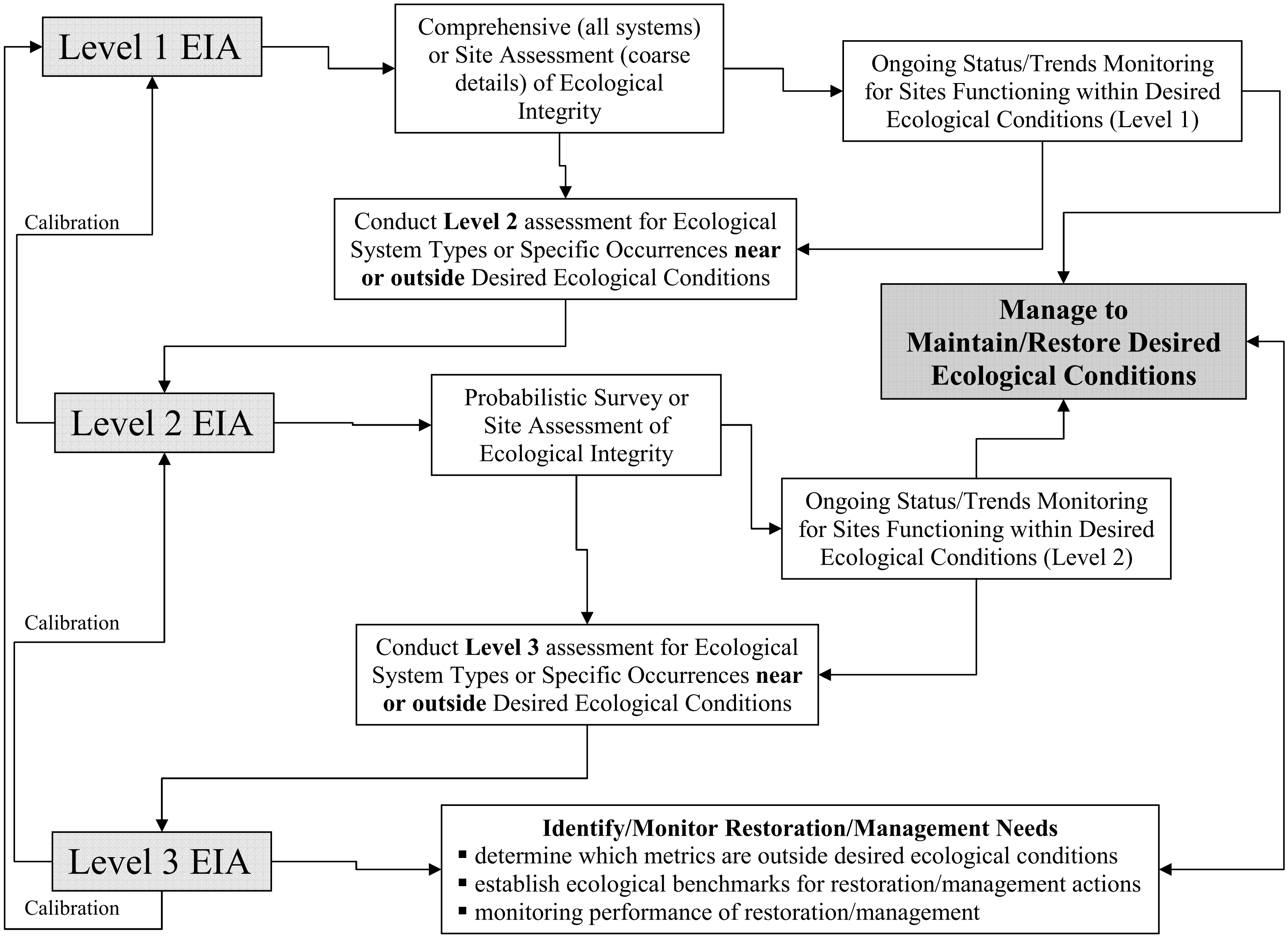

Figure 2. Generalized Schematic of Integrated Monitoring Framework

4.0 Ecological Integrity Assessment Scorecards for Washington State Wildlife Areas

4.1 Leve1 Ecological Integrity Assessment

Because a Level 1 EIA is a coarse measure of ecological integrity, most of the component metrics are applicable across all ecological system types. Table 6 presents a Level 1 EIA that is applicable to all ecological systems. Minor variations are noted in the table or metric ratings.

Table 6. Level 1 Ecological Integrity Assessment Applicable to All Natural Ecosystems (adapted from Faber-Langendoen et al. 2009a).

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	**B (4 pts.)**	**C (3 pts.)**	**D (1 pts.)**
LANDSCAPE CONTEXT	**Landscape Context**	**Edge/Buffer Length**	The buffer can be important to biotic and abiotic aspects of the wetland.	Buffer is > 75 – 100% of occurrence perimeter.	Buffer is > 50 – 74% of occurrence perimeter.	Buffer is 25 – 49% of occurrence perimeter	Buffer is < 25% of occurrence perimeter.
		Edge/Buffer Width		Average buffer width of occurrence is > 200 m	Average buffer width is 100 – 199 m	Average buffer width is 50 – 99 m.	Average buffer width is < 49 m.
		Landscape Condition Model	The intensity and types of land uses in the surrounding landscape can affect ecological integrity.	Landscape Condition Model 1.0 – 0.9	Landscape Condition Model 089-0.75	Landscape Condition Model 0.75 – 0.5	Landscape Condition Model < 0.5
		Connectivity	Intact areas have a continuous corridor of natural vegetation along the stream channel and floodplain	Intact: Embedded in 90-100% natural habitat; connectivity is expected to be high.	Variegated: Embedded in 60-90% natural habitat; habitat connectivity is generally high, but lower for species sensitive to habitat modification;	Fragmented: Embedded in 20-60% natural habitat; connectivity is generally low, but varies with mobility of species and arrangement on landscape.	Relictual: Embedded in < 20% natural habitat; connectivity is essentially absent
CONDITION	**Vegetation**	**Vegetation Structure**	Reflects natural disturbance regimes across the landscape and affects the maintenance of biological diversity.	Varies by NVC Class; see Table 7 below			

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	**B (4 pts.)**	**C (3 pts.)**	**D (1 pts.)**
	Hydrology	**Hydrologic Alterations** (non-riparian wetlands)	Degree to which stressors affect hydrology has significant impact on ecological integrity.	No alterations. No dikes, diversions, ditches, flow additions, pugging, fill or wells present in assessment area that restricts, redirects, or lowers flow or water table.	Low intensity alteration such as roads at/near grade, pugging, small diversion or ditches (< 1 ft. deep) or small amount of flow additions, or a few wells.	Moderate intensity alteration such as 2-lane road, low dikes, pugging, roads w/culverts adequate for stream flow, medium diversion or ditches (1-3 ft. deep) or moderate flow additions, or moderate number of wells on or off site.	High intensity alteration such as 4-lane Hwy., large dikes, diversions, or ditches (>3 ft. deep) capable of lowering water table, large amount of fill, or high amounts of flow additions, groundwater and well pumping.
		Floodplain Interactions (riparian)	Ecological processes are driven by the degree of overbank flooding and channel movement	Floodplain interaction is within natural range of variability. There are no geomorphic modifications (incised channel, dikes, levees, riprap, bridges, road beds, etc.) made to contemporary floodplain.	Floodplain interaction is disrupted due to the presence of a few geomorphic modifications. Up to 20% of streambanks are affected.	Floodplain interaction is highly disrupted due to multiple geomorphic modifications. Between 20 – 50% of streambanks are affected.	Complete geomorphic modification along river channel. The channel occurs in a steep, incised gulley due to anthropogenic impacts. More than 50% of streambanks are affected.
		Upstream Surface Water Retention (riparian)	Ecological processes are driven by the magnitude and frequency of peak flows and the duration and volume of base flows	< 5% of drainage basin drains to surface water storage facilities	>5 - 20% of drainage basin drains to surface water storage facilities	>20 - 50% of drainage basin drains to surface water storage facilities	> 50% of drainage basin drains to surface water storage facilities
		Upstream/On-Site Water Diversion (riparian)	Ecological processes are driven by the magnitude and frequency of peak flows and the duration and volume of base flows	No upstream, onsite, or nearby downstream water diversions present	Few diversions present or impacts from diversions minor relative to contributing watershed size. Onsite and nearby downstream diversions, if present, appear to have only minor impact on local hydrology.	Many diversions present or impacts from diversions moderate relative to contributing watershed size. Onsite and nearby downstream diversions, if present, appear to have a major impact on local hydrology.	Water diversions are very numerous or impacts from diversions high relative to contributing watershed size. Onsite and nearby downstream diversions, if present, have drastically altered local hydrology.

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	B (4 pts.)	C (3 pts.)	D (1 pts.)
	Natural Disturbance Regime	**Fire Condition Class** (uplands)	LANDFIRE's measure of the degree of departure from historic fire regime.	None	Slight	Moderate	Severe
	Physicochemical	**On Site Land Use**	The intensity of land use has a proportionate impact on the ecological processes occurring onsite.	Land Use Index Score 1.0 -0.95	Land Use Index Score 0.94-0.80	Land Use Index Score 0.79-0.40	Land Use Index Score < 0.40
SIZE	**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 (hectares)	Absolute size may be important for buffering impacts originating in the surrounding landscape	Matrix: >5,000	500-5,000	50-500	<50
				Large Patch: >500	50-500	5 – 50	<5
				Small Patch: >10	2-10	0.5-2	0.5
				Linear: > 5 km in length	1-5 km in length	0.1-1 km in length	<0.1 km in Length

Table 7. Level 1 Vegetation Structure Rankings by NVC Class

NVC Class	Rank			
	A (5 pts.)	B (4 pts.)	C (3 pts.)	D (1 pts.)
Forest (Closed Tree Canopy)	Remotely viewed total vegetation cover >80%, woody cover >40%. Either crown sizes show a wide diversity OR there are 20 or more tree stems > 50 cm dbh / ha.	Remotely viewed total vegetation cover >80%, woody cover >10%. Either crown sizes show a moderate diversity, OR there are 10 or more tree stems > 50 cm dbh / ha.	Remotely viewed total vegetation cover >50%, woody cover >10%. Either crown sizes show a low diversity, OR there are 5 or more tree stems > 50 cm dbh / ha.	Remotely viewed total vegetation cover <50%, woody cover <10%. Either crown sizes show a low diversity OR there are < 5 tree stems > 50 cm dbh / ha.
Woodland (Open Tree Canopy)	Remotely viewed total vegetation cover > 80%, woody cover >25%.	Remotely viewed total vegetation cover > 80%, woody cover >10%.	Remotely viewed total vegetation cover > 50%, woody cover >10%.	Remotely viewed total vegetation cover <50%, woody cover <10%.
Shrubland, Dwarf-shrubland (naturally closed)	Remotely viewed shrub cover is moderately high (≥40%). There is a diversity of patch types and woody cover ≤5%.		Remotely viewed shrub cover is open (25-39%). Area shows uniformity, little patch diversity both spatially and vertically (<5%).	Remotely viewed shrub cover is low (<25%). Weedy herbaceous cover may be > shrub cover.

Shrubland, Dwarf-shrubland (naturally open)	Remotely viewed shrub cover is ≥15% and ≤35%; if open shrub type has >35% shrub cover then it is usually invaded by aggressive woody species or it is misidentified moderately dense shrubland type.		Remotely viewed total vegetative cover is ≥10 and <15%	Remotely viewed shrub cover <10%.
Herbaceous Vegetation - Grasslands and Meadows	Remotely viewed total vegetation cover is high (>80%) or near reference conditions. There is a diversity of patch types and woody cover <10%. If herbaceous cover is dominated by annual vegetation, these are native species..	Remotely viewed total vegetation cover is high (>80%) or near reference conditions, woody cover <10%. The diversity of patch types may be diminished, but patch diversity still occurs. If herbaceous cover is dominated by annual vegetation, these are native species.	Remotely viewed total vegetation cover >50%, area shows uniforminity, little patch diversity both spatially and vertically, woody cover <10%.	Remotely viewed total vegetation cover <50%, woody cover >10%.
Herbaceous Vegetation - Shrub Steppe	Grass cover >80%, shrubs present and are well spaced and generally 5 -25% cover.	Grass cover 51-79%, shrubs may be present or absent; shrubs that increase (e.g. *Artemisia tridentata ssp. tridentata*) may be somewhat more dense than pre-disturbance but still <35% cover.	Total herbaceous cover at least >30% but <50%, shrub cover approaching <5%, or >25%	Grass cover <50%, and or shrubs may be quite dense, with >40% cover.
Herbaceous Vegetation - Tree Savanna	Herbaceous cover between trees is heavy enough to care surface fires with some frequency. Tree density is <30 per hectare, but may range up to 200 trees on rocky sites, which are generally small inclusions, with lower grass cover.	Herbaceous cover between trees is heavy enough to care surface fires with some frequency. Tree density is <40 per hectare, but may range up to 600 trees on rocky sites, which are generally small inclusions, with lower grass cover.	Herbaceous cover between trees is becoming sparse and is not enough to carry surface fires with some frequency. Tree density is <40 per hectare, but may range up to 600 trees on rocky sites, which are generally small inclusions, with lower grass cover.	Herbaceous growth is nearly absent, tree cover and density is very high (>800 trees/ ha) on deep soils as well as rocky soil sites.

4.1.1 Level 1 Triggers

Ecological triggers or conditions under which management activities need to be reassessed are show in the table below.

Table 8. Triggers for Level 1 EIA

Key Ecological Attribute or Metric	Trigger	Action
Any hydrology metric	C rank OR within desired ecological conditions but showing a negative trend	Conduct Level 2 OR 3 assessment; ensure current management does not result in further degradation
Vegetation Structure	C rank OR within desired ecological conditions but showing a negative trend	Conduct Level 2 OR 3 assessment; ensure current management does not result in further degradation
Physicochemical	C rank OR within desired ecological conditions but showing a negative trend	Conduct Level 2 OR 3 assessment; ensure current management does not result in further degradation
Natural Disturbance Regimes	C rank OR within desired ecological conditions but showing a negative trend	Conduct Level 2 OR 3 assessment; ensure current management does not result in further degradation

4.2 Level 2 and 3 Ecological Integrity Assessment Scorecards

4.2.1 Inter-Mountain Basins Big Sagebrush Steppe

Ecological Summary

This widespread matrix-forming ecological system occurs throughout much of the northern Intermountain west (Barbour and Billing 2000). Soil depth and texture within precipitation zones largely drive the distribution of shrub steppe and associated systems on the Columbia Basin in Washington. It is bounded by montane woodlands and the Palouse prairie (Northern Rocky Mountain Foothill and Valley Grasslands) and rings the driest portion of the Basin that supports the Big Sagebrush Shrubland and the Semi-desert Shrub Steppe systems. The distribution of shrub steppe appears in a landscape mosaic largely reflecting topography and/or soils texture and depth. Deep canyons (Snake River) dissecting the southeastern corner of the basin, support Dry Canyon grasslands distinguished by colluvial soils derived from basalt and loess and periodic slope failures and slumping. Shallow soils (lithic or deep, gravel flood deposits) occur in Pleistocene flood channels that fan across the basin and support Columbia Scabland system. Landforms that support shrub steppe are a mosaic of patch types or plant associations that reflect differences in site (soil/precipitation zone) and fire effects. Soils are deep to shallow (over 6 inches) and non-saline, often with a biological soil crust (soil mosses and lichens). The space between vascular plants usually supports a biological crust that can cover up to 90+% without disturbance. Biological crust cover may be naturally less with increasing natural disturbance of soil surface, vascular plant cover, elevation, loose surface rock, and coarseness of soil so that its presence and diversity indicate high integrity.

The natural fire regime of this ecological system maintains a patchy distribution of shrubs, so the general aspect of the vegetation is that of grassland. Where fire frequency has allowed for shifts to a native grassland condition, maintained without significant shrub invasion over a 50- to 70-year interval, the area would be considered Columbia Basin Steppe and Grassland. Fire most obviously influences the density and distribution of shrubs. In general, fire increased abundance of herbaceous perennials and decreased woody plants. Fire return interval for productive shrub steppe is 12-15 years and 50-100 years in less productive areas (Miller and Eddleman 2001). Grassland or steppe fire intervals are 1-23 years (Perryman 2001). Large native ungulate grazing in the Columbia Basin differed from that in the Great Plains grasslands in duration, seasonality, and severity (Mack and Thompson 1982, Burkhart 1996). In general, grazing was dispersed and during the winter and spring when forage was available. Growing season is typically around six-weeks (Burkhart 1996). Davies and others (2009) conclude that sites with heavy litter accumulation, (ungrazed *Artemisia tridentata* ssp. *wyomingensis/Festuca idahoensis – Achnatherium thurberiana* community) are more susceptible to exotic annual invasion following fire than those with less litter accumulation. They note that introduced species and changes in climate can change ecosystem response to natural disturbance regimes.

This ecological system is dominated by perennial grasses and forbs (>25% cover) with *Artemisia tridentata (*ssp. *tridentata*, *xericensis,* and *wyomingensis), Artemisia tripartita*, and/or *Purshia tridentata* shrubs in an open to moderately dense (5-30% cover) shrub layer. Shrubs can be represented only as seedlings. Associated graminoids can include *Pseudoroegneria spicata, Poa secunda, Poa cusickii, Koeleria macrantha Hesperostipa comata*, and *Achnatherum thurberiana*. More moist climatic areas support closed to nearly closed grasslands with *Festuca idahoensis* or *F. washingtonica.,* higher forb diversity, *Carex filifolia* an important rhizomatous species, the shrubs *Artemisia tripartita* ssp. *tripartita*, *Artemisia tridentata* ssp. *tridentata*, *Artemisia tridentata* ssp. *xericensis*, and/or *Purshia tridentata* and have fewer southern Great Basin characteristic species than on lower precipitation or shallow, more skeletal soil sites. The latter areas typically have more *Bromus tectorum* in all seres than the more moist versions of this system that are generally more robust to vegetation disturbance. Perryman (2001) summaries that depending upon site potential, when sagebrush cover reaches 5-7% herbaceous biomass production begins to decline and herbaceous density begins to decline when sagebrush cover is 12-15%.

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).

The primary land uses that alter the natural processes of this system are associated with livestock practices, annual exotic species, fire regime alteration, direct soil surface disturbance, and fragmentation. Excessive grazing stresses the system through soil disturbance, opening the biological soil crust and perennial layers to the establishment of native disturbance increasers and annual grasses and, if soil moisture is present and sagebrush seeds are available, increasing shrub density. Persistent grazing will further diminish perennial cover, exposed bare ground, increase exotic annuals, and may lead to dense stands of sagebrush. Fire further stresses livestock altered vegetation by increasing exposure of bare ground and consequent increases in exotic annuals and decrease in perennial bunchgrass and sagebrush abundance. Fire suppression, even in the absence of livestock grazing impacts, can increase shrub density that can reduce bunchgrass cover or increase grass litter and fire fuel that increase the probability of fire and vegetation responses that increase annual grass abundance (Davies et al. 2009). In more mesic sagebrush steppe, fire is not as important in maintenance of perennial grasses and forbs. Any soil and bunchgrass layer disturbances, such as vehicle tracks, chaining shrubs, will increase the probability alteration of vegetation structure and composition and response to fire as discussed above. Loss of shrub density and degradation of bunchgrass layer native diversity decreases obligate shrub steppe birds (Vander Haegen et al. 2000). Fragmentation of shrub steppe by agriculture increases cover of annual grass, total annual/biennial forbs, bare ground, decreases cover of perennial forbs and biological soil crusts, reduces obligate insects (Quinn 2004), obligate birds and small mammals (Vander Haegen et al. 2003).

Conceptual Ecological Model

The general relationships among the key ecological attributes associated with natural range of variability of the Inter-Mountain Basins Big Sagebrush Steppe Ecological System are presented below.

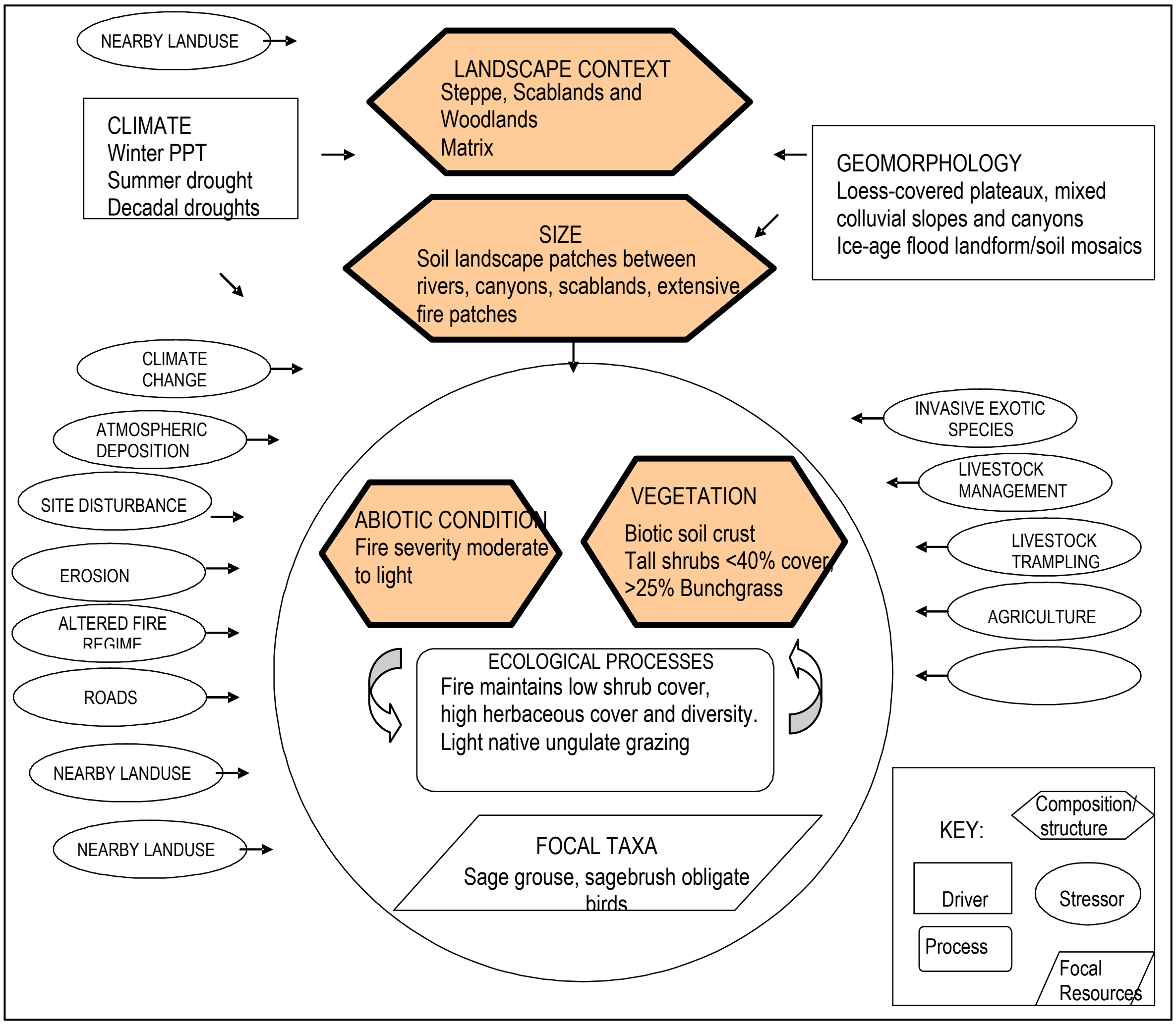

Figure 3. Conceptual Ecological Model for Inter-Mountain Basins Big Sagebrush Steppe.

Ecological Integrity Assessments (Level 2 and 3)

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 9. Intermountain Basins Big Sagebrush Steppe EIA

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	**B (4 pts.)**	**C (3 pts.)**	**D (1 pts.)**
LANDSCAPE CONTEXT	**Landscape Structure**	**Connectivity**	Intact areas have a continuous corridor of natural or semi-natural vegetation between shrub steppe 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 1.0 – 0.9	Landscape Condition Model Index 089-0.75	Landscape Condition Model Index 0.75 – 0.5	Landscape Condition Model Index < 0.5
	Edge Effects	**Edge Length**	Edge can be important to biotic and abiotic aspects. Edge Width Slope Multiplier 5-14% -->1.3; 15-40%-->1.4; >40%-->1.5	Edge with natural and semi-natural communities is > 75 – 100% of perimeter.	Edge with natural and semi-natural communities is > 50 – 74% of perimeter.	Edge with natural and semi-natural communities is 25 – 49% of perimeter	Edge with natural and semi-natural communities is < 25% of perimeter.
		Edge Width		Average Edge width of occurrence is > 200 m, adjusted for slope.	Average Edge width is 100 – 199 m, after adjusting for slope.	Average Edge width is 50 – 99 m, after adjusting for slope.	Average Edge width is < 49 m, after adjusting for slope.
		Edge Condition		Abundant (>95%) cover native vegetation, little or no (<5%) cover of non-native plants, intact soils.	Substantial (75–95%) cover of native vegetation, low (5–25%) cover of non-native plants, intact or moderately disrupted	Moderate (25–50%) cover of non-native plants, moderate or extensive soil disruption; moderate intensity of human	Dominant (>50%) cover of non-native plants, barren ground, highly compacted or otherwise disrupted soils, moderate or

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	B (4 pts.)	C (3 pts.)	D (1 pts.)
					soils; minor intensity of human visitation or recreation.	visitation or recreation.	greater intensity of human visitation or recreation, no Edge at all.
CONDITION	Vegetation	**Cover Native Plant Species**	Native species dominate this system; non-natives increase with human impacts.	Cover of native plants = relative 95-100%.	Cover of native plants relative 80-95%.	Cover of native plants relative 50 to <85%.	Cover of native plants < relative 50%.
		Native Bunchgrass	Native bunchgrass dominate; high cover is related to community resistance to invasion	Perennial bunchgrass 80% or cover or near site potential.	Perennial bunchgrasses 50-80% cover or reduced from site potential.	Perennial bunchgrasses 30-50% cover or reduced from site potential.	Perennial bunchgrass <30% cover and much reduced from site potential.
		Cover of Invasive Species	Invasive species can inflict a wide range of ecological impacts. Early detection is critical. *Bromus tectorum* abundance is critical.	None present.	Invasive species present, but sporadic (<3% cover).	Invasive species prevalent (3–10% absolute cover).	Invasive species abundant (>10% absolute cover).
		Cover of Native Increasers	Some stressors such as grazing can shift or homogenize native composition toward species tolerant of stressors.	Absent or incidental	<10% cover	10-20% cover	>20% cover
		Species Composition Note: Once developed, the Floristic Quality Assessment index could used here instead.	The overall composition of native species can shift when exposed to stressors.	Species diversity/abundance at or near reference standard conditions. Native species sensitive to anthropogenic degradation are present, functional groups indicative of anthropogenic	Species diversity/abundance close to reference standard condition. Some native species reflective of past anthropogenic degradation present. Some indicator/ diagnostic species may be absent.	Species diversity/abundance is different from reference standard condition in, but still largely composed of native species characteristic of the type. This may include ruderal ("weedy") species. Many	Vegetation severely altered from reference standard. Expected strata are absent or dominated by ruderal ("weedy") species, or comprised of planted stands of non-characteristic species, or unnaturally dominated by a single

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	B (4 pts.)	C (3 pts.)	D (1 pts.)
				disturbance (ruderal or "weedy" species) are absent to minor, and full range of diagnostic / indicator species are present.		indicator/diagnostic species may be absent.	species. Most or all indicator/diagnostic species are absent.
		Fire-sensitive Shrubs	Natural fire regime promotes patchy low cover big sagebrush or bitterbrush cover	Fire-sensitive shrubs mature and recovered from past fires; shrubs generally 3-10% cover	Fire-sensitive shrubs not recovered from past fires; represented mostly as seedlings less than height of bunchgrasses. shrubs generally <20% cover	Shrub >20% cover beginning to affect bunchgrass layer	Shrubs well >20% cover reducing bunchgrass layer or sagebrush or biiterbrush only scattered individuals or seedlings
	Physicochemical	**Biological Crust**	Crust cover and diversity is greatest where not impacted by trampling, soil surface disturbance, high plant cover, and fragmentation	intact, covers >80% of vascular plant interspaces where natural site characteristics are not limiting, i.e. steep unstable, south aspect or heavy vascular plant cover.	well-developed**,** >60% cover of vascular plant interspaces; biological crust little disturbed or may have recovered well from long-past grazing;	moderately degraded or recovering, >30% cover of vascular plant interspaces	degraded or absent, <30% cover of vascular plant interspaces;
		Soil Surface Condition	Soil disturbance can result in erosion thereby negatively affecting many ecological processes; the amount of bareground varies naturally with site type.	Bare soil areas are limited to naturally caused disturbances such as burrowing or game trails	Some bare soil due to human/livestock causes but the extent and impact is minimal.	Bare soil areas due to human/livestock causes are common. ORVs or other machinery may have left some shallow ruts.	Bare soil areas substantially & contribute to erosion or other long-lasting impacts. Deep ruts from ORVs or machinery may be present, or livestock and/or trails are widespread.
SIZE	**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	Absolute size based on shrub steppe obligate sage sparrow continuous use	Very Large (>1000 ac; 405 ha)	Large (500-1000 ac; 202-405 ha)	(300-500 ac; 120-202 ha).	Small (< 300 ac; 120 ha)

Triggers or Management Assessment Points
Ecological triggers or conditions under which management activities need to be reassessed are show 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 Tables above.

Table 10. 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 ▪ > than 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.

4.2.2 Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest

Ecological Summary

This ecological system is composed of highly variable montane coniferous forests found in the interior Pacific Northwest, from southernmost interior British Columbia, eastern Washington, eastern Oregon, northern Idaho, western and north-central Montana, and south along the east slope of the Cascades in Washington and Oregon. This system is associated with a submesic climate regime with annual precipitation ranging from 50 to 100 cm, with a maximum in winter or late spring. Winter snowpacks typically melt off in early spring at lower elevations. Elevations range from 460 to 1920 m. Most occurrences of this system are dominated by a mix of *Pseudotsuga menziesii* and *Pinus ponderosa* (but there can be one without the other) and other typically seral species, including *Pinus contorta*, *Pinus monticola*, and *Larix occidentalis*. *Pinus ponderosa* overstory is typical in frequent, low-severity, fire-maintained stands. Lack of wildfire results in an increase of *Pinus ponderosa*, *Pseudotsuga menziesii*, and *Abies grandis* in the understory. *Larix occidentalis* can be locally important. Presettlement fire regimes may have been characterized by frequent, low-intensity ground fires that maintained relatively open stands of a mix of fire-resistant species. Much more infrequent mixed-severity and stand replacement wildfire occurred and tended to generate mosaics of older, larger trees and younger regeneration.

Low and mixed severity fires favored relatively low tree density, clumped tree distribution of *Pinus ponderosa* and *Pseudotsuga menziesii*, light and patch fuel loads, simple canopy layering, and fire-tolerant tree and associated species compositions (Agee 2003; Hessburg et al. 2005). The understory varied depending on the fire interval and soil moisture. In dry sites, frequent fires results in an understory dominated by as *Calamagrostis rubescens*, *Carex geyeri*, *Pseudoroegneria spicata*, *Carex rossi,* or *Artostaphylos uva-ursi.* Moister sites or sites which may have missed a fire or two, such as north slopes, have a higher cover of shrubs such as *Acer glabrum*, *Juniperus communis*, *Physocarpus malvaceus*, *Symphoricarpos albus*, *Spiraea betulifolia*, or *Vaccinium membranaceum*. Regeneration of tree species occurs between fires but most of these seedlings and saplings are killed during the next fire. However, some tree individuals or sites escape a fire or two allowing individuals to reach an age where they are able to resist future fires resulting in the clustering of old trees and regeneration occurring across the landscape. This process of fire selection produces a forest with relatively low tree density (70-100 trees/ha), patchy distribution of young cohorts, and very little coarse woody debris and snags (Agee 2003). Many of the herbaceous and shrub species are sprouters or rhizomatous making them resilient to fire and able to quickly regrow following fire events. Stands of large mature trees become susceptible to bark beetle mortality and occasionally root disease and subsequent fires burn resulting snags and woody debris creating natural gaps where regeneration patches initiate. Collectively, fire, insect, and disease disturbance created a landscape mosaic of differing age classes and thereby spatially isolated patches where mixed or high severity would occur. Thus, snags and coarse woody debris were clustered across the landscape with their location shifting with beetle outbreaks and consumption by fire (Agee 2003). Under current conditions, the landscape mosaic is more homogenous with the predominant patch type being stands with a dense understory of shrubs and/or young trees. These stands are susceptible to mixed or high severity fires and thus have eliminated the historically patchy distribution of stands with low, mid, and high severity fire regimes. Endemic bark beetles produced patch mortality and rarely caused larger-scale overstory mortality thereby releasing understory trees. Defoliator outbreaks also cause fir mortality in some areas. Spruce budworm outbreaks are now more widespread than under historical conditions. Root diseases may play a significant role in late seral forests.

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, fire suppression, timber harvest, livestock grazing, introduced diseases, road building, development, and plantation establishments have all impacted natural disturbance regimes, forest structure, composition, landscape patch diversity, and tree regeneration (Franklin et al. 2008). Timber harvesting has focused on the large shade-intolerant, fire-resistant species in mid- and late-seral forests thereby eliminating many old forest attributes from stands (Franklin et al. 2008). Fire suppression has allowed less fire-resistant, shade-tolerant trees to become established in the understory (and sometimes dominate the canopy) creating more dense and multi-layered forests than what historically occurred on the landscape. Overgrazing may have contributed to the contemporary dense stands by eliminating grasses in some areas thereby creating suitable spots for tree regeneration as well as reducing the abundance and distribution of flashy fuels that are important for carrying surface fires. (Franklin et al. 2008; Hessburg et al. 2005). Road development has fragmented many forests creating fire breaks. Under present conditions the fire regime is mixed severity and more variable, with stand-replacing fires more common, and the forests are more homogeneous. With vigorous fire suppression, longer fire-return intervals are now the rule, and multi-layered stands of *Pseudotsuga menziesii*, *Pinus ponderosa*, and/or *Abies grandis* provide fuel "ladders," making these forests more susceptible to high-intensity, stand-replacing fires. The resultant stands at all seral stages tend to lack snags, have high tree density, and are composed of smaller and more shade-tolerant trees. Mid-seral forest structure is currently 70% more abundant than in historical, native systems. Late-seral forests of shade-intolerant species are now essentially absent. Early-seral forest abundance is similar to that found historically but lacks snags and other legacy features.

Conceptual Ecological Model

The general relationships among the key ecological attributes associated with natural range of variability of the Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest Ecological System are presented below.**Error! Reference source not found.**

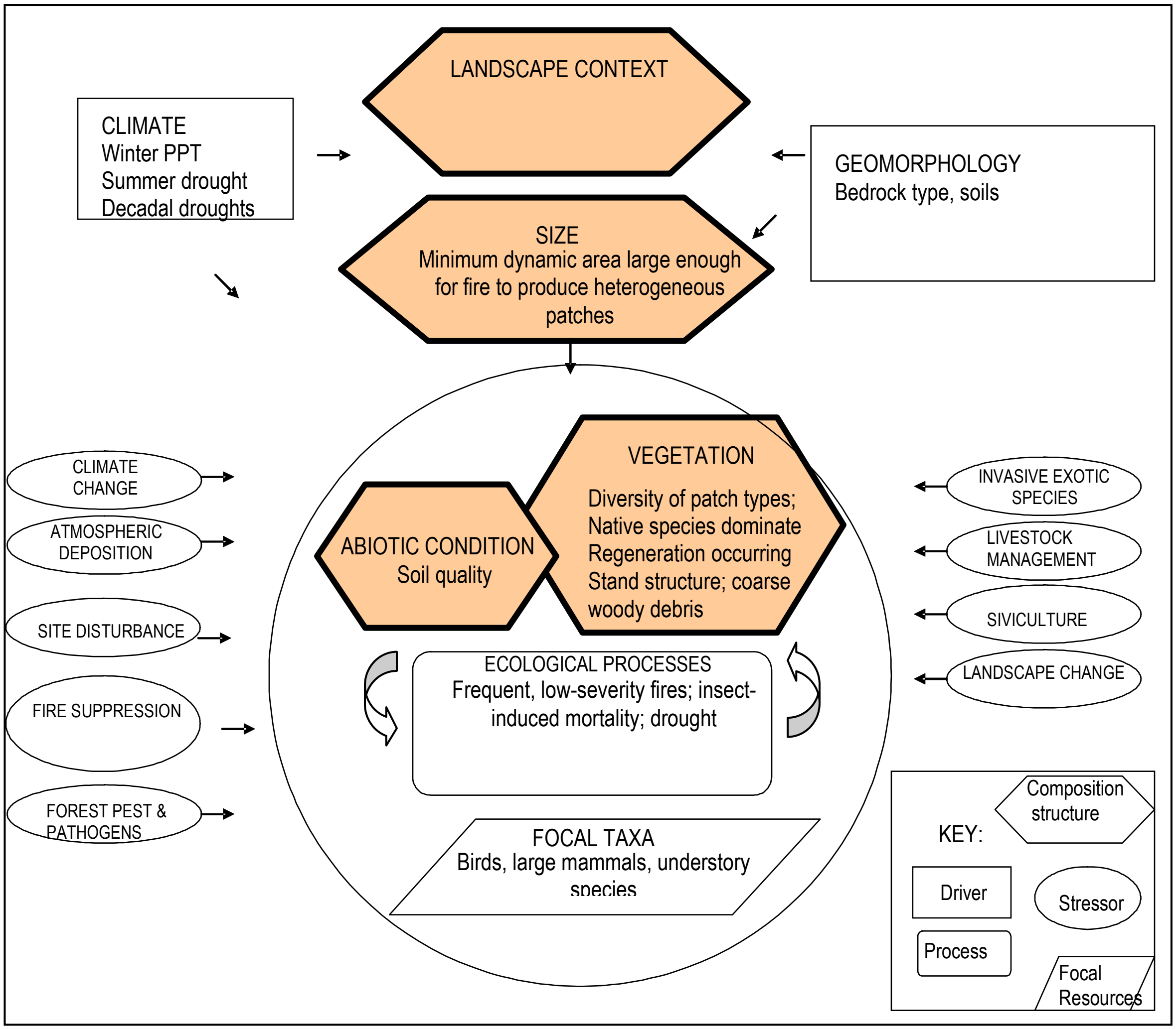

Figure 4. Conceptual Ecological Model for Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest.

Ecological Integrity Assessments (Level 2 and 3)
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 11. Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest EIA

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	B (4 pts.)	C (3 pts.)	D (1 pts.)
LANDSCAPE CONTEXT	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 at least <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
	Landscape Structure	Landscape Condition Model	The intensity and types of land uses within a 50 ha circle around the occurrence can affect ecological integrity.	Landscape Condition Model 1.0 – 0.9	Landscape Condition Model 089-0.75	Landscape Condition Model 0.75 – 0.5	Landscape Condition Model < 0.5

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	B (4 pts.)	C (3 pts.)	D (1 pts.)
		Connectivity	The percentage of anthropogenic (altered) patches provides an estimate of connectivity among natural ecological systems.	Intact: Embedded in 90-100% natural habitat; connectivity is high. Remaining natural habitat is in good condition (low modification); and a mosaic with gradients.	Variegated: Embedded in 60-90% natural habitat; habitat connectivity is generally high, but lower for species sensitive to habitat modification; Remaining natural habitat with low to high modification and a mosaic that may have both gradients and abrupt boundaries.	Fragmented: Embedded in 10-60% natural habitat; connectivity is generally low, but varies with mobility of species and arrangement on landscape. Remaining natural habitat with low to high modifications and gradients shortened.	Relictual: Embedded in < 10% natural habitat; connectivity is essentially absent. Remaining natural habitat generally highly modified and generally uniform.
CONDITION	**Vegetation Composition**	**Cover Native Understory Plant Species**	Native species dominate the understory; non-natives increase with human impacts.	Cover of native plants = 95-100%.	Cover of native plants 80-95%.	Cover of native plants 50 to <85%.	Cover of native plants <50%.
		Cover of Invasive Species	Invasive species can inflict a wide range of ecological impacts. Early detection is critical.	None present.	Invasive species present, but sporadic (<3% cover).	Invasive species prevalent (3–10% absolute cover).	Invasive species abundant (>10% absolute cover).
		Cover of Understory Native Increasers	Some stressors can shift or homogenize native composition toward species tolerant of high anthropogenic stress.	Absent or incidental	<10% cover	10-20% cover	>20% cover

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	B (4 pts.)	C (3 pts.)	D (1 pts.)
		Composition of Overstory Canopy	Composition of old forest stands indicates integrity of disturbance regimes and presence of important functional attributes	Single or two-storied stands dominated by fire tolerant species *Pinus ponderosa*, or *Larix occidentalis*. *Pseudotsuga menziesii* may be present but is typically not more abundant than pine unless on moist or protected sites where it may dominate canopy.	On dry sites, *Pseudotsuga menziesii* codominant or slightly more than *Pinus ponderosa*. On moist sites, *Abies grandis* may be codominant	On dry sites, *Pseudotsuga menziesii* dominant. On moist sites, *Abies grandis* is dominant .	
		Species Composition Once developed the Floristic Quality Assessment Index can replace this metric (FQA measures percentage of conservative native species)	The overall composition of native species can shift when exposed to stressors.	Composed of appropriate species and proportions. Native species sensitive to degradation are present, functional groups indicative of degradation (e.g., pioneer or early successional trees) are absent to minor, full range of diagnostic/indicator species are present.	Functional groups indicative of degradation are present but low in abundance. Some indicator/diagnostic species may be absent.	Native species characteristic of the type remain present but weedy (pioneer, early successional) native species that develop after clearcutting or clearing are dominant. Many indicator/diagnostic species may be absent.	Severely altered from reference condition. Most or all indicator/diagnostic species are absent. Native species consist mostly of weedy species.
	Vegetation Structure	**Fine-scale mosaic**	The diversity and interspersion of seral patches across the occurrence is indicative of intact disturbance regimes.	Diverse assemblage of cohorts or seral patches (clusters of similar sized trees) that are distributed in a complex mosaic. Younger stands occur in natural gaps created by fire or root rot. 40-60% of occurrence is old growth with the rest consisting of patches of dense regeneration	Diversity of cohorts remains but late-seral patches are less than previous while low to mid-seral patches are increasing. OR interspersion of seral patches is becoming simplified.	Cohort diversity is low with most being early to mid-seral. Interspersion is simplified.	Single cohort present.

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	B (4 pts.)	C (3 pts.)	D (1 pts.)
		Late Seral Tree Size and Age	Stands with late seral trees provide the structural attributes that are found in forests functioning with its natural range of variability.	Clusters of old, >150 yr. old *Pinus ponderosa*, *Pseudotsuga menziesii,* and/or *Larix occidentalis* trees present. Vast majority of the old trees have not been harvested, i.e. there are only a few if any large stumps; > 8 live trees/ac (>20/ha) >21"dbh	Some (10-30%) of the old (> 150 yrs.) *Pinus ponderosa*, *Pseudotsuga menziesii*, and/or *Larix occidentalis* may have been harvested. 4-8 live trees/ac (10-20/ha) >21"dbh	Many (over 50%) of the old (> 150 yrs.), *Pinus ponderosa*, *Pseudotsuga menziesii*, and/or *Larix occidentalis* may have been harvested. 2-4 live trees/ac (5-10/ha) >21"dbh	Many, if not all, old (> 150 yrs.) *Pinus ponderosa, Pseudotsuga menziesii*, and/or *Larix occidentalis* have been harvested. <2 live trees/ac (<5/ha) >21"dbh
		Tree Regeneration	The amount and spatial distribution of regeneration is important to maintaining historical structure and is an indication of the integrity of disturbance regimes	Regeneration is limited and occurs in natural gaps or in small clusters within an older stand. On dry sites, dominated by *Pseudotsuga menziesii* or *Pinus ponderosa;* Moist sites will have more *Pseudotsuga menziesii* and occassional *Abies grandis*;	Regeneration occurring outside of natural gaps, moist sites, or protected sites (10-25% of site). Density of total trees >1" dbh average < 110 live trees/ac.	Regeneration occurring outside of natural gaps, moist sites, or protected sites (25-50% of site). Small and medium size tree are beginning to create multiple layered canopies throughout much of site. Density of total trees >1" dbh average 110- 300 live trees/ac.	Dominated by *Abies grandis* and *Pseudotsuga menziesii*. Small and medium size tree have created multiple layered canopies throughout. Density of total trees >1" dbh frequently average > 300 live trees/ac.
		Coarse Woody Debris	Accumulation of coarse woody debris is minimal in these forests due to recurring fire. Too much CWD can increase risk from fire.	Within old forest patches: Few large (> 6ft high and 12" dbh) snags and down logs.	Snags and down logs between 4-12" or < 6 ft. high may be abundant.	Snags and down logs between 4-12" or < 6 ft. are very abundant.	
	Natural Disturbance Regimes	**Fire Condition Class**	Frequent, low severity fire (~10-50 yrs.) is vital to maintaining ecological integrity.	No departure from historic fire regime. Evidence of multiple low to moderate severity fire since 1900 (Euro-America settlement period) exists in the stand. Most of stand is open and park-like with little risk of fuel laddering.	Slight departure from historic fire regime. Evidence of at least one low to moderate severity fire since 1900 (Euro-America settlement period). Fuel laddering may be present in these areas.	Moderate departure from historic fire regime. No evidence of low to moderate severity fire since early 1900's (Euro-America settlement period). Fuel laddering is common;	Severe departure from historic fire regime. Fire suppression is evident; Fuel laddering is severe and throughout much of stand.

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	B (4 pts.)	C (3 pts.)	D (1 pts.)
SIZE	Size	**Relative Patch 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 Patch Size	Absolute size may be important for buffering impacts originating in the surrounding landscape	>5,000 ha	500-5,000 ha	50-500 ha	<50 ha

Triggers or Management Assessment Points

Ecological triggers or conditions under which management activities need to be reassessed are show 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 Tables above.

Table 12. 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 ▪ > than 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.

4.2.3 Northern Rocky Mountain Lower Montane Riparian Woodland and Forest

Ecological Summary
This system includes riparian forests and woodlands consisting of deciduous, coniferous, and mixed conifer-deciduous forests that occur on streambanks and river floodplains of the lower montane and foothill zones. In Washington, this linear system occurs on streambanks and river floodplains of the lower montane and foothill zones in the northern Rocky Mountains, the Okanogan Highlands, the Blue Mountains, and sporadically on the slopes of the northeast Cascades. In the Okanogan, this system is defined as all the cottonwood-dominated or codominated riparian systems below subalpine and above the ponderosa pine zone. Complex geomorphic and biotic components and processes maintain the long-term integrity of this system (Gregory et al. (1991). Annual flooding is a key ecological process which results in a diversity of patch types such as woodlands, shrublands, wet meadows, and marshes. Woodlands are often dominated by *Populus balsamifera* which is the key indicator species. Several other tree species can be mixed in the canopy, including *Populus tremuloides*, *Betula papyrifera*, and *Betula occidentalis*. On high or older terraces or along steep reaches, conifer species found in the surrounding matrix may occur within the system. *Picea engelmannii* or *Thuja plicata* may also occur in slightly wetter environments. Shrub understory components include *Cornus sericea*, *Acer glabrum*, *Alnus incana*, *Betula papyrifera*, *Oplopanax horridus*, and *Symphoricarpos albus*. Ferns and forbs of mesic sites are commonly present in many occurrences, including such species as *Athyrium filix-femina*, *Gymnocarpium dryopteris*, and *Senecio triangularis*.

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).

Historic contemporary and land use practices have impacted hydrologic, geomorphic, and biotic structure and function of riparian areas in eastern Washington. Human land uses both within the riparian area as well as in adjacent and upland areas have fragmented many riparian reaches which has reduced connectivity between riparian patches and riparian and upland areas. Adjacent and upstream land uses also have the potential to contribute excess nutrients into riparian areas Reservoirs, water diversions, ditches, roads, and human land uses in the contributing watershed can have a substantial impact on the hydrology regime. Management effects on woody riparian vegetation can be obvious, e.g., removal of vegetation by dam construction, roads, logging, or they can be subtle, e.g., removing beavers from a watershed, removing large woody debris, or construction of a weir dam for fish habitat. In general, excessive livestock or native ungulate use leads to less woody cover and an increase in sod-forming grasses particularly on fine-textured soils. Undesirable forb species, such as stinging nettle and horsetail, increase with livestock use. Non-native plants or animals, which can have wide-ranging impacts, also tend to increase with these stressors. All of these stressors have resulted in many riparian areas being incised, supporting altered riparian plant communities, as well as numerous non-native species. This system has also decreased in extent due to agricultural development, roads, dams and other flood-control activities.

Conceptual Ecological Model

The general relationships among the key ecological attributes associated with natural range of variability of the Northern Rocky Mountain Lower Montane Riparian Woodland and Forest Ecological System are presented below:**Error! Reference source not found.**

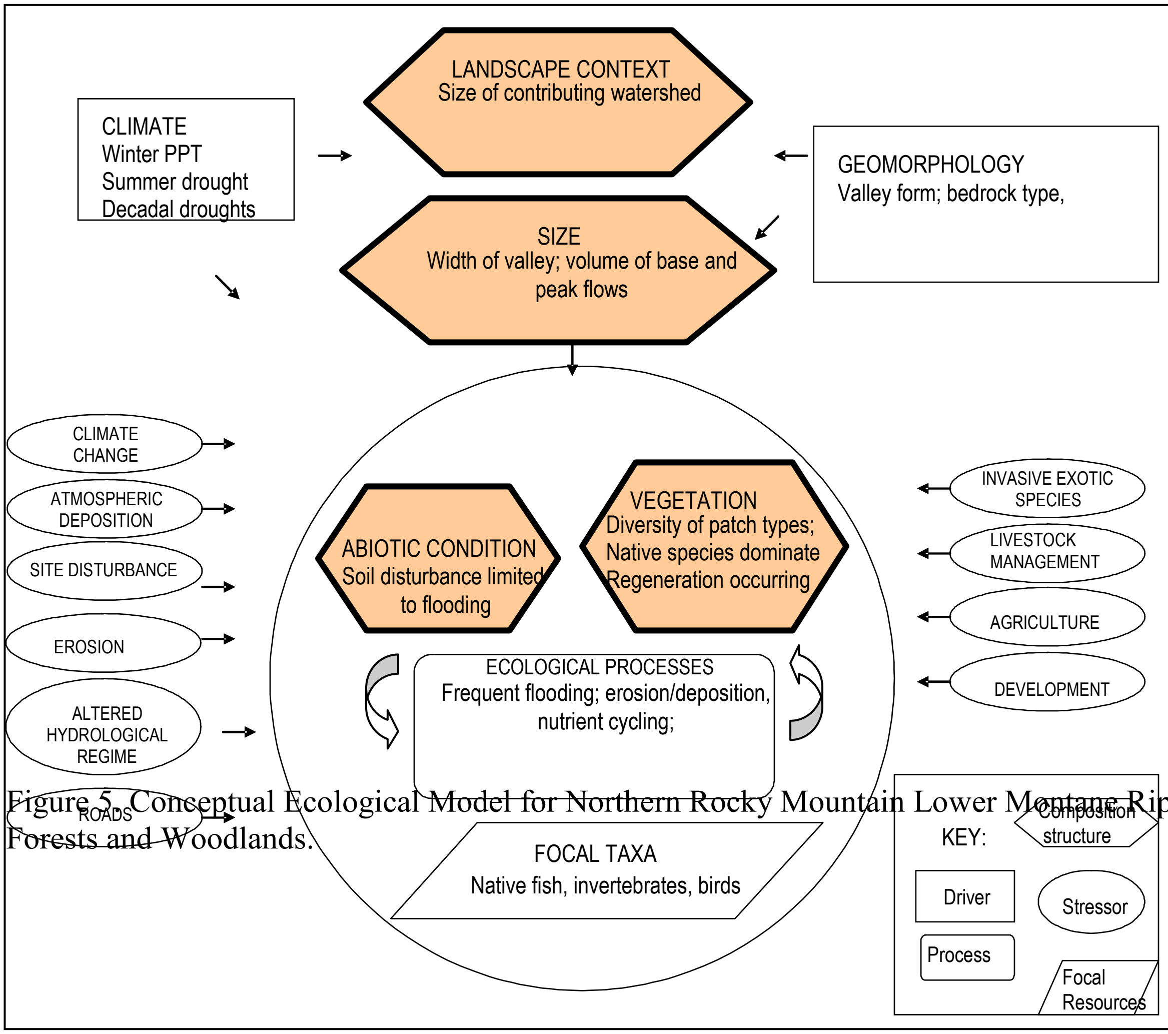

Figure 5. Conceptual Ecological Model for Northern Rocky Mountain Lower Montane Riparian Forests and Woodlands.

Ecological Integrity Assessments (Level 2 and 3)
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 13. Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland EIA.

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	**B (4 pts.)**	**C (3 pts.)**	**D (1 pts.)**
LANDSCAPE CONTEXT	**Buffer**	**Buffer Length**	The buffer can be important to biotic and abiotic aspects of the wetland. Buffer Width Slope Multiplier 5-14% -->1.3; 15-40%-->1.4; >40%-->1.5	Buffer is > 75 – 100% of occurrence perimeter.	Buffer is > 50 – 74% of occurrence perimeter.	Buffer is 25 – 49% of occurrence perimeter	Buffer is < 25% of occurrence perimeter.
		Buffer Width		Average buffer width of occurrence is > 200 m, adjusted for slope.	Average buffer width is 100 – 199 m, after adjusting for slope.	Average buffer width is 50 – 99 m, after adjusting for slope.	Average buffer width is < 49 m, after adjusting for slope.
		Buffer Condition		Abundant (>95%) cover native vegetation, little or no (<5%) cover of non-native plants, intact soils, AND little or no trash or refuse.	Substantial (75–95%) cover of native vegetation, low (5–25%) cover of non-native plants, intact or moderately disrupted soils; minor intensity of human visitation or recreation.	Moderate (25–50%) cover of non-native plants, moderate or extensive soil disruption; moderate intensity of human visitation or recreation.	Dominant (>50%) cover of non-native plants, barren ground, highly compacted or otherwise disrupted soils, moderate or greater intensity of human visitation or recreation, no buffer at all.
	Landscape Structure	**Connectivity**	Intact areas have a continuous corridor of natural vegetation along the stream channel and floodplain	Combined length of all non-buffer segments is less than 200 m (<10%) for wadable (2-sided) sites, 100 m (<10%) for non-wadable (1-sided) sites.	Combined length of all non-buffer segments is between 200 m and 800 m (10-40%) for "2-sided" sites; between 100 m and 400 m (10-40%) for "1-sided" sites.	Combined length of all non-buffer segments is between 800 and 1800 m (40-90%) for "2-sided" sites; between 400 m and 900 m (40-90%) for "1-sided" sites.	Combined length of all non-buffer segments is greater than 1800 m for "2-sided" (>90%) sites, greater than 900 m f or "1-sided" sites (>90%).

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	B (4 pts.)	C (3 pts.)	D (1 pts.)
CONDITION	Vegetation	**Cover Native Plant Species**	Native species dominate this system; non-natives increase with human impacts.	Cover of native plants = 95-100%.	Cover of native plants 80-95%.	Cover of native plants 50 to <85%.	Cover of native plants <50%.
		Cover of Exotic Invasive Species	Invasive species can inflict a wide range of ecological impacts. Early detection is critical.	None present.	Invasive species present, but sporadic (<3% cover).	Invasive species prevalent (3–10% absolute cover).	Invasive species abundant (>10% absolute cover).
		Cover of Native Increasers	Some stressors such as grazing can shift or homogenize native composition toward species tolerant of stressors.	Absent or incidental	<10% cover	10-20% cover	>20% cover
		Species Composition Note: Once developed, the Floristic Quality Assessment index could be used here instead.	The overall composition of native species can shift when exposed to stressors.	Species diversity/abundance at or near reference standard conditions. Native species sensitive to anthropogenic degradation are present, functional groups indicative of anthropogenic disturbance (ruderal or "weedy" species) are absent to minor, and full range of diagnostic / indicator species are present.	Species diversity/abundance close to reference standard condition. Some native species reflective of past anthropogenic degradation present. Some indicator/ diagnostic species may be absent.	Species diversity/abundance is different from reference standard condition in, but still largely composed of native species characteristic of the type. This may include ruderal ("weedy") species. Many indicator/diagnostic species may be absent.	Vegetation severely altered from reference standard. Expected strata are absent or dominated by ruderal ("weedy") species, or comprised of planted stands of non-characteristic species, or unnaturally dominated by a single species. Most or all indicator/diagnostic species are absent.
		Regeneration of Woody Species	Regeneration of woody species is expected in riparian areas with intact hydrology	Saplings/seedlings of native woody species (cottonwood/willow) present in expected amount; Obvious regeneration.	Saplings/seedlings of native woody species (cottonwood/willow) present but less than expected; Some seedling/saplings present.	Saplings/seedlings of native woody species (cottonwood/willow) present but in low abundance; Little regeneration by native species.	No reproduction of native woody species

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	B (4 pts.)	C (3 pts.)	D (1 pts.)
		Canopy structure	Intact riparian areas should have a diversity of tree age classes.	Average tree cover generally > 25%; mixed age	Largely heterogeneous in age or size; some gaps and variation in tree sizes AND overall density moderate and greater than 25% tree cover.	Somewhat homogeneous in density and age, AND canopy cover >90% OR <25%	Canopy extremely homogeneous, sparse, or absent (<10% cover).
		Organic Matter Accumulation	Accumulation of coarse and fine debris is integral to a variety of ecological processes	A wide size-class diversity of downed coarse woody debris (logs) and standing snags, with > 10 logs and snags exceeding 30 cm dbh and 2 m in length	A wide size-class diversity of downed coarse woody debris (logs) and standing snags, with 5 – 9 or more logs and snags exceeding 30 cm dbh and 2 m in length, and logs in various stages of decay.	A moderately wide size-class diversity of downed coarse woody debris (logs) and standing snags, with 1-4 logs and snags exceeding 30 cm dbh and 2 m in length, and logs in various stages of decay.	A low size-class diversity of downed coarse woody debris (logs) and standing snags, with logs and snags absent to rarely exceeding 30 cm dbh and 2 m in length, and logs in mostly early stages of decay (if present).
	Hydrology	**Water Source**	Anthropogenic sources of water can have detrimental effects on the hydrological regime	Source is natural or naturally lacks water in the growing season. No indication of direct artificial water sources	Source is mostly natural, but site directly receives occasional or small amounts of inflow from anthropogenic sources	Source is primarily urban runoff, direct irrigation, pumped water, artificially impounded water, or other artificial hydrology	Water flow has been substantially diminished by human activity
		Channel Stability	Alteration in hydrology or sediment loads or some onsite stressors can degrade channel stability	Natural channel; no evidence of severe aggradation or degradation	Most of the channel has some aggradation or degradation, none of which is severe	Evidence of severe aggradation or degradation of most of the channel	Concrete, or artificially hardened, channels through most of the site
		Hydrological Connectivity	Floodwater should have access to the floodplain. Stressors resulting in entrenchment affect hydrological connectivity	**LEVEL 2:** Completely connected to floodplain (backwater sloughs and channels)	Minimally disconnected from floodplain by dikes, tide gates, elevated culverts, etc	Moderately disconnected from floodplain by dikes, tide gates, elevated culverts, etc.	Extensively disconnected from floodplain by dikes, tide gates, elevated culverts, etc.
				LEVEL 3: Unconfined: Entrenchment ratio is > 4.0; Confined: Entrenchment ratio is > 1.4	Unconfined: Entrenchment ratio is 1.4 – 2.2; Confined: Entrenchment ratio is 1.0 – 1.4	Unconfined: Entrenchment ratio is < 1.4; Confined: Entrenchment ratio is < 1.0	

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	B (4 pts.)	C (3 pts.)	D (1 pts.)
	Physicochemical	**Physical Patch Types**	Intact sites have a diversity of physical environments	> 10 patches	7-10 patch types	3-6 patch types	< 3 patch types
		Soil Surface Condition	Soil disturbance can result in erosion thereby negatively affecting many ecological processes	Bare soil areas are limited to naturally caused disturbances such as flood deposition or game trails	Some bare soil due to human causes but the extent and impact is minimal. The depth of disturbance is limited to only a few inches and does not show evidence of ponding or channeling water.	Bare soil areas due to human causes are common. There may be pugging due to livestock resulting in several inches of soil disturbance. ORVs or other machinery may have left some shallow ruts.	Bare soil areas substantially & contribute to altered hydrology or other long-lasting impacts. Deep ruts from ORVs or machinery may be present, or livestock pugging and/or trails are widespread. Water will be channeled or ponded.
		Water Quality	Excess nutrients, sediments, or other pollutant have an adverse affect on natural water quality	No evidence of degraded water quality. Water is clear; no strong green tint or sheen.	Some negative water quality indicators are present, but limited to small and localized areas. Water may have a minimal greenish tint or cloudiness, or sheen.	Negative indicators or wetland species that respond to high nutrient levels are common. Water may have a moderate greenish tint, sheen or other turbidity with common algae.	Widespread evidence of negative indicators. Algae mats may be extensive. Water may have a strong greenish tint, sheen or turbidity. Bottom difficult to see during due to surface algal mats and other vegetation blocking light to the bottom.
SIZE	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	Absolute size may be important for buffering impacts originating in the surrounding landscape	>1.5 km (at least 10 m wide)	1-1.5 km; (at least 10 m wide)	0.5 - 1 km; (at least 10 m wide)	< 0.5 km; (at least 10 m wide)

Triggers or Management Assessment Points

Ecological triggers or conditions under which management activities need to be reassessed are show 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 Tables above.

Table 14. 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 ▪ > than 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.

4.2.4 Temperate Pacific Freshwater Emergent Marsh

Ecological Summary
This system includes wetlands or the portion of wetlands dominated by emergent (mostly graminoid) species where standing water is seasonally or more typically semi-permanently present. This system mostly occurs as a small patch and confined to limited areas in suitable floodplain or basin topography. Freshwater marshes are found at all elevations below timberline throughout the temperate Pacific Coast. However, the dynamic hydrological regimes, high nutrient status, and relatively warm growing season of lowlands in western Washington make this system more abundant at lower than higher elevations (MacKenzie and Moran 2004). At higher elevations, marshes are most commonly found along wave-washed lakeshores and stream floodplains where continuous, oxygenated water flow prevents peat accumulation and keeps nutrient availability high whereas peatlands tend to form in isolated basin as higher elevations (MacKenzie and Moran 2004). Marsh development along riparian areas is driven by the magnitude and frequency of flooding, valley and substrate type, and beaver activity. Seasonal and episodic flooding scour depressions in the floodplain, create side channels and floodplain sloughs, and force channel migration which can result in oxbows. Marsh vegetation establishes in these landforms if there is semi-permanent to permanent water contained within them. Marshes also occur near the fringes of lakes and ponds where their development is dictated by the gradient of the shoreline and fluctuation of lake or pond levels. Relatively flat or gently sloping shorelines support a much larger marsh system than a steep sloping shoreline. Water is at or above the surface for most of the growing season but in some areas can fluctuate with dramatic drawdowns exposing bare soil by later summer in some sites. The frequency and magnitude of water level fluctuations determine the extent of each marsh zone (floating, submerged, emergent, etc.). Water level fluctuations also support the development of different marsh zones (floating, submergent, emergent, etc.) which vary according to the degree of inundation. Soils are muck or mineral, and water is nutrient rich. High nutrients favor aggressive species resulting in relatively low diversity of plant species (MacKenzie and Moran 2004). Freshwater marshes are dominated by emergent herbaceous species, mostly graminoids (*Carex, Scirpus* and/or *Schoenoplectus, Eleocharis, Juncus, Typha latifolia*) but also some forbs. Trees, shrubs and bryophytes are typically absent or very sparse (MacKenzie and Moran 2004). Occurrences of this system typically are found in a mosaic with other wetland systems. Common emergent and floating vegetation includes species of *Scirpus* and/or *Schoenoplectus, Typha, Eleocharis, Sparganium, Sagittaria, Bidens, Cicuta, Rorippa, Mimulus*, and *Phalaris*. In relatively deep water, there may be occurrences of the Temperate Pacific Freshwater Aquatic Bed system, where there are floating-leaved genera such as *Lemna, Potamogeton, Polygonum, Nuphar, Hydrocotyle*, and *Brasenia*. A consistent source of freshwater is essential to the function of these systems.

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).

Historic and contemporary land use practices have impacted hydrologic, geomorphic, and biotic structure and function of marshes in western Washington. Reservoirs, water diversions, ditches, roads, and human land uses in the contributing watershed can also have a substantial impact on the hydrological regime. Direct alteration of hydrology (i.e., channeling, draining, damming) or indirect alteration (i.e., roads or removing vegetation on adjacent slopes) results in changes in amount and pattern of herbaceous wetland habitat. If the alteration is long term, wetland systems may reestablish to reflect new hydrology, e.g., cattail is an aggressive invader. Human land uses both within the marshes as well as in adjacent upland areas have reduced connectivity between wetland patches and upland areas. Land uses in contributing watershed have the potential to contribute excess nutrients into to the system which could lead to the establishment of non-native species and/or dominance of native increasing species. In general, excessive livestock or native ungulate use leads to a shift in plant species composition. Non-native plants or animals, which can have wide-ranging impacts, also tend to increase with these stressors. Although most wetlands receive regulatory protection at the national, state, and county level, many wetlands have been and continued to be filled, drained, grazed, and farmed extensively in the lowlands of Washington. Montane wetlands are less altered than lowland wetlands even though they have undergone modification as well. A keystone species, the beaver, has been trapped to near extirpation in parts of the Pacific Northwest and its population has been regulated in others. Herbaceous wetlands (including freshwater emergent marsh) have decreased along with the diminished influence of beavers on the landscape.

Conceptual Ecological Model

The general relationships among the key ecological attributes associated with natural range of variability of the Temperate Pacific Freshwater Emergent Marsh Ecological System are presented below:**Error! Reference source not found.**

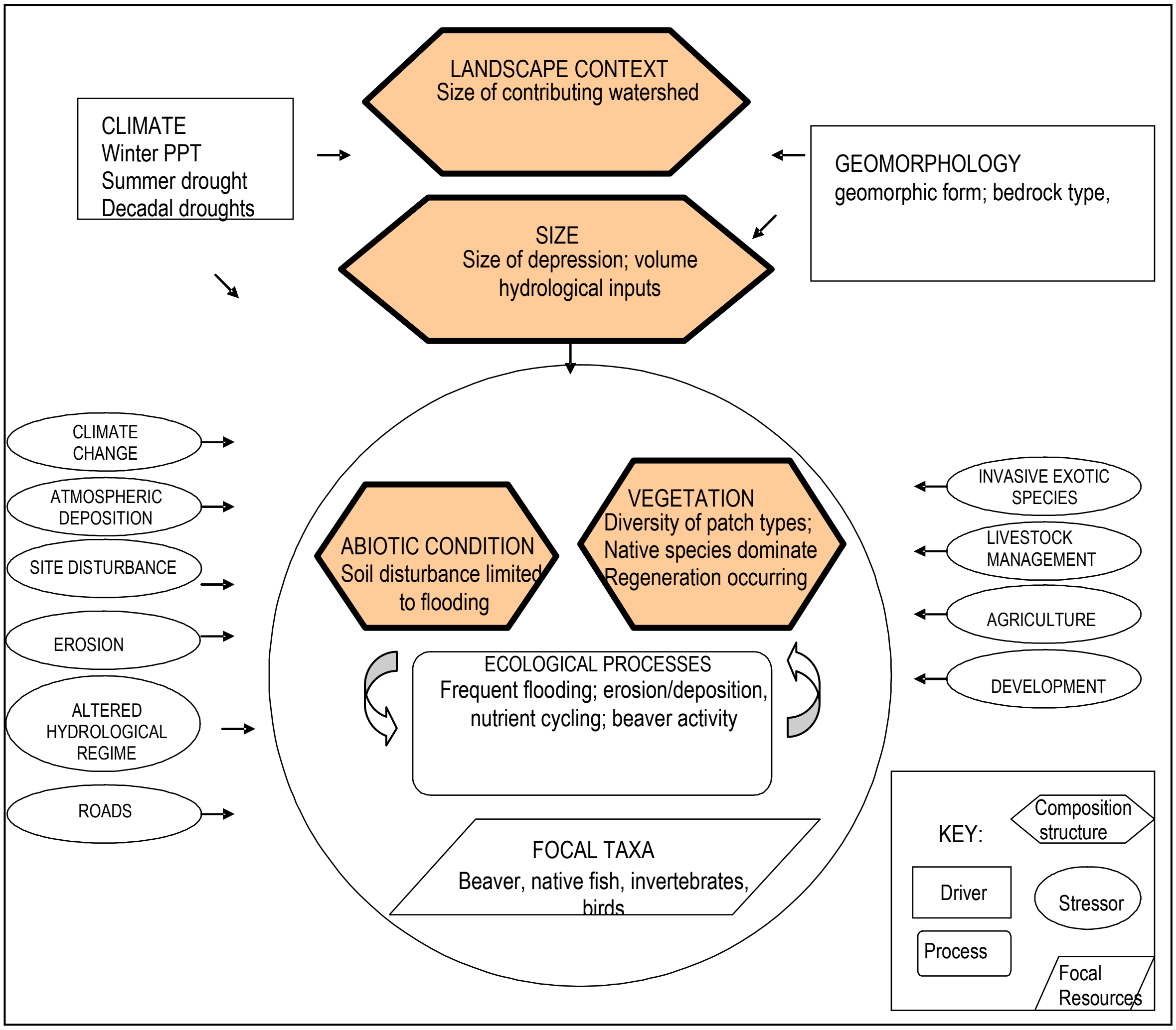

Figure 6. Conceptual Ecological Model for Temperate Pacific Freshwater Emergent Marsh

Ecological Integrity Assessments (Level 2 and 3)

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 15. Temperate Pacific Freshwater Emergent Marsh EIA.

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	**B (4 pts.)**	**C (3 pts.)**	**D (1 pts.)**
LANDSCAPE CONTEXT	**Buffer**	**Buffer Length**	The buffer can be important to biotic and abiotic aspects of the wetland. Buffer Width Slope Multiplier 5-14% -->1.3; 15-40%-->1.4; >40%-->1.5	Buffer is > 75 – 100% of occurrence perimeter.	Buffer is > 50 – 74% of occurrence perimeter.	Buffer is 25 – 49% of occurrence perimeter	Buffer is < 25% of occurrence perimeter.
		Buffer Width		Average buffer width of occurrence is > 200 m, adjusted for slope.	Average buffer width is 100 – 199 m, after adjusting for slope.	Average buffer width is 50 – 99 m, after adjusting for slope.	Average buffer width is < 49 m, after adjusting for slope.
		Buffer Condition		Abundant (>95%) cover native vegetation, little or no (<5%) cover of non-native plants, intact soils, AND little or no trash or refuse.	Substantial (75–95%) cover of native vegetation, low (5–25%) cover of non-native plants, intact or moderately disrupted soils; minor intensity of human visitation or recreation.	Moderate (25–50%) cover of non-native plants, moderate or extensive soil disruption; moderate intensity of human visitation or recreation.	Dominant (>50%) cover of non-native plants, barren ground, highly compacted or otherwise disrupted soils, moderate or greater intensity of human visitation or recreation, no buffer at all.
	Landscape Structure	**Connectivity**	Intact areas have a continuous corridor of natural vegetation along the stream channel and floodplain	Combined length of all non-buffer segments is less than 200 m (<10%) for wadable (2-sided) sites, 100 m (<10%) for non-wadable (1-sided) sites.	Combined length of all non-buffer segments is between 200 m and 800 m (10-40%) for "2-sided" sites; between 100 m and 400 m (10-40%) for "1-sided" sites.	Combined length of all non-buffer segments is between 800 and 1800 m (40-90%) for "2-sided" sites; between 400 m and 900 m (40-90%) for "1-sided" sites.	Combined length of all non-buffer segments is greater than 1800 m for "2-sided" (>90%) sites, greater than 900 m f or "1-sided" sites (>90%).

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	B (4 pts.)	C (3 pts.)	D (1 pts.)
CONDITION	**Vegetation**	**Cover Native Plant Species**	Native species dominate this system; non-natives increase with human impacts.	Cover of native plants = 95-100%.	Cover of native plants 80-95%.	Cover of native plants 50 to <85%.	Cover of native plants <50%.
		Cover of Exotic Invasive Species	Invasive species can inflict a wide range of ecological impacts. Early detection is critical.	None present.	Invasive species (e.g., *Typha, Phalaris, Phragmites*) present, but sporadic (<3% cover).	Invasive species species (e.g., *Typha, Phalaris, Phragmites*) prevalent (3–10% absolute cover).	Invasive species species (e.g., *Typha, Phalaris, Phragmites*) abundant (>10% absolute cover).
		Cover of Native Increasers	Some stressors such as grazing can shift or homogenize native composition toward species tolerant of stressors.	Absent or incidental	<10% cover	10-20% cover	>20% cover
		Species Composition Note: Once developed, the Floristic Quality Assessment index could be used here instead.	The overall composition of native species can shift when exposed to stressors.	Species diversity/abundance at or near reference standard conditions. Native species sensitive to anthropogenic degradation are present, functional groups indicative of anthropogenic disturbance (ruderal or "weedy" species) are absent to minor, and full range of diagnostic / indicator species are present.	Species diversity/abundance close to reference standard condition. Some native species reflective of past anthropogenic degradation present. Some indicator/ diagnostic species may be absent.	Species diversity/abundance is different from reference standard condition in, but still largely composed of native species characteristic of the type. This may include ruderal ("weedy") species. Many indicator/diagnostic species may be absent.	Vegetation severely altered from reference standard. Expected strata are absent or dominated by ruderal ("weedy") species, or comprised of planted stands of non-characteristic species, or unnaturally dominated by a single species. Most or all indicator/diagnostic species are absent.

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	B (4 pts.)	C (3 pts.)	D (1 pts.)
		Organic Matter Accumulation	Accumulation of coarse and fine debris is integral to a variety of ecological processes	The site is characterized by a moderate amount of fine organic matter. There is some matter of various sizes, but new materials seem much more prevalent than old materials. Litter layers, duff layers, and leaf piles in pools or topographic lows are thin.		The site is characterized by occasional small amounts of coarse organic debris, such as leaf litter or thatch, with only traces of fine debris, and with little evidence of organic matter recruitment, or somewhat excessive littler.	The site contains essentially no significant amounts of coarse plant debris, and only scant amounts of fine debris. OR too much debris
	Hydrology	**Water Source**	Anthropogenic sources of water can have detrimental effects on the hydrological regime	Source is natural or naturally lacks water in the growing season. No indication of direct artificial water sources	Source is mostly natural, but site directly receives occasional or small amounts of inflow from anthropogenic sources	Source is primarily urban runoff, direct irrigation, pumped water, artificially impounded water, or other artificial hydrology	Water flow has been substantially diminished by human activity
		Hydroperiod LEVEL 2	Adjacent land use or some onsite stressors can alter the hydrological regime.	Hydroperiod of the site is characterized by natural patterns of filling or inundation and drying or drawdown.	The filling or inundation patterns in the site are of **greater** magnitude (and greater or lesser duration than would be expected under natural conditions, but thereafter, the site is subject to **natural drawdown or drying.**	The filling or inundation patterns in the site are characterized by **natural** conditions, but thereafter are subject to **more rapid or extreme drawdown or drying**, as compared to more natural wetlands. OR The filling or inundation patterns in the site are of substantially **lower magnitude or duration** than would be expected under natural conditions, but thereafter, the site is subject to **natural drawdown or drying.**	Both the filling/inundation and drawdown/drying of the site deviate from natural conditions (either increased or decreased in magnitude and/or duration).

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	B (4 pts.)	C (3 pts.)	D (1 pts.)
		Flashiness Index LEVEL 3 version of Hydroperiod	Adjacent land use or some onsite stressors can alter the hydrological regime.	Flashiness Index = 1.0 - 2.0	Flashiness Index = 1.0 - 2.0	Flashiness Index = between 2.0 -3.0 if wetland is NOT associated with riverine	Flashiness Index = > 3.0 if wetland is NOT associated with riverine environment
		Hydrological Connectivity	Floodwater should have access to the floodplain. Stressors resulting in entrenchment affect hydrological connectivity	Rising water in the site has unrestricted access to adjacent upland, without levees, excessively high banks, artificial barriers, or other obstructions to the lateral movement of flood flows.	Lateral excursion of rising waters is partially restricted by unnatural features, such as levees or excessively high banks, but < than **50%** of the site is restricted by barriers to drainage. Restrictions may be intermittent along the site, or the restrictions may occur only along one bank or shore. Flood flows may exceed the obstructions, but drainage back to the wetland is incomplete due to impoundment.	Lateral excursion of rising waters is partially restricted by unnatural features, such as levees or excessively high banks, and **50-90%** of the site is restricted by barriers to drainage. Flood flows may exceed the obstructions, but drainage back to the wetland is incomplete due to impoundment.	All water stages in the site are contained within artificial banks, levees, sea walls, or comparable features, or **greater than 90%** of wetland is restricted by barriers to drainage. There is essentially no hydrologic connection to adjacent uplands.
	Physicochemical	**Physical Patch Types**	Intact sites have a diversity of physical environments	> 6 patches	4-5 patch types	2-3 patch types	< 2 patch types
		Soil Surface Condition	Soil disturbance can result in erosion thereby negatively affecting many ecological processes	Bare soil areas are limited to naturally caused disturbances such as flood deposition or game trails	Some bare soil due to human causes but the extent and impact is minimal. The depth of disturbance is limited to only a few inches and does not show evidence of ponding or channeling water.	Bare soil areas due to human causes are common. There may be pugging due to livestock resulting in several inches of soil disturbance. ORVs or other machinery may have left some shallow ruts.	Bare soil areas substantially & contribute to altered hydrology or other long-lasting impacts. Deep ruts from ORVs or machinery may be present, or livestock pugging and/or trails are widespread. Water will be channeled or ponded.

Rank Factor	Key Ecological Attribute	Metric	Justification	Rank			
				A (5 pts.)	B (4 pts.)	C (3 pts.)	D (1 pts.)
		Water Quality	Excess nutrients, sediments, or other pollutant have an adverse affect on natural water quality	No evidence of degraded water quality. Water is clear; no strong green tint or sheen.	Some negative water quality indicators are present, but limited to small and localized areas. Water may have a minimal greenish tint or cloudiness, or sheen.	Negative indicators or wetland species that respond to high nutrient levels are common. Water may have a moderate greenish tint, sheen or other turbidity with common algae.	Widespread evidence of negative indicators. Algae mats may be extensive. Water may have a strong greenish tint, sheen or turbidity. Bottom difficult to see during due to surface algal mats and other vegetation blocking light to the bottom.
SIZE	**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	Absolute size may be important for buffering impacts originating in the surrounding landscape (from PSP specs; J.Christy)	Very large (> 200 ac/80 ha)	Large (75-200 ac/30-80 ha)	Moderate (5-75 ac/2-30 ha)	Small (< 5 ac/2 ha)

Triggers or Management Assessment Points

Ecological triggers or conditions under which management activities need to be reassessed are show 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 Tables above.

Table 16. 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 ▪ > than 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.

5.0 Protocols for Measuring Metrics

5.1 Landscape Context Metrics

5.1.1 Landscape Connectivity

Definition: A measure of the percent of unaltered (natural) habitat within a specified landscape area (non-riverine), or degree to which the riverine corridor above and below a floodplain area exhibits connectivity with adjacent natural systems (riverine). Typically, the specification of "landscape area" varies depending on the spatial scale of the system under study. For matrix types, a 10,000 ha (25,000 ac) "large landscape" area can be used. Alternatively, a large landscape of 4,000 ha (10,000 ac) landscape area can also be justified, based on Anderson (2006). Large patch types could use a "small landscape" of 1000 ha (10 km^2) or ~2,500 ac (4 mi^2), and the "local landscape" of 100 ha (1 km^2 area) or 250 ac (0.4 mi^2). Small patch communities could use the "local landscape" of 100 ha (1 km^2 area) or 250 ac (0.4 mi^2). But when a level 1 assessment is applied to broadly classified types (e.g. deciduous forest, evergreen shrubland, perennial grassland), it is hard to know what the appropriate scale of the landscape area should be.

Source: Metric is taken from McIntyre and Hobbs (1999). The riverine metric is adapted from Collins et al. (2007; CRAM 4.5.2).

Rationale for Selection of the Variable:
Habitat loss and fragmentation have synergistic, cumulative impacts upon remaining natural areas. As more habitat is altered and converted to anthropogenic habitat, remaining fragments become more important to remaining wildlife populations, and are also more likely to be isolated and have disruptions to structure, biotic composition, ecosystem functions, and natural disturbance regimes, such as grazing or fires. The percentage of anthropogenic (altered) patches provides an estimate of connectivity among natural ecological systems.

McIntyre and Hobbs (1999) reviewed the full continuum of landscape alteration, and summarized the changes into four landscape states, from intact, to variegated, fragmented and relictual. This metric primarily accounts for outright conversion of natural habitat to other habitats; it does not directly address the degree of "habitat modification" or condition of the remaining natural habitat (McIntyre and Hobbs 1999, fig. 4). It is also primarily a gross assessment of landscape alteration, and individual species may respond differently to these four states.

<u>Non-riverine</u>**:** The metric is fairly simple, treating the landscape in a binary fashion (either natural or non-natural), and for a level 1 metric this may be sufficient. But a more sophisticated metric should accommodate the idea that landscape types having varying degrees of connectivity, depending on the variety of natural and non-natural ecosystem types.

<u>Riverine</u>: Riverine areas are typically comprised of a continuous corridor of intact natural vegetation along the stream channel and floodplain (Smith 2000). These corridors allow

uninterrupted movement of animals to up- and down-stream portions of the riparian zone as well as access to adjacent uplands (Gregory et al. 1991). These corridors also allow for unimpeded movement of surface and overbank flow, which are critical for the distribution of sediments and nutrients as well as recharging local alluvial aquifers. Fragmentation of the riverine corridor can occur as a result of human alterations such as roads, power and pipeline corridors, agriculture activities, and urban/industrial development (Smith 2000). See additional rationale in Collins et al. (2007). Note that Collins et al. (2007) have considerably refined this metric from earlier versions.

Measurement Protocol:
This metric is measured by estimating the amount of natural habitat in a pre-defined landscape area surrounding the stand or polygon and dividing that by the total area. Natural habitat includes both natural and semi-natural habitat, but excludes cultural habitat, namely agriculture and developed (urban, suburban) habitats. This measure can be completed in the office using aerial photographs or GIS, then, if possible or desirable, verifying the natural cover in the field. <u>Riverine</u>: See Collins et al. (2007; CRAM manual).

Scaling Rationale:
Less altered habitat increases connectivity between natural ecological systems and thus allow for natural exchange of species, nutrients, and water. The categorical ratings are based principally on McIntyre and Hobb's (1999) review of the literature showing that organisms are largely unaffected by landscapes with at least 60% habitat retention, whereas below 10% there appears to be a dramatic difference in bird composition on landscapes and fragmentation effects are severe (Andrén 1994). We use 20% as a more precautionary cutoff. The Heinz Center (2002) used <90% forest as a measure of unaltered or unfragmented habitat (core = 100%, interior=90-99%), and between 60-90% as "connected" forest. The Heinz Center is also investigating the use of a fragmentation index that takes into account roads that occur within the neighborhood area. (Cavender-Bares pers. comm. 2005). It is assumed that landscape connectivity operates similarly in other vegetation types.

<u>Riverine</u>: As continuous buffer decreases, the continuity of natural vegetated patches in the riparian decreases, along with corresponding changes in species, sediment, nutrient, and water movement. The ratings are partly based on the CRAM rating of Collins et al. (2007), but their scaling is very conservative; that is, buffer widths of between 5 and 10% non-natural are ranked C, and >10% non-natural is D. Here the scaling is modified to correspond to that of the non-riverine metric. Further review is needed of the scaling for this buffer.

5.1.2 Buffer and Edge Length, Width and Condition

Definition: A measure of the overall area and condition of the area immediately surrounding a wetland, using three measures: **Buffer** Length, width and condition or an upland area by the same three **Edge** measures. Buffers and edges are vegetated, natural (non-anthropogenic) areas that surround a wetland assessment area.

Source: Metric is adapted from Collins et al. (2006). The buffer of wetlands can be important to biotic and abiotic aspects of the wetland. The Environmental Law Institute (2008) has also recently reviewed the role of buffers for wetlands. Rationale for upland edges are similar so we use the same metric.

Rationale for Selection of the Variable: There is abundant evidence on the value of buffers for wetlands (Environmental Law Institute 2008) and uplands (Forman 1995 among other sources)

Measurement Protocol: This metric is measured using field-based, rapid protocols. GIS can be used to prior or after field visit to aid in determining buffer or edge length and width. The edge width applied could vary based system being assessed; we assumed a 200 m width would be capture effects for most vegetation or habitat units.

Scaling Rationale: See Collins et al. (2006). There is abundant evidence on the value of even short buffers between 10 to 50 m (Environmental Law Institute 2008); thus the CRAM Buffer width scale is extended to have an A-E rating.

5.1.3 Landscape Condition Model Index

Definition: This metric addresses the intensity of human dominated land uses within a specified landscape area. The landscape condition model index incorporates multiple stressors, their varying individual intensities, the combined and cumulative effect of those stressors, and if possible, some measure of distance away from each stressor where negative effects remain likely.

Source: Metric is adapted from Comer, P.J. and J. Hak. 2009. NatureServe Landscape Condition Model. Internal documentation for NatureServe Vista decision support software engineering, prepared by NatureServe, Boulder CO.

Rationale for Selection of the Variable: The intensity and types of land uses around the assessment area can affect ecological integrity. This model has been developed and applied to Washington State.

Measurement Protocol: The Landscape Integrity Model (LIM), a GIS-based algorithm which plugs various land use GIS layers (roads, land cover, water diversions, groundwater wells, dams, mines, etc.) weighted according to their perceived impact on ecological integrity (Table 1 for example), into a distance-based, decay function to determine what effect these stressors have on landscape integrity.

Table 1. Land Use Coefficient Table (modified from Hauer et al. 2002)

Current Land Use	Coefficient
Paved roads/parking lots/domestic or commercially developed buildings/mining (gravel pit, quarry, open pit, strip mining).	0
Unpaved Roads (e.g., driveway, tractor trail) / abandoned mines	0.1
Agriculture (tilled crop production) / intensively developed vegetation (golf courses, lawns, etc).	0.2
Vegetation conversion (chaining, cabling, rotochopping, clearcut)	0.3
Heavy grazing on rangeland or pastures	0.3
Heavy logging or tree removal with 50-75% of trees >30 cm dbh removed	0.4

Intense recreation (ATV use/camping/sport fields/popular fishing spot, etc.) / Military training areas (armor, mechanized)	0.4
Agriculture - permanent crop (vineyards, orchards, nurseries, berry production, introduced hay field and pastures etc)	0.4
Commercial tree plantations / Christmas tree farms	0.5
Dam sites and flood disturbed shorelines around water storage reservoirs	0.5
Recent old fields and other disturbed fallow lands dominated by ruderal and exotic species.	0.5
Moderate grazing on rangeland	0.6
Moderate recreation (high-use trail)	0.7
Mature old fields and other fallow lands with natural composition	0.7
Selective logging or tree removal with <50% of trees >30 cm dbh removed	0.8
Light grazing / light recreation (low-use trail) / haying of native grassland	0.9
Natural area / land managed for native vegetation	1

The result is that each grid-cell (30 m) is assigned an integrity "score". The product is a watershed map depicting areas according to their potential "integrity".

The LCM integrates various GIS land use layers (roads, land cover, water diversions, groundwater wells, dams, mines, etc.) at a 30-90 m or 1 km pixel scale. These layers are the basis for various stressor-based metrics. The metrics are weighted according to their perceived impact on ecological integrity, into a distance-based, decay function to determine what effect these stressors have on landscape integrity. The result is that each grid-cell (30 m or more) is assigned a stressor "score". The product is a landscape or watershed map depicting areas according to their potential "integrity." The index is segmented into four rank classes, from Excellent (slightly impacted) to Poor (highly impacted).

Scaling Rationale: Land uses may have different impacts on ecological patterns and processes. Some land uses have minimal impact, such as simply altering the integrity of native vegetation (e.g., recreation and grazing), while other activities (e.g., hay production and agriculture) may replace native vegetation with nonnative or cultural vegetation yet still provide potential cover for species movement. Intensive land uses (i.e., urban development, roads, mining, etc.) may completely destroy vegetation and drastically alter ecological processes. The coefficients were assigned according to best scientific judgment regarding each land use's potential impact

5.2 Condition Metrics

VEGETATION

5.2.1 Canopy Structure (Vegetation Structure)

Definition: An assessment of the overall structural complexity of the dominant vegetation layer, including the density, stem size, and canopy cover relative to reference conditions.

Source: Metric is adapted from Faber-Langendoen and others (2008) Vegetation Structural Classes-Forest information.

Rationale for Selection of the Variable: Intact riparian areas will have a diversity of tree age classes. Canopy structure is an important reflection of dynamics and creates heterogeneity within the community. The distribution of total cover, crown diversity, and stem size reflects natural disturbance regimes across the landscape and affects the maintenance of biological diversity, particularly of species dependent upon specific stages.

Measurement Protocol: This metric consists of evaluating the density, stem size, and canopy cover of the dominant layer relative to the reference and intensity of measurement will vary with level of assessment. Level 1 and Level 2 if aerial photographs are used interpret smaller scale patches, requires an evaluation of the canopy cover of the observable layers of vegetation, as well as total vegetation cover. Often, ground verification will be very helpful in interpreting the remote sensing signature. Field survey method for estimating structure may be either a (1) Site Survey (semi-quantitative) method where the observers walks the entire occurrence, or assessment area within the occurrence, and make notes on vegetation strata, their cover, and exotic species. (2) Quantitative Plot Data, where a fixed area is surveyed, using either standard plots, transects or plotless methods. The plots are typically a "rapid", but a single intensive plot can also be taken.

Scaling Rationale: Scaling is based on NatureServe Ecology staff professional judgment. For forests, we consulted old growth patterns (Tyrrell et al 1998) across many forest types. However, note that high montane and boreal forests may not have as many large stems typical of many lower elevation temperate forests. Conversely, stands in the Pacific coast rain forests may require a higher number of stems per size class or a change in size class limits (e.g. no. of stems that exceed 100 cm dbh).

5.2.2 Coarse Woody Debris

Definition: A stand structure measure of accumulated downed logs and snags over 4 inches diameter.

Source: Metric is adapted from Interim old growth definitions for interior Douglas-fir series (USFS 1993) and Franklin and others (2008).

Rationale for Selection of the Variable: Accumulation of coarse woody debris is minimal in these forests due to recurring fire. Too much coarse woody debris can increase risk from fire.

Measurement Protocol: This metric is measured using field-based, rapid protocols for Level 2 assessment. Field survey method for estimating structure may be either a (1) Site Survey (semi-quantitative) method where the observers walks the entire occurrence, or assessment area within the occurrence, and make notes on size, distribution and abundance of dead woody material or (2) Quantitative Plot Data, where a fixed area is surveyed, using either standard plots or transects methods. The plots are typically a "rapid", but a single intensive plot can also be taken. Level 3 measurements are more intensive and follow standard protocols developed by USFS. Coarse woody debris methods have been outlined by Brown (1974. [James K. Brown. 1974. Handbook for inventorying downed woody material. of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 24 p.]

Scaling Rationale: Scaling is based on NatureServe Ecology staff professional judgment after review of literature. The metric is scaled based on the similarity between the observed coarse woody debris accumulation and what is expected based on reference condition. Reference conditions reflect the accumulated experience of field ecologists, studies from sites where natural processes are intact, regional surveys and historic sources (USFS 1993).

5.2.3 Composition of Overstory Canopy

Definition: An assessment of the overstory species composition and importance of the tree layer in stand(s).

Source: Metric is adapted from descriptions of dry mixed-conifer forests in Franklin and others (2008), eastern Cascades forests (Agee 2003) and dry forests (Hessburg et al 2005).

Rationale for Selection of the Variable: This metric is one aspect of the condition of a stand or polygon and is a widely used metric. Composition of old forest stands indicates integrity of disturbance regimes and presence of important functional attributes.

Measurement Protocol: This metric consists of evaluating the species composition of the tree layers. The protocol is an ocular evaluation of variation in composition. This metrics require the ability to recognize the major dominant tree species.

A field form should be used that describes composition using either strata or growth forms (Jennings et al. 2008). For the strata method, list all major tree and then estimate strata cover and cover of dominant (>5% cover.

Field survey method for estimating structure may be either a (1) Site Survey (semi-quantitative) method where the observers walks the entire occurrence, or assessment area within the occurrence, and make notes on size, distribution and abundance of tree species or (2) Quantitative Plot Data, where a fixed area is surveyed, using either standard plots, plotless or transect methods. The plots are typically a "rapid", but a single intensive plot can also be taken. Level 3 measurements are more intensive and follow standard protocols (Jennings et al. 2008).

Scaling Rationale: The metric is scaled based on the similarity between the dominant species composition of the vegetation and what is expected based on reference condition. Reference conditions reflect the accumulated experience of field ecologists, studies from sites where natural processes are intact, regional surveys and historic sources (Franklin et al. 2008; Agee 2003; Hessburg et al 2005).

5.2.4 Cover of Invasive Species and Cover of Exotic Invasive Species

Definition: The percent cover of a selected set of plant species that are considered invasive (new to the system) with human stressors. Some systems the percent cover of **only** exotic species that are considered invasive is a more narrowly defined metric.

Source: This metric has been drafted by NatureServe's Ecological Integrity Assessment Working Group, based in part on work by Tierney et al. 2008) and Miller et al. (2006) and for shrub steppe systems (Pellent et al. 2000).

Rationale for Selection of the Variable: Invasive plants become established in habitats, they can inflict a suite of ecological damage to native species including loss of habitat, loss of biodiversity, decreased nutrition for herbivores, competitive dominance, overgrowth, struggling, and shading, resource depletion, alteration of biomass, energy cycling, productivity, and nutrient cycling (Dukes and Mooney 1999). Invasive plant species can also affect hydrologic function and balance, making water scarce for native species. Native species may become invasive when a process has been altered, such as fire suppression or changed in duration or intensity as with introduced novel grazing regimes. Exotic invasive species with characteristic novel to a system or introduce new system responses to natural processes, such as, the fire-cheatgrass cycle, are targeted.

Measurement Protocol: This metric consists of evaluating the exotic and native species or only exotics composition of the vegetation. The protocol is an ocular evaluation of exotic species cover. A field form should be used that describes exotic species composition using either strata or growth forms (Jennings et al. 2008). For the strata method, list all major strata - tree, shrub, field, non-vascular, floating, submerged – then estimate strata cover and cover of exotic species. For the growth form approach, list major growth forms - tree (subdivided into overstory and regeneration), shrub (subdivided by tall, and medium/low), herb, nonvascular, floating, submerged, epiphyte, and liana – then estimate strata cover and cover of exotic species.

Field survey method for estimating structure may be either a (1) Site Survey (semi-quantitative) method where the observers walks the entire occurrence, or assessment area within the occurrence, and make notes on vegetation strata, its cover and the cover of exotics. (2) Quantitative Plot Data, where a fixed area is surveyed, using either plots or transects. The plot or transect is typically a "rapid" plot, but a single intensive plot can also be taken.

Scaling Rationale: The criteria are based on best scientific judgment.

5.2.5 Cover of Native Increaser Species and Cover of Understory Native Increasers

Definition: The percent cover of a selected set of plant species that are part of the system being assessed and increase in abundance with human stressors.

Source: Metric is adapted from Faber-Langendoen and others (2008) metric of invasive species.

Rationale for Selection of the Variable: Native increasers increase in abundance where there are human stressor disturbances, such as artificially drained wetlands (Cooper 1990; Johnson 1996) or grazing (Dyksterhuis 1949). Although these species are native, they can be indicative of disturbance if they dominate areas previously occupied by reference sites dominants.

Measurement Protocol: This metric consists of evaluating the exotic and native species that increase with disturbance. The protocol is an ocular evaluation of species cover. A field form should be used that describes species composition using either strata or growth forms (Jennings et al. 2008). For the strata method, list all major strata - tree, shrub, field, non-vascular, floating, submerged – then estimate strata cover and cover of exotic species. For the growth form approach, list major growth forms - tree (subdivided into overstory and regeneration), shrub (subdivided by tall, and medium/low), herb, nonvascular, floating, submerged, epiphyte, and liana – then estimate strata cover and cover of exotic species. Species behavior as an increaser or decreaser with human stressor varies with system assessed. Shrub steppe and grassland vegetation guides and NRCS document often have species listed by response and often disturbance. Either developing a list of indicator species prior to field survey can be used or an evaluation of a more complete species list and determining species behavior later.

Field survey method for estimating structure may be either a (1) Site Survey (semi-quantitative) method where the observers walks the entire occurrence, or assessment area within the occurrence, and make notes on vegetation strata, its cover and the cover of increasers. (2) Quantitative Plot Data, where a fixed area is surveyed, using either plots or transects. The plot or transect is typically a "rapid" plot, but a single intensive plot can also be taken.

Scaling Rationale: The criteria are based on best scientific judgment.

5.2.6 Cover of Native Species and Cover Native Understory Species

Definition: Measures of the percent cover of all plant species native to the region on the assessed area or in forested areas all species except trees.

Source: This metric has been developed by the NatureServe's Ecological Integrity Assessment Working Group, building on a variety of related metrics that assess relative species richness of exotic species (Miller et al. 2006).

Rationale for Selection of the Variable: Native species dominate this system when it has excellent ecological integrity. This metric is a measure of the degree to which native plant communities have been altered by human disturbance. With increasing human disturbance, non-native species invade and can dominate the site.

Measurement Protocol: This metric consists of evaluating the native species composition of the vegetation. The protocol is an ocular evaluation of species cover. A field form should be used that describes species composition using either strata or growth forms (Jennings et al. 2008). For the strata method, list all major strata - tree, shrub, field, non-vascular, floating, submerged – then estimate strata cover. For the growth form approach, list major growth forms - tree (subdivided into overstory and regeneration), shrub (subdivided by tall, and medium/low), herb, nonvascular, floating, submerged, epiphyte, and liana – then estimate strata cover.

Field survey method for estimating structure may be either a (1) Site Survey (semi-quantitative) method where the observers walks the entire occurrence, or assessment area within the occurrence, and make notes on vegetation strata, its cover. (2) Quantitative Plot Data, where a fixed area is surveyed, using either plots or transects. The plot or transect is typically a "rapid" plot, but a single intensive plot can also be taken.

The metric is calculated by first estimating the total cover of the vegetation, [preferably by layer – tree, shrub, herb, and non-vascular- thus the total could easily exceed 100%]. For understory species metric, exclude tree layer value.

Scaling Rationale: : The criteria are based on extrapolated thresholds from ecological site descriptions from NRCS (2005), Cooper (1990), Windell et al. (1996), CNHP (2005), and best scientific judgment. These criteria need further validation. Scaling of this metric using exotic species richness rather than cover is an alternative approach (Miller et al. 2006).

5.2.7 Species Composition

Definition: An assessment of the overall species composition and diversity, including by layer, and evidence of specific species diseases or mortality.

Source: This metric has been drafted by NatureServe's Ecological Integrity Assessment Working Group (2008).

Rationale for Selection of the Variable: The overall composition of native species can shift when exposed to stressors. Trees, shrubs, herbs, and alga play an important role in providing wildlife habitat, and they are the most readily surveyed aspect of biodiversity. Vegetation is also the single, largest component of net primary productivity. More detailed assessment can be derived from a composition list, such as, functional/structural indictors in Rangeland Health Indicators guides (Pellant et al. 2000) appropriate for Level 3 assessments.

Measurement Protocol: This metric consists of evaluating the species composition of the vegetation. The protocol is an ocular evaluation of variation in overall composition. These metrics require the ability to recognize the major-dominant plants species of each layer or stratum. When a field team lacks the necessary botanical expertise, voucher specimens will need to be collected using standard plant presses and site documentation. This can greatly increase the time required to complete an assessment.

A field form should be used that describes composition using either strata or growth forms (Jennings et al. 2008). For the strata method, list all major strata - tree, shrub, field, non-vascular, floating, submerged – then estimate strata cover and cover of dominant (>5% cover), characteristic, and exotic species. For the growth form approach, list major growth forms - tree (subdivided into overstory and regeneration), shrub (subdivided by tall, and medium/low), herb, nonvascular, floating, submerged, epiphyte, and liana – then estimate strata cover and cover of dominant (>5%), characteristic, and exotic species.

Field survey method for estimating structure may be either a (1) Site Survey (semi-quantitative) method where the observers walks the entire occurrence, or assessment area within the occurrence, and make notes on vegetation strata, their cover, and exotic species. (2) Quantitative Plot Data, where a fixed area is surveyed, using either plots or transects. The plot or transect is typically a "rapid" plot, but a single intensive plot can also be taken.

Scaling Rationale: The metric is scaled based on the similarity between the dominant species composition of the vegetation and what is expected based on reference condition. Reference conditions reflect the accumulated experience of field ecologists, studies from sites where natural processes are intact, regional surveys and historic sources (Collins et al. 2006.

5.2.8 Native Bunchgrass

Definition: A measure of the overall area dominance by native bunchgrasses.

Source: Level 2 metric is adapted from Washington Natural Heritage element occurrence ranking that were based cover values in Daubenmire (1970) and field experience. Native bunchgrass cover varies by site type and climatic regime so measurement need to be standardized by sites (See NRCS functional/structural types for historic reference conditions). Level 3 metric is adapted from Pellant (1996).

Rationale for Selection of the Variable: Native bunchgrasses dominate native shrub steppe and related grasslands. High density or narrow distance among bunches provides community resistance to invasion (Pellant 1996; Pyke et al. 2009). Native bunchgrass abundance varies by site type and climatic regime so cover measurement need to be evaluated by sites (See NRCS functional/structural types for historic reference conditions).

Measurement Protocol: Level 2 metric is measured using field-based, rapid protocols which may be either: (1) Site Survey (semi-quantitative) method where the observers walks the entire occurrence, or assessment area within the occurrence, and make notes on vegetation strata, their cover, and exotic species or (2) Quantitative Plot Data, where a fixed area is surveyed, using either plots or transects. The plot or transect is typically a "rapid" plot, but a single intensive plot can also be taken. Level 3 metric would apply the same metric but use more standardized and consistent methods such as line-intercept (Pellent et al. 2000).

Scaling Rationale: The criteria are based on best scientific judgment based on values found in the literature cited above.

5.2.9 Fire-sensitive Shrubs

Definition: A measure of the cover of deep rooted, non-sprouting shrubs (*Artemisia tridentata* vars. *tridentata, wyomingensis* and *xericensis, Purshia tridentata).*

Source: Metric is adapted from NRCS (2004) functional/structural groups historic cover range and information in Perryman (2001) and Davies and others (2004). Level 2 metric is adapted from Washington Natural Heritage element occurrence ranking that were based cover values in Daubenmire (1970) and field experience.

Rationale for Selection of the Variable: Natural fire regime promotes patchy low cover big sagebrush or bitterbrush cover; Perryman (2008) discusses effects of shrub cover on herbaceous layer.

Measurement Protocol: Field survey method for estimating structure may be either a (1) Site Survey (semi-quantitative) method where the observers walks the entire occurrence, or assessment area within the occurrence, and make notes on shrub cover. (2) Quantitative Plot Data, where a fixed area is surveyed, using either plots or transects. The plot or transect is typically a "rapid" plot, but a single intensive plot can also be taken. Level 3 assessments are best accomplish using line-intercept transects (Pellant et al. 2005).

Scaling Rationale: The criteria are based on best scientific judgment based on values found in the literature cited above.

5.2.10 Regeneration of Woody Species

Definition: This metric estimates the amount of regeneration of native woody plants.

Source: Metric is adapted from Rocchio (2006) EIA of Rocky Mountain Lower Montane Riparian Woodland and Shrubland Ecological System in Colorado.

Rationale for Selection of the Variable: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems. Intensive grazing by domestic livestock and/or alteration of natural flow regime can reduce to eliminate regeneration by native woody plants (Elmore and Kauffman 1994). Species such as willows depend on flooding to create new bare surfaces suitable for germination of willow seedlings (Woods 2001). In addition, base flows following flooding need to be high enough to maintain soil water content in these areas at or above 15% through July and August in order for these seedlings to survive long enough to establish a deep root system (Woods 2001). Beaver dams also create bare areas suitable for regeneration of woody species, especially as they accumulate silt and/or there is a breach in the dam. Lack of regeneration is indicative of altered ecological processes and has adverse impacts to the biotic integrity of the riparian area.

Measurement Protocol: This metric is measured by determining the degree of regeneration of native woody species present along the streambank and edges of beaver ponds/dams. This is completed in the field and ocular estimates are used to match regeneration with the categorical ratings in the scorecard.

Scaling Rationale: The criteria are based on best scientific judgment.

5.2.11 Tree Regeneration

Definition: A measure or estimate of the amount and spatial distribution of natural regeneration of tree species.

Source: Metric is adapted from Faber-Langendoen and others (2009).

Rationale for Selection of the Variable: There is abundant evidence that the amount and spatial distribution of regeneration is important to maintaining historical structure and is an indication of the integrity of disturbance regimes (USFS 1993; Franklin et al. 2008; Agee 2003; Hessburg, et al. 2005).

Measurement Protocol: This metric is measured by determining the distribution and abundance of each tree species' regeneration in the assessment area. This is completed in the field and ocular estimates are used to match regeneration with the categorical ratings in the scorecard. Level 2 estimates are either: (1) Site Survey (semi-quantitative) method where the observers walks the entire occurrence, or assessment area within the occurrence, and make notes on shrub cove or (2) Quantitative Plot Data, where a fixed area is surveyed, using either plots. The plot is typically a "rapid" plot, but a single intensive plot can also be taken. More intensive level 3 assessments are typically fixed radius 400 sq. m or 1/10th acre plots arranged along transects or placed to sample the variation in canopy structure.

Scaling Rationale: The criteria are based on best scientific judgment.

5.2.12 Late-seral Tree Size and Age

Definition: A measure or estimate of the amount and spatial distribution of tree species through the canopy and observation of cut stumps or other evidence of last tree harvest.

Source: Metric is adapted from Faber-Langendoen and others (2009).

Rationale for Selection of the Variable: Stands with late seral trees provide the structural attributes that are found in forests functioning with its natural range of variability (Franklin et al. 2008; Agee 2003 and Hessburg, et al. 2005). Late seral trees are target of most timber harvesting and their structure is lost to forest functions.

Measurement Protocol: This metric consists of evaluating the density and stem size of the dominant layers relative to the reference condition. The protocol requires an evaluation of the canopy trees of the observable layers of vegetation. It is important to be sensitive to natural variation in vegetation structure and site conditions. Level 2 estimates are either: (1) Site Survey (semi-quantitative) method where the observers walks the entire occurrence, or assessment area within the occurrence, and make notes on tree species diameter (age) distributions or (2) Quantitative Plot Data, where a fixed area is surveyed, using either plots or standard plotless (BAF) methods. The plot is typically a "rapid" plot, but several intensive plots can also be taken. More intensive level 3 assessments are standardized "timber cruising" methods. Evaluation of forest inventory data from timber management can be used in all assessment levels.

Scaling Rationale: Scaling is based on NatureServe Ecology staff professional judgment. For dry forests, we consulted old growth patterns in numerous publications notabily(Franklin et al. 2008; Agee 2003 and Hessburg, et al. 2005).

5.2.13 Fine-scale Mosaic

Definition: The number of biotic/abiotic patches or habitat types present in the riparian area. The metric is not a measure of the spatial arrangement of each patch.

Source: Metric is adapted from Rocchio (2006) EIA of Rocky Mountain Lower Montane Riparian Woodland and Shrubland Ecological System in Colorado..

Rationale for Selection of the Variable: This metric is one aspect of the condition of specific occurrences of wetland and riparian ecological systems. Ecological diversity of a site is correlated with biotic/abiotic patch richness (Collins et al. 2004). Unimpacted sites have an expected range of biotic/abiotic patches. Human-induced alterations can decrease patch richness by homogenizing microtopography, altering channel characteristics, etc.

Measurement Protocol: This metric is measured by determining the number of biotic/abiotic patches present at a site and dividing by the total number of possible patches for the specific riparian type (see Table 4). This percentage is then used to rate the metric in the scorecard.

Scaling Rationale: The scaling criteria are based on Collins et al. (2004); however, best scientific judgment was used to modify patch types to correspond with Northern Rocky Mountain riparian areas.

5.2.14 Organic Matter Accumulation

Definition: An assessment of the overall organic matter accumulation, whether both fine and coarse litter (non-forested wetlands) or coarse woody debris and snags (primarily forested wetlands)

Source: This metric is adapted from the CRAM manual (Collins et al. 2006) by the NatureServe Ecological Integrity Assessment Working Group.

Rationale for Selection of the Variable: See Collins et al. (2006).
The accumulation of organic material and an intact litter layers are integral to a variety of wetland functions, such as surface water storage, percolation and recharge, nutrient cycling, and support of wetland plants. Intact litter layers provide areas for primary production and decomposition that are important to maintaining functioning food chains. They nurture fungi essential to the growth of rooted wetland plants. They support soil microbes and other detritivores that comprise the base of the food web in many wetlands. The abundance of organic debris and coarse litter on the substrate surface can significantly influence overall species diversity and food web structure. Fallen debris serves as cover for macroinvertebrates, amphibians, rodents, and even small birds. Litter is the precursor to detritus, which is a dominant source of energy for most wetland ecosystems. However, organic matter accumulation can be a problem in vernal pools and playas because it encourages biological invasions and can lead to deleterious algal blooms.

Measurement Protocol: This metric consists of evaluating the organic matter accumulation
The protocol is an evaluation of variation in overall organic matter size and number of standing snags, downed logs, and their decay, or amount of fine litter accumulation, including litter layers, duff layers, and leaf piles in pools. A field form should be used that describes the organic matter accumulation. Collins et al (2006) recommend that for estuarine habitats (salt marsh and mangrove) the metric should be assessed in areas that would typically support sedimentation of fine-grained, organic-rich substrates, such as back bays, off-channel basins, or on the surface of

the main salt marsh plain. Areas that are hydro-dynamically active, including tidal channels or areas near the inlet to water, should not be used to evaluate this metric.

Field survey method for estimating organic matter accumulation may be either a (1) Site Survey (semi-quantitative) method where the observers walks the entire occurrence, or assessment area within the occurrence, and make notes on organic matter accumulation, or (2) Quantitative Plot Data, where a fixed area is surveyed, using either plots or transects. The plot or transect is typically a “rapid” plot, but a single intensive plot can also be taken. .

Scaling Rationale: Revised from Collins et al. (2006), with input from Adamus (2006). The metric is scaled based on the similarity between the observed organic matter accumulation and what is expected based on reference condition. Reference conditions reflect the accumulated experience of field ecologists, studies from sites where natural processes are intact, regional surveys and historic sources (Collins et al. 2006).

Salt marshes include both brackish / deltaic and marine. Some wetlands don’t have organic matter. The time of year that a salt marsh is visited affects how much fine debris may be found. Coastal plain ponds depend on fire and herbaceous ground cover. The California vernal pool option from CRAM was eliminated, as it is too fine a level for a national assessment, but it could be used at a System or Macrogroup level. Ratings for number of logs in Pacific salt marshes is adapted from Adamus (2006: Appendix A, code 33).

PHYISOCHEMICAL

5.2.15 Biological Crust

Definition: A measure of the overall area and condition of moss and lichen (biological crust).

Source: Level 2 metric is adapted from Washington Natural Heritage element occurrence ranking based on best scientific judgment, field experience, Belnap and others (2001) and Pellant and others (2005).

Rationale for Selection of the Variable: There is abundant evidence that biological crust occupy most of the vascular plant interspaces where natural site characteristics are not limiting, i.e. steep unstable slopes, south aspects, sandy soil or heavy vascular plant cover. Biological crust provide resistance to erosion, in stabilizing soil surfaces, increasing or reducing the water infiltration through the soil surface, and enhancing soil water retention. Livestock trampling and other physical site disturbances break-up biological crust and its cover is an indicator of site disturbance (Belnap and others 2001). Susceptibility to mechanical disturbance varies by dominant morphological group of biological crusts.

Measurement Protocol: Level 2 estimates are either: (1) Site Survey (semi-quantitative) method where the observers walks the entire occurrence, or assessment area within the occurrence, and make notes of biological crust abundance and distributions or (2) Quantitative Plot Data, where a fixed areas are surveyed, using either plots or transects. The plot is typically a “rapid” plot, but several intensive plots can also be taken. More intensive level 3 assessments are standardized monitoring methods (Belnap and others 2001).

Scaling Rationale: The criteria are based on best scientific judgment.

5.2.16 Physical Patch Diversity

Definition: A checklist of the number of different physical surfaces or features that may provide habitat for species.

Source: Metric is from Faber-Langendoen (2009) adapted from Collins et al. (2006), but has been greatly simplified by NatureServe's Ecological Integrity Assessment Working Group.

Rationale for Selection of the Variable: Intact sites have a diversity of physical environments. The rationale for this variable as used by CRAM tended to connect increasing physical complexity with increasing ecological functions, beneficial uses, as well as overall condition. Here we revise the metric to primarily emphasize condition. For each wetland class, there are visible patches of physical structure that typically occur at multiple points along the hydrologic / moisture gradient. But not all patch types will occur in all wetland types. Therefore, the rating is based on the percent of total expected patch types for a given wetland class.

Measurement Protocol: Prior to fieldwork, the imagery of the site should be reviewed to survey the major physical features or patch types present. The office work must be field-checked using the Structural Patch Worksheet below, by noting the presence of each of the patch types expected for a given wetland type, and calculating the percentage of expected patch types actually found in the site.

Scaling Rationale: Scaling rationale focuses more on a range of variability of physical path types, rather than a presumption that more physical patch types is better than less.

5.2.17 Soil Surface Condition

Definition: An indirect measure of soil condition based on stressors that increase the potential for erosion or sedimentation of the soils, assessed by evaluating intensity of human dominated land uses on the site.

Source: This metric is partly based on a metric developed by Tierney and Faber-Langendoen (2005), Mack (2001), and the NatureServe Ecological Integrity Working Group. Shrub steppe reflects Pellant and others (2005).

Rationale for Selection of the Variable: Bare ground is exposed mineral or organic soil that is susceptible to erosion. The amount and distribution of bare ground is important to site stability and is a direct indicator of site susceptibility to accelerated wind or water erosion. Large patches of exposed soil are less stable than where bare soil is distributed in small patches (Pellant et al. 2005).

Measurement Protocol: Bare ground is soil surface not covered by vegetation (basal and canopy, litter, standing dead plants, gravel/rock, and biological crust. Level 2 estimates are either: (1) Site Survey (semi-quantitative) method where the observers walks the assessment area, and make notes of bareground abundance, distributions and origin or (2) Quantitative Plot Data, where a fixed areas are surveyed, using either plots or transects.

Scaling Rationale: In progress. Percentages of bare soil due to human disturbance adapted from Adamus (2006: Appendix A, code 5).

5.2.18 Water Quality

Definition: An assessment of water quality based on visual evidence of water clarity and eutrophic species abundance.

Source: Metric was developed by the NatureServe Ecological Integrity Assessment Working Group in Faber-Langendoen and others (2009).

Rationale for Selection of the Variable: Not fully developed, although implicit are observations on pollutants, nutrient and sediment loads, which are not always observable in field. Remote sensing and other research are more likely sources of info on those stressors (through level 1 metrics).

Measurement Protocol: Some of the data on water quality available from rivers an lakes could be very relevant to riverine and lakeshore wetland types.

Scaling Rationale: Not fully developed.

HYDROLOGY

5.2.19 Water Source

Definition: An assessment of the extent, duration, and frequency of saturated or ponded conditions within a wetland, as affected by the kinds of direct inputs of water into, or any diversions of water away from, the wetland.

Source: Water Sources encompass the forms, or places, of direct inputs of water to the assessment area as well as any unnatural diversions of water from that area. Diversions are considered a water source because they affect the ability of the assessment area to function as a source of water for other habitats while also directly affecting the hydrology of that area. Metric is taken from Collins et al. (2006) in Faber-Langendoen (2009).

Rationale for Selection of the Variable: See Collins et al. (2006).
"Wetlands, by definition, depend on constant or recurrent, shallow inundation or saturation at or near the surface of the substrate (National Research Council 2001). Consistent, natural inflows of water to a wetland are important to their ability to perform and maintain most of their intrinsic ecological, hydrological, and societal functions. The flow of water into a wetland also affects sediment processes and the physical structure/geometry of the wetland. Sudol and Ambrose

(2002) found that one of the greatest causes of failed wetland mitigation or restoration projects is inadequate, or inappropriate hydrology. "

Measurement Protocol: See Collins et al. (2006).
"The assessment of this metric is the same for all wetland classes. It is assessed initially in the office using the site imaging, and then revised based on the field visit. For all wetlands, including fringe habitat for estuaries and lagoons, this metric focuses on *direct* sources of non-tidal water as defined above (see Figure 4.1). The natural sources will tend to be more obvious than the unnatural sources. Evaluation of this metric should therefore emphasize the identification of the unnatural sources or diversions that directly affect the AA. Permanent or semipermanent features that affect water source at the overall watershed or regional level should not be considered in the evaluation of this metric.

The office work should initially focus on the immediate margin of the AA and its wetland, and then expand in focus to include the smallest watershed or storm drain system that directly contributes to the AA or its immediate environment, such as another part of the same wetland or adjacent reach of the same riverine or riparian system. Landscape indicators of unnatural water sources include adjacent intensive development or irrigated agriculture, nearby wastewater treatment plants, and nearby reservoirs (see Table 4.7b). The office work will yield a preliminary assessment based on the schedule of scores provided below. These scores are applicable to all wetland classes.

Riverine, Depressional, Lacustrine, Lagoons, and Playas: Natural sources of water for these wetlands include rainfall, groundwater, riverine flows, and (for lagoons) ocean water. Whether the wetlands are perennial or seasonal, alterations in the water sources result in changes in either the high water or low water levels. Such changes can be assessed based on the patterns of plant growth along the wetland margins or across the bottom of the wetlands."

Scaling Rationale: Metric ratings are taken from Collins et al. (2006).

5.2.20 Channel Stability

Definition: An assessment of the aggradation and degradation of a stream channel.

Source: Metric is taken from Collins et al. (2006)

Rationale for Selection of the Variable: See Collins et al. (2006). A basic understanding of the natural hydrology or channel dynamics of the type wetland being evaluated is needed to apply this metric. For instance high gradient riparian areas in mountainous areas have very different dynamics from those in flat coastal plains, especially in terms of aggradation or degradation.
"For riverine systems, the patterns of increasing and decreasing flows that are associated with storms, releases of water from dams, seasonal variations in rainfall, or longer term trends in peak flow, base flow, and average flow are more important that hydroperiod. The patterns of flow, in conjunction with the kinds and amounts of sediment with which the flow interacts, largely determine the form of riverine systems, including their floodplains, and thus also control their ecological functions. Under natural conditions, the opposing tendencies for sediment to stop

moving and for flow to move the sediment tend toward a dynamic equilibrium, such that the form of the channel that contains the sediment and the flow remains relatively constant over time (Leopold 1994). Large and persistent changes in either the flow regime or the sediment regime tend to destabilize the channel and cause it to change form. Such regime changes are associated with upstream land use changes, alterations of the drainage network of which the channel of interest is a part, and climatic changes. A riverine channel is an almost infinitely adjustable complex of interrelations between flow, width, depth, bed resistance, sediment transport, and riparian vegetation. Change in any one will be countered by adjustments in the others. The degree of channel stability can be assessed based on field indicators."

Measurement Protocol: Riverine: See Collins et al. (2006).
"Every stable riverine channel tends to have a particular form in cross section, profile, and plan view that is in dynamic equilibrium with the inputs of water and sediment. If these supplies change enough, the channel will tend to adjust toward a new equilibrium form. For example, an increase in the supply of sediment, relative to the supply of water, can cause a channel to aggrade (i.e., the elevation of the channel bed increases), which might cause simple increases in the duration of inundation for existing wetlands, or complex changes in channel location and morphology through braiding, avulsion, burial of wetlands, creation of new wetlands, spray and fan development, etc. An increase in water relative to sediment might cause a channel to incise (i.e., the bed elevation decreases), leading to bank erosion, headward erosion of the channel bed, floodplain abandonment, and dewatering of riparian habitats. For most riverine systems, chronic incision (i.e., bed degradation) is generally regarded as more deleterious than aggradation because it is more likely to cause significant decreases in the extent of riverine wetland and riparian habitats (Kondolf *et al*. 1996). There are many well-known field indicators of equilibrium conditions, or deviations from equilibrium, that can be used to assess the existing mode of behavior of a channel and hence the degree to which its hydroperiod can sustain wetland and riparian habitats."

"To score this metric, visually survey the AA for field indicators of aggradation or degradation (listed in Table 4.8). After reviewing the entire AA and comparing the conditions to those described in the table, determine whether the AA is in equilibrium, aggrading, or degrading, then assign a rating score using the alternative state descriptions in Table 4.9"

Scaling Rationale: Metric ratings are taken from Collins et al. (2006), except for Bog & Fen, which were drafted by the NatureServe Ecological Integrity Assessment Working Group.

5.2.21 Flashiness Index

Definition: This metric measures the variability of water table fluctuations and rates it compared to a reference standard.

Source: This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems summarized from Faber-Langendoen and Rocchio (2005).

Rationale for Selection of the Variable: A wetland's hydrologic regime is the most important ecological processes given its affect on the wetland's soils and flora and fauna communities

(Mitsch and Gosselink 2000). The natural variability of water level fluctuations (e.g., hydroperiod) has a strong impact on the floristic composition, nutrient dynamics, and fauna distributions in a wetland. Thus, alterations to the hydroperiod can have negative impacts to ecological processes, including a shift in species composition and an alteration of biogeochemical cycling.

Measurement Protocol: To measure a change in the hydroperiod, a "flashiness" index, developed by Fennessey et al. (2004) for Ohio wetlands is used. The Flashiness Index is calculated by averaging the absolute value of the differences between ground water measurements from the measurement just preceding it. Thus, long-term well or staff-gauge data are needed to calculate the metric.

Staff gauges should be placed in deep open water areas whereas shallow groundwater monitoring wells should be placed in less deep water.

If quantitative vegetation data are being collected, monitoring wells should be located within these plots to allow correlations with vegetation data. For example, if using the 20 x 50 m plots described by Peet et al. (1998), wells would be located within each of the intensive modules (See section A.2.2 for further information regarding plot establishment).

Monitoring wells are set vertically in the ground to intercept the groundwater passively. Shallow monitoring wells should be installed according the protocol identified in the technical note, *Installing Monitoring Wells/Piezometers in Wetlands* (U.S. Army Corps of Engineers 2000). To summarize, 3.8 cm PVC pipe is perforated from just below the ground surface to the bottom of the pipe. Using a soil auger, a hole is dug to at least 40 cm. Sand is placed in the bottom of the well, the pipe is placed in the hole which is then backfilled with the excavated soil. Bentonite clay is then used to seal the opening of the hole and to ensure surface water does not infiltrated freely into the hole. Water levels inside the pipe result from the integrated water pressures along the entire length of perforations.

Water levels can be read with a steel measuring tape marked with a water-soluble marker. The only equipment needed is the tape, marker, and a rag to wipe the tape dry after each reading. The height of the well above the ground surface should be noted every time the instrument is read because pipes are known to move (U.S. Army Corps of Engineers 2000). Another simple measuring tool for measuring water levels is that described in Henszey (1991). This instrument is attached to a meter tape, lowered into the well, and beeps when it contacts water, at which point a measurement is taken from the tape and subtracted from the height of the well above the soil surface to give the depth of the water table.

Water levels should be checked weekly during the summer months. Automatic recording devices record water levels with down-well transducers or capacitance-based sensors are efficient for season-long monitoring but these cost much more than manually read instruments (U.S. Army Corps of Engineers 2000). However, automatic recorders may be less expensive than total travel costs and salaries. In addition, the credibility of monitoring data is enhanced by automatic wells (U.S. Army Corps of Engineers 2000). Automatic water-level recorders should be periodically checked and recalibrated as necessary (U.S. Army Corps of Engineers 2000).

Consideration of annual precipitation (or more specifically, annual snowpack) and its deviation from long-term averages from the closest weather station are needed to assess the reliability of this metric. During years of average precipitation (e.g. average snowpack) this metric is a reliable rapid metric of the integrity of groundwater levels in the marsh. Long-term monitoring of ground water in the wetland coupled with an analysis of climatic variation during that time-frame will provide the most reliable information.

Water table averages should be calculated for each month and hydrographs should be constructed to visually inspect trends.

Scaling Rationale: Data are not available to distinguish between Excellent and Good; thus, they are lumped into one category. These criteria are tentative hypotheses as they have not been validated with quantitative data throughout the range of this type. The scaling is based on best scientific judgment and on Fennessey et al. (2004) who found that Ohio wetlands with very strong depressional hydrology (vertical hydrologic pathway driven by precipitation and evapotranspiration) had flashiness scores of 1.0 to ~2.0 while riverine marshes had scores of between 2 and 3. Wetland with small to moderate stormwater inputs were also found to have scores between 2-3 while Scores greater than 3 were indicative of high stormwater inputs disrupting the natural hydroperiod. Scaling criteria are only provided for non-riverine marshes. Additional research needs to be conducted for riverine marshes. This metric could also be used to monitor site-specific changes if long-term baseline, as well as post-impact, data are available.

5.2.22 Floodplain Interaction

Definition: An assessment of the degree to which flooding interactions and geomorphic structure of floodplains have been impacted by negative anthropogenic alterations to riparian (riverine) wetlands.

Source: This metric addresses hydrologic stressors on riverine associated wetlands.

Rationale for Selection of the Variable: Ecological processes directly in the riparian areas are driven to a large degree by the degree of overbank flooding and channel movement. The biotic and physical integrity of riparian areas are dependent on the natural variation associated with these flow characteristics (Gregory et al. 1991, Poff et al. 1997).

Measurement Protocol: This metric is estimated using GIS to observe signs of overbank flooding, channel migration, and geomorphic modifications that are present within the riparian area.

Scaling Rationale: The scaling is based on best scientific judgment. Additional research is needed and may suggest changes to the scaling criteria.

5.2.23 Hydrological Alterations

Definition: The degree to which onsite or adjacent land uses and human activities have altered hydrological processes.

Source: Metric is modified from Mack (2001).

Rationale for Selection of the Variable: Land uses within or near a wetland can reduce soil permeability, affect surface water inflows, impede subsurface flow, and lower water tables.

Measurement Protocol: This metric is measured by utilizing GIS datasets to evaluate land use(s) and human activity within or near the wetland which appear to be altering the hydrological regime of the site. The ratings in the scorecard reflect various degrees of hydrological alteration.

Scaling Rationale: The criteria are based on best scientific judgment.

5.2.24 Hydroperiod

Definition: An assessment of the characteristic frequency and duration of inundation or saturation of a wetland during a typical year.

Source: Metric is taken from Collins et al. (2006).

Rationale for Selection of the Variable: See Collins et al. (2006). A basic understanding of the natural hydrology or channel dynamics of the type wetland being evaluated is needed to apply this metric. "For all wetlands except riverine wetlands, hydroperiod is the dominant aspect of hydrology. The pattern and balance of inflows and outflows is a major determinant of wetland functions Mitch and Gosselink (1993). The patterns of import, storage, and export of sediment and other water-borne materials are functions of the hydroperiod. In most wetlands, plant recruitment and maintenance are dependent on hydroperiod. The interactions of hydroperiod and topography are major determinants of the distribution and abundance of native wetland plants and animals. Natural hydroperiods are key attributes of successful wetland projects (National Academy of Sciences 2001).

For riverine systems, the patterns of increasing and decreasing flows that are associated with storms, releases of water from dams, seasonal variations in rainfall, or longer term trends in peak flow, base flow, and average flow are more important that hydroperiod. The patterns of flow, in conjunction with the kinds and amounts of sediment with which the flow interacts, largely determine the form of riverine systems, including their floodplains, and thus also control their ecological functions. Under natural conditions, the opposing tendencies for sediment to stop moving and for flow to move the sediment tend toward a dynamic equilibrium, such that the form of the channel that contains the sediment and the flow remains relatively constant over time (Leopold 1994). Large and persistent changes in either the flow regime or the sediment regime tend to destabilize the channel and cause it to change form. Such regime changes are associated with upstream land use changes, alterations of the drainage network of which the channel of interest is a part, and climatic changes. A riverine channel is an almost infinitely adjustable complex of interrelations between flow, width, depth, bed resistance, sediment transport, and riparian vegetation. Change in any one will be countered by adjustments in the others. The degree of channel stability can be assessed based on field indicators."

Measurement Protocol: See Collins et al. (2006).
"This metric evaluates recent changes in the hydroperiod, flow regime, or sediment regime of a wetland and the degree to which these changes affect the structure and composition of the wetland plant community or, in the case of riverine wetlands, the stability of the riverine channel. Common indicators are presented for the different wetland classes. This metric focuses on changes that have occurred in the last 2-3 years."

Scaling Rationale: Metric ratings are taken from Collins et al. (2006), except for Bog & Fen, which were drafted by the NatureServe Ecological Integrity Assessment Working Group.

5.2.25 Hydrological Connectivity

Definition: An assessment of the ability of the water to flow into or out of the wetland, or to inundate adjacent areas.

Source: Metric is taken from Collins et al. (2006, CRAM manual 4.0, but cf 4.2.3.). A salt marsh, mangrove, and Bog & Fen variant of the metric was added.

Rationale for Selection of the Variable: See Collins et al. (2006).
"Hydrologic connectivity between wetlands and adjacent uplands supports ecologic function by promoting exchange of water, sediment, nutrients, and organic carbon. Inputs of organic carbon are of great importance to ecosystem function. Litter and allochthonous input from adjacent uplands provides energy that subsidizes the aquatic food web (Roth 1966). Connection with adjacent water bodies promotes the import and export of water-borne materials, including nutrients. Surface and subsurface hydrologic connections, including connections with shallow aquifers and hyporheic zones, influence most wetland functions. Plant and animal communities are affected by these hydrologic connections. Plant diversity tends to be positively correlated with connectivity between wetlands and natural uplands and negatively correlated with increasing inter-wetland distances (Lopez 2002). Diversity of amphibian communities is directly correlated with connectivity between streams and their floodplains (Amoros and Bornette, 2002). Linkages between aquatic and terrestrial habitats allow wetland-dependent species to move between habitats to complete life cycle requirements."

The number of junctions in tidal channels (Adamus 2005: 76; 2006: Appendix A, code 54A) provides a measure of the number of branches in typically dendritic networks of channels in tidal marsh, and provides an indication of existing tidal connectivity or potential connectivity at proposed restoration sites. Occurrences are determined by channels visible in 1:24,000 air photos. Time elapsed since restoration of tidal circulation and extent of restoration (Adamus 2005: 54; Adamus 2006) provides a measure of rate and extent of sediment accretion.

Measurement Protocol: See Collins et al. (2006).
"Scoring of this metric is based solely on field indicators. No office work is required. This metric pertains only to Riverine, Estuarine, Lagoon, Vernal Pool and Playas and individual Vernal Pools.
Riverine: See Collins et al. (2006).

“For riverine wetlands and riparian habitats, Hydrologic Connectivity is assessed based on the degree of channel entrenchment (Leopold *et al*. 1964; Rosgen 1996; MacDonald and Montgomery 2002). Entrenchment is a field measurement calculated as the flood-prone width divided by the bankfull width. Bankfull width is the channel width at the height of bankfull flow. The flood-prone channel width is measured at the elevation of twice the maximum bankfull depth. The process for estimating entrenchment in outlined below.

Entrenchment varies naturally with channel confinement. Channels in steep canyons naturally tend to be confined, and tend to have small entrenchment ratios indicating less hydrologic connectivity. Assessments of hydrologic connectivity based on entrenchment must therefore be adjusted for channel confinement, according to the following worksheets.”

Riverine Wetland Entrenchment Ratio Calculation Worksheet
Step 1: Identify bankfull contour.
This is a critical step requiring experience. If the stream is entrenched, the height of bankfull flow is identified as a scour line, narrow bench, or the top of active point bars well below the top of apparent channel banks. If the stream is not entrenched, bankfull stage can correspond to the elevation of a broader floodplain with indicative riparian vegetation.

Step 2: Estimate maximum bankfull depth.
Once the bankfull contour is identified, estimate its height above the nearest point along the channel bottom.

Step 3 Estimate flood prone height.
Double the estimate of maximum bankfull depth from Step 2, and note the location of the new height on the channel bank.

Step 4: Estimate flood prone width. Estimate the width of the channel at the flood prone height.

Step 5: Calculate entrenchment ratio. Divide the flood prone width (results of Step 4) by the maximum bankfull depth Result of Step 2)

Riverine Wetland Confinement Calculation Worksheet

Step 1: Estimate bankfull width of AA
Estimate channel width at bankfull based on the Step 1 of the entrenchment worksheet immediately above.

Step 2: Estimate effective valley width for AA
Estimate the maximum distance from the top of either bank to the adjacent land that is at least 10 feet higher than the bank top.

Step 3: Determine confinement of AA Channel is confined if valley width (Step 2) is less than twice bankfull width (Step 1).

Scaling Rationale: Metric ratings are taken from Collins et al. (2006). Number of channel junctions adapted from Adamus (2006: Appendix A, code 54A). Time elapsed since restoration of tidal flooding adapted from Adamus (2006: Appendix A, code 13D).

5.2.26 Upstream Surface Water Retention

Definition: A measure of the percentage of the contributing watershed which drains into water storage facilities (e.g., reservoirs, sediment basins, retention ponds, etc.) which are capable of storing surface water from several days to months. Applies to riparian (riverine) wetlands.

Source: This metric is modified from Smith (2000).

Rationale for Selection of the Variable: Ecological processes of riparian areas are driven to a large degree by the magnitude and frequency of peak flows and the duration and volume of base flows (Poff et al. 1997). The biotic and physical integrity of riparian areas are dependent on the natural variation associated with these flow characteristics (Gregory et al. 1991, Poff et al. 1997). The amount of water retained in upstream facilities has a direct effect on these flows and subsequent effects on the continued biotic and physical integrity of the riparian area (Poff et al. 1997). For example, retention of surface water can decrease or eliminate episodic, high intensity flooding, decrease seasonal high flows (e.g., spring snowmelt) and increase base flows during seasonal dry periods causing a shift in channel morphology and altering the dispersal capabilities, germination, and survival of many plant species dependent on those flows (Poff et al. 1997; Patten 1998).

Measurement Protocol: This metric is measured as the percent of the contributing watershed to the riparian area that occurs upstream of a surface water retention facility. First the total area of the contributing watershed needs to be determined. Next, the area of the contributing watershed which is upstream of the surface water retention facility furthest downstream is calculated for each stream reach (e.g., main channel and/or tributaries) then summed, divided by the total area of the contributing watershed, then multiplied by 100 to arrive at the metric value. For example if a dam occurs on the main channel, then the entire watershed upstream of that dam is calculated whereas if only small dams occur on tributaries then the contributing watershed upstream of each dam on each of the tributaries would be calculated then summed.

These calculations can be conducted using GIS themes of surface water retention facilities, USGS 7.5 minute topographic maps, and/or Digital Elevation Models. The contributing watershed can be calculated or digitized using Digital Elevation Models in a GIS. The percentage of the contributing watershed upstream of surface water retention facilities is simply "cut" from the original contributing watershed layer and its area is then calculated then compared to the total area.

Scaling Rationale: The scaling is based on Smith (2000) and best scientific judgment. Additional research may suggest changes to the scaling criteria.

5.2.27 Upstream/Onsite Water Diversions

Definition: A measure of the number of water diversions (e.g., ditch, well, reservoir, spring, mine, pipeline, pump, power plant) and their impact in the contributing watershed and in the wetland relative to the size of the contributing watershed. Applicable to riparian (riverine) wetlands.

Source: Rocchio (2006)

Rationale for Selection of the Variable: Ecological processes of riparian areas are driven to a large degree by the magnitude and frequency of peak flows and the duration and volume of base flows (Poff et al. 1997). The biotic and physical integrity of riparian areas are dependent on the natural variation associated with these flow characteristics (Gregory et al. 1991, Poff et al. 1997). The amount of water imported, exported, or diverted from a watershed can affect these processes by decreasing episodic, high intensity flooding, seasonal high flows (e.g., spring snowmelt), and base flows (Poff et al. 1997, Patten 1998).

Measurement Protocol: This metric can be measured by calculating the total number of water diversions occurring in the upstream contributing watershed as well as those onsite. The number of diversions relative to the size of the contributing basin is considered and then compared to the scorecard to determine the rating. Examples of water diversions include ditch, well, reservoir, spring, mine, pipeline, pump, power plant. For stream reaches that receive water from local ground water (i.e. gaining reaches), the degree to which water tables are affected by area water wells must be considered.

Since the riparian area may occur on a variety of stream orders and since the corresponding upstream or contributing watershed differs in area, it is difficult to set standard guidelines. Thus, the user must use their best scientific judgment regarding the number of diversions and their impact relative to the size of the contributing watershed. If available, attributes such as capacity (cubic feet/second) of each diversion can be considered in the assessment.

Scaling Rationale: The scaling is based on best scientific judgment. Additional research is needed and may suggest changes to the scaling criteria.

NATURAL DISTRUBANCE REGIME

5.2.28 Fire Condition Class

Definition: This is a fire regime condition class measure of the departure of vegetation structure and composition from vegetation under the natural regime.

Source: Metric is synthesized from Franklin and others (2008), Agee (2003) and Hessburg, and others (2005).

Rationale for Selection of the Variable: Frequent, low severity fire (~10-50 yrs; Fire Regime Classes I and III) is vital to maintaining ecological integrity. Fire suppression (prolonging fire return interval and/or its severity) alters forest composition, structure and fire effects (Franklin et al. 2008; Agee 2003; Hessburg, et al. 2005).

Measurement Protocol: Level 1 estimates are based on LANDFIRE data (www.landfire.gov). Level 2 estimates are either: (1) Site Survey (semi-quantitative) method where the observers walks the entire occurrence, or assessment area within the occurrence, and make notes of tree species diameter-classes, height-classes, canopy vertical structure, snags, downed logs, and evidence of fire (charcoal, fire scars) or (2) Quantitative Data, where a fixed areas are surveyed, using either plots or transects. The "rapid" assessment may include determining age of trees with an increment corer. Van Pelt (2008) provides a field guide to identifying old trees and forest.

Scaling Rationale: These forests often occur in large areas (hundreds to thousands of acres) that, due to fire and insect disturbances, often contained mosaics of older, larger trees and smaller trees. This addresses the condition at a stand level.

5.2.29 On Site Land Use

Definition: This metric assesses the intensity of human dominated land uses within the occurrence.

Source: Hauer et al. (2002)

Rationale for Selection of the Variable: The intensity of human activity in the wetland often has a proportionate impact on the ecological processes occurring onsite. Each land use type is assigned a coefficient ranging from 0.0 to 1.0 indicating its relative impact to the wetland (Hauer et al. 2002).

Measurement Protocol: This metric is measured by documenting land use(s) within the wetland. This should be completed in the field then verified in the office using aerial photographs or GIS. However, with access to current aerial photography and/or GIS data a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use within 100 m of the wetland edge.

To calculate a Total Land Use Score estimate the % of the wetland area under each Land Use type and then plug the corresponding coefficient (Table 6) with some manipulation to account for regional application) into the following equation:

> *Sub-land use score* = $\sum$ LU x PC/100
> where**:** LU = Land Use Score for Land Use Type; PC = % of adjacent area in Land Use Type.

Complete this step for each land use, then sum the Sub-Land Use Score(s) to arrive at a Total Land Score. For example, if 30% of the wetland was under moderate grazing (0.3 * 0.6 = 0.18), 10% composed of unpaved roads (0.1 * 0.1 = 0.01), and 40% was a natural area (e.g. no human land use) (1.0 * 0.4 = 0.4), the Total Land Use Score would = 0.59 (0.18 + 0.01 + 0.40).

Table 17. Current Land Use and Corresponding Land Use Coefficients (based on Table 21 in Hauer ete al. (2002))

Current Land Use	Coefficient
Paved roads/parking lots/domestic or commercially developed buildings/gravel pit operation	0.0
Unpaved Roads (e.g., driveway, tractor trail) / Mining	0.1
Agriculture (tilled crop production)	0.2
Heavy grazing by livestock / intense recreation (ATV use/camping/popular fishing spot, etc.)	0.3
Logging or tree removal with 50-75% of trees >50 cm dbh removed	0.4
Hayed	0.5
Moderate grazing	0.6
Moderate recreation (high-use trail)	0.7
Selective logging or tree removal with <50% of trees >50 cm dbh removed	0.8
Light grazing / light recreation (low-use trail)	0.9
Fallow with no history of grazing or other human use in past 10 yrs	0.95
Natural area / land managed for native vegetation	1.0

Scaling Rationale: The coefficients were assigned according to best scientific judgment regarding each land use's potential impact (Hauer et al. 2002). Land uses have differing degrees of potential impact. Some land uses have minimal impact, such as simply altering the integrity of native vegetation (e.g., recreation and grazing), while other activities (e.g., hay production and agriculture) may replace native vegetation with nonnative or cultural vegetation yet still provide potential cover for species movement. Intensive land uses (i.e., urban development, roads, mining, etc.) may completely destroy vegetation and drastically alter hydrological processes.

5.3 Size Metrics

5.3.1 Absolute Size

Definition: A measure of the current size (ha) of the occurrence or stand compared to reference stands of the type throughout its range.

Source: Metric is adapted from Faber-Langendoen and others (2008a) "Patch Size" metric. This metric is one aspect of the size of specific types. The metric rating is taken from NatureServe's Ecological Integrity Assessment Working Group.

Rationale for Selection of the Variable: Size can be an important aspect of integrity although complex when considering landscape and ecological processes. For some types, diversity of animals or plants may be higher in larger occurrences than in small occurrences that are otherwise similar. For occurrences in mosaics, the larger occurrences often have more micro-habitat features. Larger wetlands are more resistant to hydrologic stressors, larger uplands more resistant to invasion by exotics, since they buffer their own interior portions. Thus size can serve as a readily measured proxy for some ecological processes and the diversity of interdependent assemblages of plants and animals.

Measurement Protocol: Current size can be measured in GIS using aerial photographs, orthophoto quads, National Wetland Inventory maps, etc. Size ranges of reference stands can be derived from National Wetland Inventory maps, other previous mapping efforts, and estimates from expert-based efforts such as Ecoregional Assessments or Natural Heritage Program efforts.

Scaling Rationale: Scaling criteria are based on the NatureServe Ecological Integrity Assessment Working Group (2008).

5.3.2 Relative Size

Definition: A measure of the current size of the area (in hectares) divided by the historic size (within most recent period of intensive settlement or 200 years), multiplied by 100.

Source: Metric is adapted from Faber-Langendoen and others (2008a) "Patch Size Condition" metric. This metric is one aspect of the size of specific occurrences of a wetland type or other types. The metric rating is taken from Rondeau (2001) and best scientific judgment. It is an optional metric.

Rationale for Selection of the Variable: Relative size is an indication of the amount of the change caused by human-induced disturbances. It provides information that allows the user to calibrate the current size to the historic area of the occurrence of the type. For example, if a wetland has a current size of 1 hectare but the historic size was 2 hectares, this indicates that half (50%) of the original wetland has been lost or severely degraded. Complicating the use of this metric is that wetland size may either increase or decrease due to human disturbances.

Measurement Protocol: This metric is measured using field-based, rapid protocols with GIS support in level 1. Field calibration of size may be required since it can be difficult to discern the historic area from remote sensing data. Relative size can also be estimated in the field using 7.5 minute topographic quads, NPS Vegetation Mapping maps, National Wetland Inventory maps, or a global positioning system. The definition of the "historic" timeframe will vary by region, but generally refers to the intensive Euro-American settlement and influence on ecological processes in the mid-1800s. If the historic time frame is unclear, use a 200 yr time period, long enough to ensure that the effects of wetland loss are well-established.

Scaling Rationale: Scaling criteria are based on Rondeau (2001), NatureServe Ecological Integrity Assessment Working Group (2008) and best scientific judgment.

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