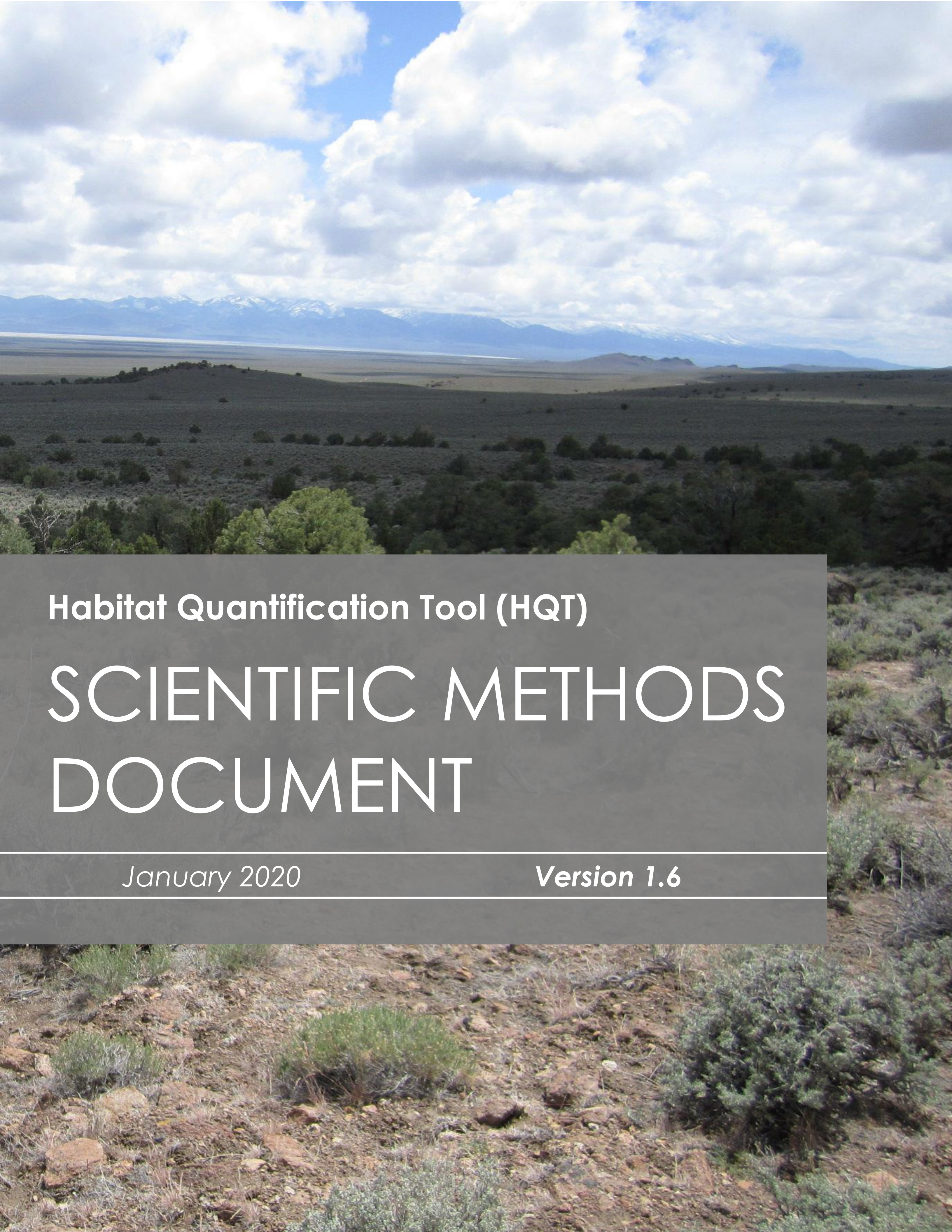

Habitat Quantification Tool (HQT)

SCIENTIFIC METHODS DOCUMENT

January 2020 **Version 1.6**

ACKNOWLEDGEMENTS

This scientific methods document was developed for the State of Nevada Department of Conservation and Natural Resources and Nevada Sagebrush Ecosystem Council (SEC). The project was funded by Question 1 Bond funding through a contract with the State of Nevada Natural Heritage Program.

This scientific methods document is based on the scientific methods document developed for the Colorado Habitat Exchange. Significant appreciation is given to the Colorado Science Team that spent several years developing the Colorado Scientific Methods Document.

The following individuals provided invaluable guidance and direction throughout development of this scientific methods document to ensure it accurately reflects the unique ecological systems and greater sage-grouse needs in the State of Nevada.

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CREDIT SYSTEM DOCUMENTS

The Nevada Conservation Credit System is described in multiple documents intended for different audiences. This is the Scientific Methods document. This document defines the attributes assessed to measure habitat function for greater sage-grouse and documents the rationale for the attributes selected. This document is intended for the Administrator and science contributors. If this does not describe you, please use the diagram below to identify the document most relevant to your needs.

Credit System Manual

Provides guidance and information needed to participate in the Credit System including an overview of the program, policy and technical requirements, and operational protocols.

- **Administrator**
- **Credit Developers and Credit Buyers**
- **Technical Support Providers**

Scientific Methods Document

Defines the attributes assessed to measure habitat conditions relevant to greater sage-grouse and document the rationale for the attributes selected.

- **Administrator**
- **Science Contributors**

User's Guide

Provides step-by-step guidance for efficiently and accurately calculating functional acres, credits and debits for projects in the Credit System, including the desktop analysis and field data collections methods.

- **Administrator**
- **Technical Support Providers**

Calculator

Calculates functional acres, credits and debits for proposed and implemented projects.

- **Administrator**
- **Technical Support Providers**

Table of Contents

1.0 INTRODUCTION

The Nevada Greater Sage-Grouse Habitat Quantification Tool (HQT) Scientific Methods Document (Scientific Methods Document) describes a scientific approach to quantify habitat function for greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) habitat in the State of Nevada. The HQT can be used to quantify habitat function for a range of purposes including evaluating outcomes of conservation and development projects, and tracking anthropogenic and natural disturbances across the landscape. The Nevada Conservation Credit System (Credit System) uses the HQT to determine credits generated by conservation projects and debits generated by anthropogenic disturbances, target credit and debit projects to the most beneficial locations for the sage-grouse, and track the contribution of the Credit System to sage-grouse habitat and population goals over time.

This Scientific Methods Document includes a description of the attributes measured by the HQT, methods for measuring those attributes, and supporting rationale (e.g., peer-reviewed literature, gray literature, expert opinion) for why those specific attributes and methods were chosen. A scoring approach to generate a single habitat function score based on the measurements for a specific site is also described, and an example project is used to illustrate the application of the scoring approach.

Users and Uses

The primary audiences of Scientific Methods Document are the Credit System Administrator (Administrator) and science contributors. The Administrator will use the methods document as the basis for adaptive management of the HQT and will update this Scientific Methods Document as the HQT is improved over time. Other stakeholders may use the Scientific Methods Document to understand the scientific basis for the HQT and scientists and other experts may be asked to review the Scientific Methods Document in order to provide recommended improvements to the HQT.

The HQT has been specifically designed for use in the Credit System. However, it could benefit other sage-grouse conservation programs in the State of Nevada. For example, the HQT could be used to target investment of public or non-governmental organization funding for sage-grouse conservation unrelated to the Credit System, and quantify the benefits of future conservation actions to sage-grouse.

Development Process

The HQT is based on a well-established and academically-supported framework, derived from the Stiver et al. (2010) Habitat Assessment Framework and described within this document. The first release of the HQT was prepared by Environmental Incentives, Inc. and EcoMetrix Solutions Group in 2014. The Greater Sage-grouse Habitat Quantification Tool Scientific Methods Document developed for the Colorado Habitat Exchange provided the basis for this document. Environmental Incentives convened a group of local biologists and rangeland ecologists, the Technical Review Group (TRG), to revise the methods, attributes and scoring curves to reflect the best available scientific understanding of sage-grouse in Nevada.

2.0 OVERVIEW OF THE HABITAT QUANTIFICATION TOOL

The HQT is a scientific approach for assessing habitat function and conservation outcomes for sage-grouse. The purpose of the HQT is to quantify habitat function for a given location with respect to sage-grouse needs. The HQT uses a set of measurements and methods, applied at multiple spatial scales, to evaluate criteria related to sage-grouse habitat function.

2.1 HABITAT QUALITY & SPECIES PERFORMANCE

Habitat represents a particular combination of resources (e.g., food, shelter, and water) and environmental conditions that support survival and reproduction (Morrison et al. 2006). Habitat can vary in quality and therefore in its ability to support survival and reproduction over time (i.e., function). Inherent in the HQT approach is the assumption that there is a direct relationship between availability of high quality habitat and population resiliency. Conversely, poor quality habitat is assumed to result in low survival and reproduction (Van Horne 1983), leading to poor population resiliency. Marginal habitat may support some amount of occupancy by a species, but these marginal conditions may still result in low survival or reproduction and uncertain resiliency, which will likely lead to population declines.

As with many ecological processes, habitat selection occurs at multiple spatial scales, with individuals choosing to settle in a location by keying in to different features at different scales (Hilden 1965, Johnson 1980, Wiens et al. 1987, Wiens 1989, Orians and Wittenberger 1991, Fuhlendorf and Smeins 1996, Fuhlendorf et al. 2002, Morrison et al. 2006). This applies to vegetation in particular, as birds may first perceive vegetation structure over a relatively large, landscape scale, and then settle across the landscape according to more fine-scale vegetation composition and other factors (Wiens et al. 1987). Addressing the multiple spatial scales relevant to a species' habitat use and performance is essential for effective and efficient conservation and management (Johnson 1980).

2.2 ANTHROPOGENIC DISTURBANCES

In addition to vegetation structure and composition, research consistently indicates that greater sage-grouse select habitat based on the presence or absence of anthropogenic disturbances nearby or key demographic rates may be influenced due to proximity to anthropogenic disturbances (e.g. decreased nesting success due to change in predator community in proximity to powerlines) (see Appendix D for a review of literature pertaining to the effects of anthropogenic disturbance on sage-grouse). The presence of anthropogenic disturbances surrounding a site can reduce the integrity of the site itself as habitat—even if the site has habitat characteristics beneficial to sage-grouse. This effect is known as an 'indirect effect'. Research suggests that the indirect effects on sage-grouse are based on the proximity to the anthropogenic disturbance; as the distance from the disturbance increases, the effect on sage-grouse decreases (Manier et al. 2013). Additionally, the indirect effects of disturbances with higher levels of human activity may be more significant than that of disturbances with lower levels of activity. The HQT accounts for the indirect effects associated with anthropogenic disturbance by applying scientifically-informed distance-decay curves to sage-grouse habitat near disturbance when quantifying habitat function.

2.3 FRAMEWORK FOR QUANTIFYING HABITAT FUNCTION

The HQT was developed to account for habitat characteristics or attributes, both natural and anthropogenic, which influence sage-grouse habitat selection across multiple scales. These habitat characteristics were based on different orders of selection (Johnson 1980, Stiver et al. 2010), which represent four spatial scales at which habitat attributes influence where sage-grouse reside and obtain resources necessary for survival and reproduction[1]. Johnson (1980:69) describes this hierarchical nature of selection as: "a selection process will be of higher order than another if it is conditional upon the latter." For example, habitat conditions at the site may be conducive to successful breeding and early brood-rearing, but if suitable late brood-rearing habitat is not accessible within the landscape, the value of that habitat is diminished or negligible. The HQT assessed habitat quality at four orders.

- **Range-wide Scale (1st order):** 1st order selection is described by the geographic range of the sage-grouse population in Nevada. An important objective at this scale is to evaluate the contribution of changed habitat conditions resulting from site-level management actions to regional or statewide habitat and population conservation goals.
- **Landscape Scale (2nd order):** 2nd order selection determines the home range of a sage-grouse population or subpopulation. The purpose of measuring attributes at this scale is to provide a means of delineating the best areas for conservation and identifying where credit projects should be targeted and development should be avoided.
- **Local Scale (3rd order):** Within their home range, sage-grouse select seasonal habitats according to their life cycle needs. Factors that affect sage-grouse use of, and movement between, seasonal use areas determine habitat quality at this scale. Attributes are measured at the 3rd order to inform and incentivize management actions that meet the conservation goals prescribed at the 2nd order.
- **Site Scale (4th order):** At the 4th order, sage-grouse select for vegetation structure and composition that provide for their daily needs, including forage and cover. Measurements at this scale focus on vegetation attributes known to be meaningful to sage-grouse, and in part, are identified as components of structural habitat guidelines and are important in sage-grouse habitat selection (Connelly et al. 2000, Connelly et al. 2003, Hagen et al. 2007; BLM 2013).

The use of multiple spatial scales results in a more ecologically comprehensive approach to broad-scale siting of anthropogenic features and conservation decisions in conjunction with site-based assessments of local environmental suitability conditions. Information provided at the respective scales can be used through either a top-down or a bottom-up manner. For example, using it in a top-down manner provides for effective conservation planning and targeting; applying the information in a bottom-up manner provides an essential perspective for understanding overall benefits and detriments to landscape integrity over time (Figure 1).

[1] While the term 'selection' may be interpreted as relating to individual bird behavior, in this context the term is applied broadly to describe the four geographic scales at which sage-grouse occur, are organized into populations and use habitat (per Johnson 1980, Connelly et al 2003, Stiver et al 2010). These four scales also correspond to scales at which sage-grouse policy and management are typically implemented (Stiver et al. 2010). Throughout this document, orders of selection will be identified by their descriptive terms (e.g., site scale, local scale, landscape scale).

HABITAT QUANTIFICATION FRAMEWORK

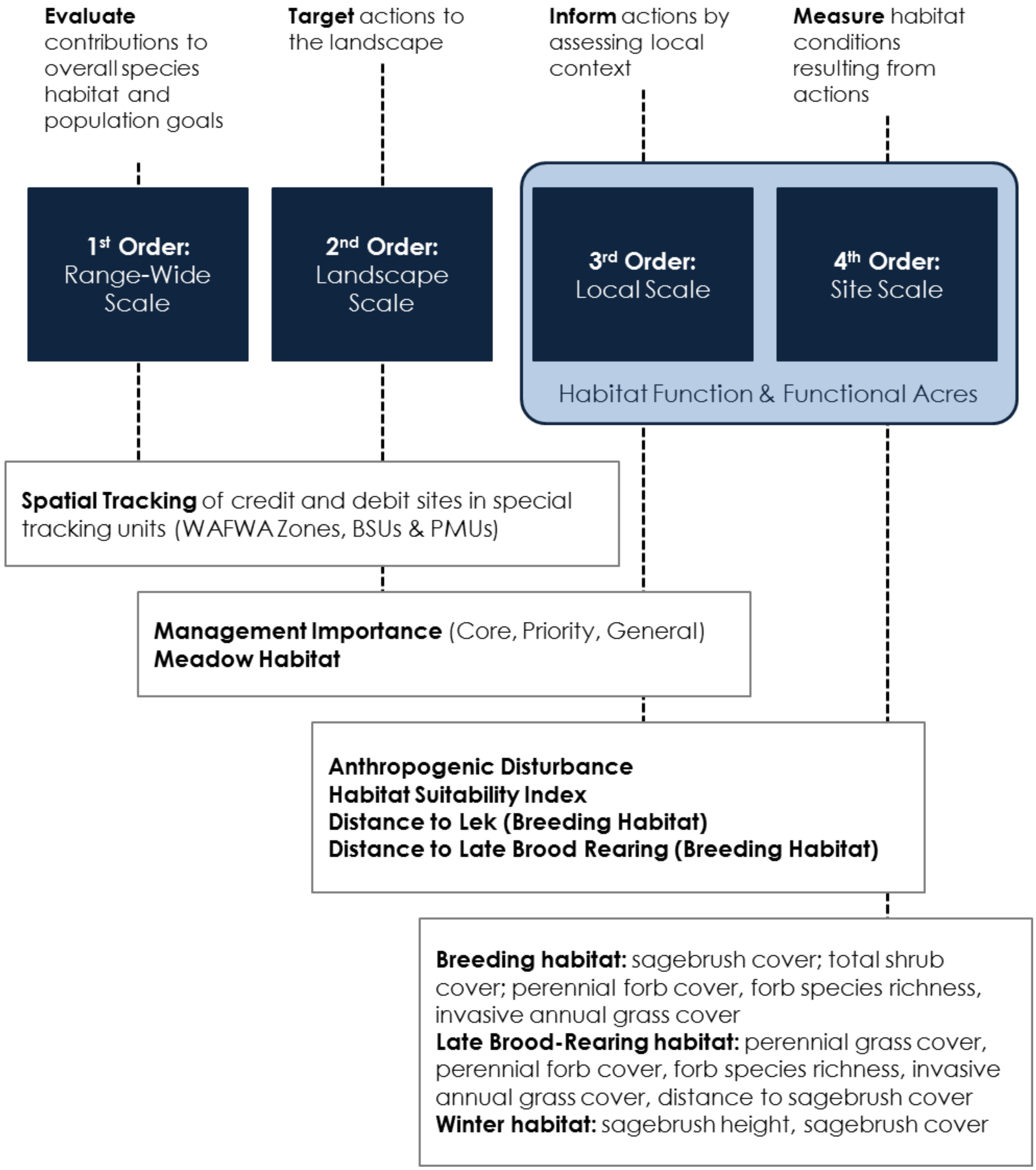


Figure 1: Use of multiple spatial scales for quantifying habitat function for greater sage-grouse

2.4 FUNCTIONAL ACRE APPROACH

The HQT measures the quantity and quality of habitat at a site for sage-grouse in terms of functional acres. Habitat function refers to the quality of the habitat for meeting life history requirements (reproduction, recruitment and survival) for sage-grouse at multiple scales (site, local and landscape), and includes biotic and abiotic factors as well as the direct and indirect effects of anthropogenic disturbances on and surrounding the site.

Functional acres are a product of the site-scale habitat function, the local-scale habitat function, and the area assessed. Landscape-scale attributes are measured to provide information for targeting management actions on the landscape; they are not a component of the functional acre calculation for a site. They are incorporated into the quantification of credits and debits through the mitigation ratio defined in the *Credit System Manual*.

2.4.1 SEASONAL HABITAT TYPES

Different vegetation structure and composition is required for different seasonal periods of habitat use. Therefore, different criteria are measured for different seasonal habitat types essential to the sage-grouse lifecycle. The HQT focuses on three seasonal periods and their habitat associations: breeding, late brood-rearing and winter habitat[2]. The HQT calculates a unique habitat function for each seasonal habitat type for every area of habitat assessed.

- **Breeding:** The breeding season includes habitats associated with the pre-nesting, nesting and very early brood-rearing season (approximately mid-March – June).
- **Late Brood-Rearing:** The late brood-rearing season includes habitats associated with mesic forb availability in late summer for brood-rearing females and broods, males and unsuccessful females (approximately July – September).
- **Winter:** the winter season includes habitats that are almost exclusively sagebrush dominated (November – mid-March; Connelly et al. 2011c).

2.4.2 BENEFITS OF THE FUNCTIONAL ACRE APPROACH

The functional acre approach has several advantages.

- **Establishes a common currency.** Functional acres serve as the basis of the currency of the Credit System: credits. Functional acres account for the quantity and quality of the habitat at multiple spatial scales. The integration of habitat quantity and quality allows for direct comparison of detriments and benefits, which provides a clearer understanding of whether or not conservation goals are being met (McKenney and Kiesecker 2010, Gardner et al. 2013). A common currency allows for standardization in the calculation of credits and debits, which affords the opportunity to conduct mitigation consistently across projects, land ownership and jurisdictional boundaries. It also provides a common language and metric for mitigation across agencies and industries, while striving to be responsive to new science as it emerges.

[2] There are many citations outlining these seasons, summarized by Hagen et al. (2007) and Connelly et al. (2011c), and it is not the goal of this document to conduct an exhaustive review of the sage-grouse habitat use nomenclature. The HQT does not consider transitional periods where habitat selection is less uniform (Connelly et al. 2000).

- **Provides full accounting of impacts.** Functional acres account for both direct and indirect effects of anthropogenic disturbance. Accounting for indirect effects provides a more accurate representation of the full biological impact of a disturbance on sage-grouse. It also provides a strong incentive for targeting debits and credits to the most appropriate places on the landscape, clustering development where it will have the least species impact and focusing conservation efforts where they will have the greatest benefit.
- **Focuses on outcomes.** Rather than rewarding the completion of management actions or practices that may or may not succeed, the Credit System focuses the activities of developers, ranchers and conservationists on what matters most to the sage-grouse – the resulting habitat outcomes of the practices. Paying for outcomes (i.e., effectiveness) rather than practices, (i.e., implementation) has been shown to achieve more conservation per dollar spent than paying for management practices (Just and Antle 1990, Antle et al. 2003). The outcomes-based functional acre approach of the HQT enables the Credit System to provide strong incentives to achieve habitat benefits at the multiple scales relevant to sage-grouse.
- **Tracks the contribution of the Credit System to species habitat and population goals in Nevada over time.** The use of functional acres allows for a simple metric to measure the overall performance of the Credit System, which aims to provide net benefit of functional acres in Nevada to sage-grouse in response to anthropogenic disturbance.

3.0 HABITAT QUANTIFICATION METHODS AND ATTRIBUTES

This section describes the attributes measured by the HQT at each of the four orders of selection (i.e., range-wide, landscape, local and site scales) to quantify habitat function and functional acres. Habitat function and functional acres can be quantified using the HQT for multiple purposes, including:

- **At a point in time** to understand the current condition of an area for sage-grouse.
- **At multiple points in time** for the same area to quantify changes in habitat function and functional acres to sage-grouse habitat.
- **To calculate credits and debits** associated with credit and debit projects in the Credit System. In order to calculate credits and debits, credit and debit baseline functional acres must be calculated as defined in the *Credit System Manual*. Credits and debits represent functional acre difference relative to baseline functional acres, multiplied by a mitigation ratio based in part on attributes measured by the HQT at the landscape scale.

3.0.1 Project Area & Map Units

Habitat function should be quantified over a discrete area when calculating functional acres. Thus, the project area must be clearly defined. When quantifying habitat function for a conservation project (e.g., a credit project), the project area should include all sage-grouse habitats (HMA map) within the exterior boundaries of the project. When quantifying the direct and indirect effects of anthropogenic disturbance on habitat function (e.g., a debit project), the project area must include all sage-grouse habitats (HMA map) directly or indirectly affected by the disturbance. Indirect effects associated with anthropogenic disturbance are discussed in *Section 3.3.1 Anthropogenic Disturbance*.

To facilitate the habitat assessment, the project area is divided into map units (Figure 2). Map units are sub-divisions of the project area based on unique vegetation communities and vegetation structure. Map units are delineated based on variation in vegetative, soil and ecological site characteristics to identify units of similar habitat function attributes that are assessed by the HQT, such as sagebrush canopy cover, forb abundance and distance to sagebrush cover. Guidance for delineating map units within a credit or debit site is provided in the *Credit System User's Guide*. All attributes are measured individually for each map unit and all map units are scored separately. Map Unit 1 of an example credit project shown below will be assessed throughout this section to illustrate the scoring approach.

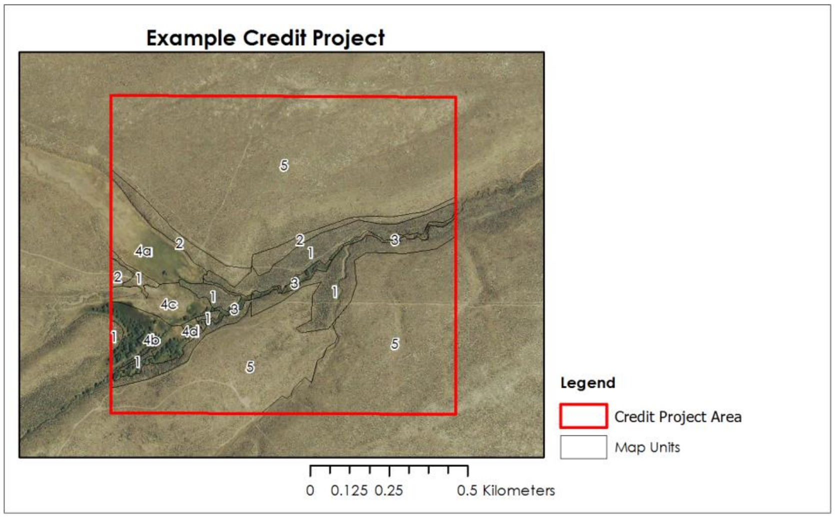


Figure 2. Map units delineated within the project area for an example credit project

3.0.2 Habitat Function & Functional Acres

The HQT generates local-scale habitat function and site-scale habitat function for each seasonal habitat type. The product of the local-scale habitat function and site-scale habitat function for each seasonal habitat type determines overall habitat function for each seasonal habitat type for a map unit. The overall habitat function for each seasonal habitat type is multiplied by the acreage of the map unit to produce a functional acre value for each seasonal habitat type. Table 1 provides an example calculation of functional acres for Map Unit 1 of the example credit project.

Table 1: Example calculation of functional acres for a single map unit

SEASONAL HABITAT TYPE	LOCAL-SCALE HABITAT FUNCTION	SITE-SCALE HABITAT FUNCTION	OVERALL HABITAT FUNCTION	ACRES	FUNCTIONAL ACRES
Breeding	38%	61%	23%	18	4.2
Late Brood-Rearing	36%	70%	25%	18	4.5
Winter	28%	64%	18%	18	3.2

Seasonal Habitat Types

The HQT focuses on three seasonal habitat types: breeding, late-brood rearing, and winter habitat. The scoring process is repeated for each seasonal habitat type considered by the HQT. Attributes must be measured during the permissible window for field data collection, except for attributes only used to score winter habitat which can be measured at any time, to ensure that habitat function and functional acres are quantified correctly.

Landscape-Scale Attributes

Landscape-scale attributes are measured to provide information for targeting management actions on the landscape; they are not a component of the functional acre calculation for a site. They are incorporated into the quantification of credits and debits through the mitigation ratio defined in the *Credit System Manual* (see *Section 2.2.3 Mitigation Ratio*).

3.0.3 Credits & Debits

To calculate credits or debits, credit or debit baseline functional acres are calculated as defined in the Credit System Manual (see *Section 2.3.4: Calculating Credit Baseline Habitat Function* and *Section 2.5.4: Calculating Debit Baseline Habitat Function* in the *Credit System Manual* for credit and debit projects respectively). Credits and debits are calculated from the difference between post-project functional acres (i.e., functional acres present after the debit or credit project is implemented) and the credit or debit baseline functional acres, respectively. A mitigation ratio is applied to the difference in functional acres for each map unit based in part on attributes measured at the landscape scale (see *Section 2.2.2: Mitigation and Proximity Ratios* in the *Credit System Manual*). See the *Credit System Manual* (*Section 2.2: Habitat Quantification and Credit and Debit Calculation*) for more information on calculating credits and debits.

The following sections describe the attributes measured at each scale, the rationale for the attributes selected, the methods for measuring each attribute, and the process for translating attribute measurements into scores that are used to calculate habitat function and functional acres. An example map unit will be used to illustrate the process. For a complete, step-by-step description of the scoring process used by the HQT, please see the *Credits System User's Guide*.

1ST ORDER: RANGE-WIDE SCALE

3.1 RANGE-WIDE SCALE (1ST ORDER)

Geographic Scope

The Credit System's geographic scope is the mapped Biologically Significant Units (BSU), which is shown in Figure 3 and was developed by the Nevada Department of Wildlife. Documented changes to the estimated range will be tracked and incorporated into the HQT over time through the Credit System Management System described in the *Credit System Manual*.

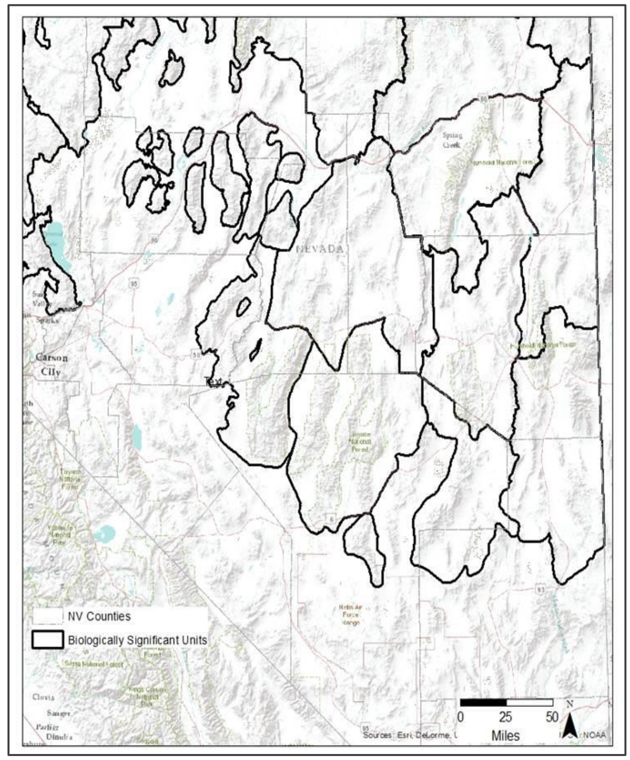


Figure 3. BSU Area map

Spatial Tracking

The Credit System tracks the location of credit and debit sites in spatial tracking units. Spatial tracking units include Nevada Department of Wildlife Population Management Units (PMU), Nevada Biologically Significant Unites (BSU) and Western Association of Fish and Wildlife Agencies Management Zones (WAFWA Zones). PMUs are used to understand the functional acre change to each population, BSUs are used to understand the functional acre change to connected regional populations, and WAFWA Zones are used to understand the functional acre change to populations connected through dispersal (Figure 4).

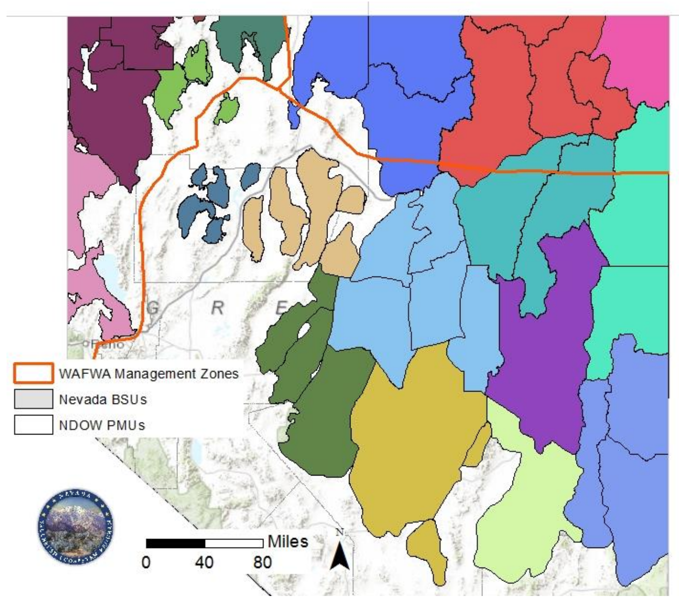
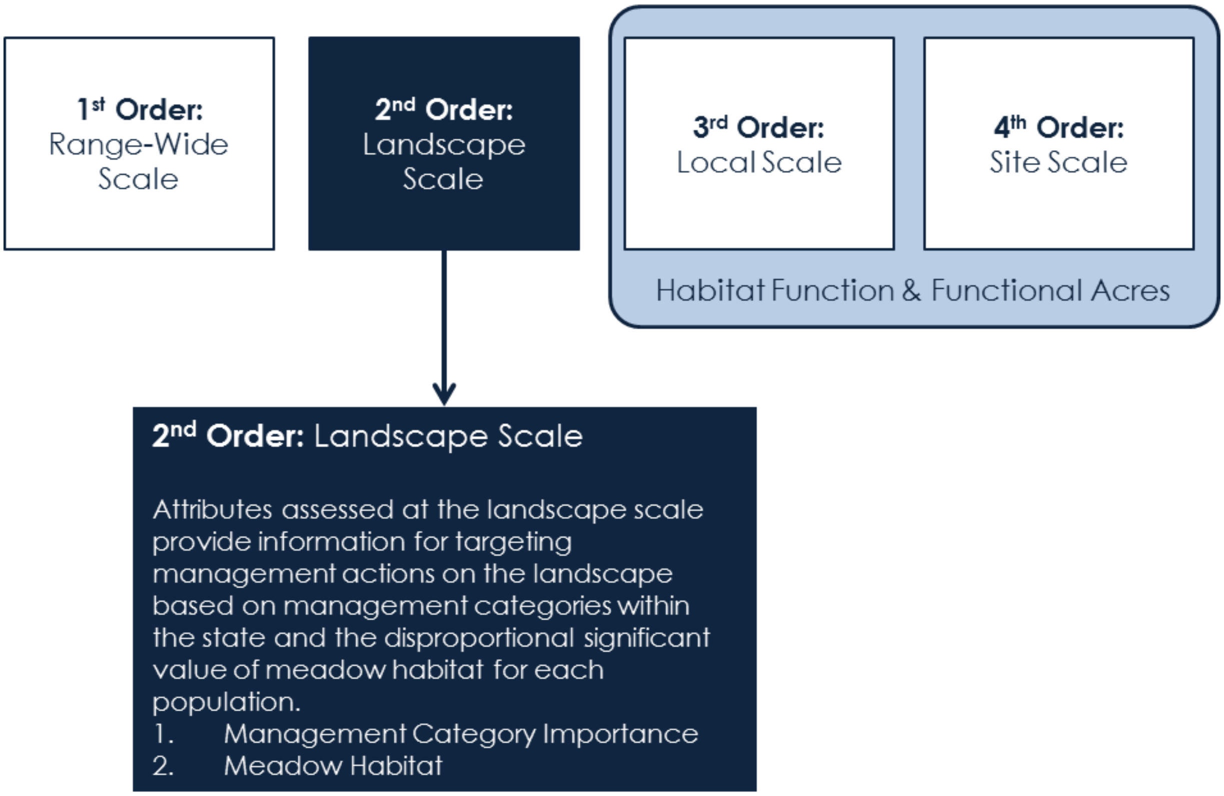


Figure 4. WAFWA Management Zones, Nevada Biological Significant Units and NDOW Population Management Units

2ND ORDER: LANDSCAPE SCALE



3.2 LANDSCAPE SCALE (2ND ORDER)

3.2.1 MANAGEMENT CATEGORY IMPORTANCE

The Sagebrush Ecosystem Program's Management Categories map is used to determine management category importance (Figure 5). The map delineates three habitat management categories based on the intersection of modelled habitat suitability and sage-grouse space use: Priority Habitat Management Area (PHMA), General Habitat Management Area (GHMA), and Other Habitat Management Area (OHMA).

- **Priority Habitat Management Area:** Areas of high estimated space use in suitable sage-grouse habitat in the State of Nevada. These areas represent the strongholds (or "the best of the best") for sage-grouse populations in the State and support the highest density of breeding populations[3].
- **General Habitat Management Area:** Areas that are determined to be highly suitable habitat for sage-grouse in areas of estimated low space use and areas of non-habitat which overlap with areas of estimated high space use.
- **Other Habitat Management Area:** Areas determined to be moderately suitable habitat for sage-grouse in areas of estimated low space use.

Predictions of sage-grouse occurrence based on space use models and indices in combination with habitat suitability models and indices (e.g., Doherty et al., 2010a; Coates et al., 2013) provide valuable information regarding the relative importance of areas to sage-grouse (Coates et al. 2014a, 2016). This information can be used to prioritize areas for different management scenarios and aid decision making processes across the landscape (Coates et al. 2014a, 2016). This information is used by the Credit System to inform the Credit System mitigation ratio applied to each map unit, see the Credit System Manual for more information.

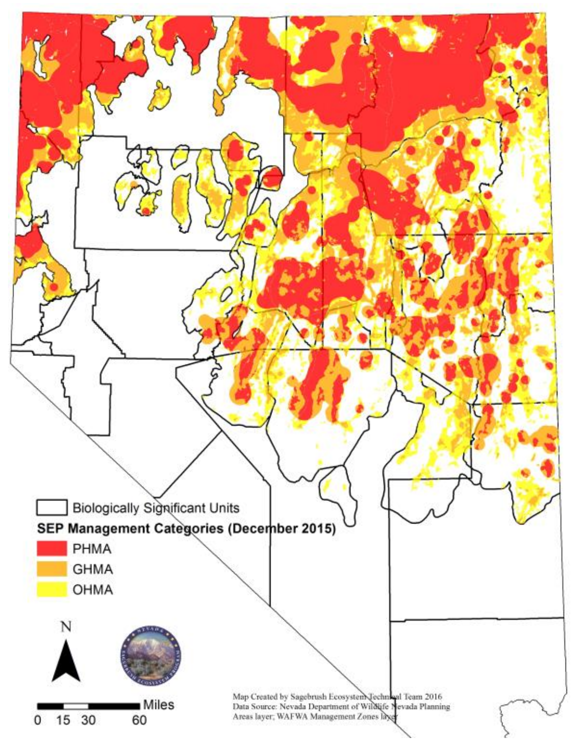


Figure 5. Sagebrush Ecosystem Program's Management Categories Map used to determine habitat importance at the landscape scale

[3] Habitat suitability and space use are determined by models developed by the USGS in partnership with the State of Nevada Sagebrush Ecosystem Technical Team (SETT), the Nevada Department of Wildlife (NDOW), the Bureau of Land Management, and the California Department of Fish and Wildlife (CDFW). See Coates et al. 2016, *Spatially explicit modeling of annual and seasonal habitat for greater sage-grouse (*Centrocercus urophasianus*) in Nevada and northeastern California—An updated decision-support tool for management: U.S. Geological Survey Open-File Report 2016-1080.*

3.2.2 MEADOW HABITAT

Sage-grouse typically move between different seasonal habitat types (breeding, late brood-rearing, winter) in order to meet resource requirements during different phases of their life cycle. If one or more of these habitat types is impacted to the point that it can no longer support the corresponding life cycle phase, then the entire area is potentially no longer suitable for sage-grouse. However, information is currently lacking on how much of a particular seasonal habitat type is required to fulfill the corresponding life cycle phase and how to quantify when a particular seasonal habitat type is limiting sage-grouse populations.

Meadows are considered a limited habitat throughout the sagebrush ecosystem landscape in Nevada. Yet, meadow habitat is crucial for sage-grouse to fulfill their late brood-rearing life cycle requirements, so the absence of meadows across a greater landscape can make the surrounding upland habitats unsuitable for sage-grouse without this crucial component. Also, meadow habitats are disproportionately important for sage-grouse life cycle requirements because they are typically small in acreage; however they result in a relatively smaller functional acre scores due to their limited area in comparison to uplands habitats. Map units designated as meadow habitat should be prioritized for conservation efforts.

The significant importance of meadow habitat for sage-grouse populations is incorporated into the Credit System by applying a mitigation ratio to each map unit designated as meadow; see the Credit System Manual for more information.

Box 1 | Example Map Unit Calculation (Landscape Scale)

Map Unit 1 is located within a Priority Habitat Management Area as defined by the Sagebrush Ecosystem Program's Management Categories map. In addition, Map Unit 1 is not designated as meadow habitat. These landscape-scale parameters are depicted in the table below.

	Management Category	Meadow Habitat	Local-Scale Function	Site-Scale Function	**Overall Function**	Acres	**Functional Acres**
Breeding	PHMA	No Meadow				18	
LBR	PHMA	No Meadow				18	
Winter	PHMA	No Meadow				18	

3.2.3 PINYON-JUNIPER REMOVAL

Pinyon and juniper trees have encroached upon the sagebrush steppe in the Intermountain Region in recent history, and even sparse pinyon-juniper (P/J) cover has been found to have a negative impact on sage-grouse (Coates et al. 2017). Sage-grouse tend to see immediate benefit when P/J removal is conducted in close proximity to sage-grouse populations likely through the removal of predator perches and perceived threats, increased forage, and increased connections to mesic areas, leading to greater overall utility from sage grouse (Sandford et al. 2017). Phase 1 removal in Oregon resulted in a 19% increase in nest survival of sage-grouse compared to control sites (Severson et al. 2017). Sage-grouse probability of nest success has been found to decrease with each increasing P/J cover class (Sandford et al. 2017), and modeling efforts revealed potential sage-grouse benefits from P/J removal are highest where denser P/J cover is treated in close proximity to lek locations (Farzan et al. 2015). Phase 1 P/J is still utilized by sage-grouse yet with increased predation; however, Phase 2 P/J is generally avoided (Coates et al. 2017), suggesting that when Phase 2 is cut, the significant, yet unquantifiable, added benefits of reclaiming currently unused habitat and stopping conversion into Phase 3 woodland are realized. This nearly irreversible conversion from Phase 2 to Phase 3 occurs at a rate of more than 100,000 acres of lost sage-grouse habitat per year in the Great Basin (Miller et al. 2008).

Removal of pinyon-juniper encroachment in otherwise high quality sage-grouse habitat is a tremendous opportunity to enhance sage-grouse habitats. Where situations are likely to benefit sage-grouse, the Credit System recognizes the importance of the completion of this habitat enhancement. In these situations, P/J removal factors for map units defined as Phase 1 (1-10% canopy cover) or Phase 2 P/J (>10% canopy cover) will be applied upon the local scale habitat function to determine the immediate uplift credits for completion of these enhancements. See the Credit System Manual for more information.

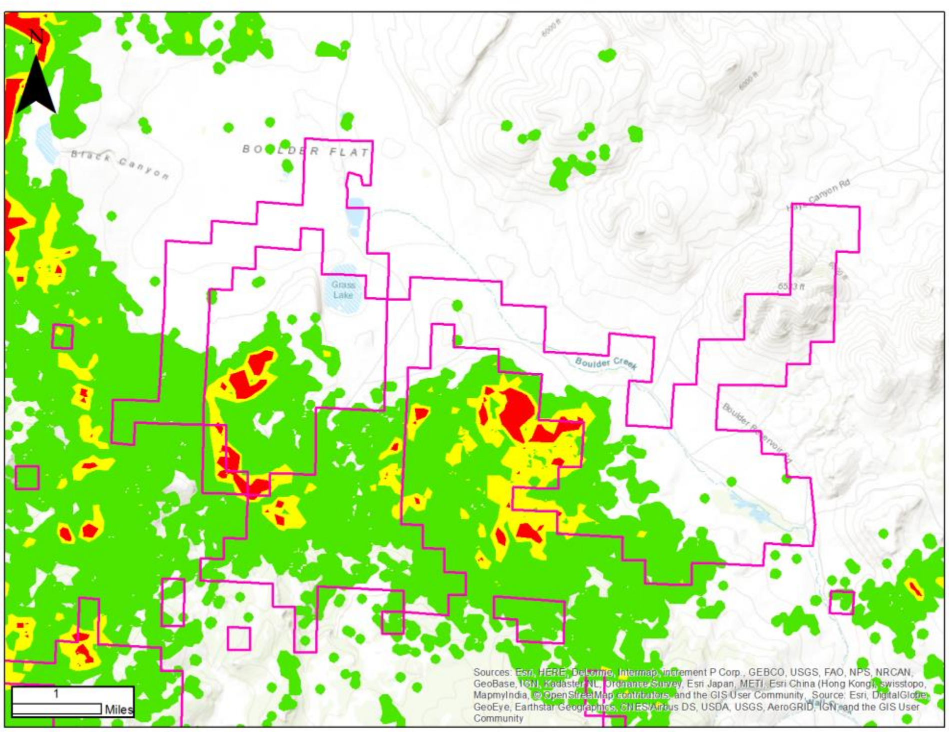
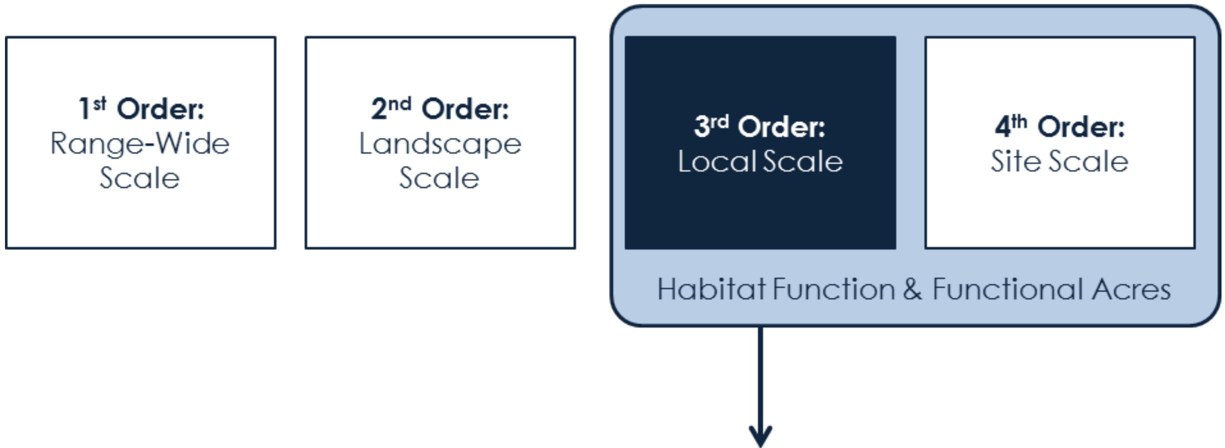


Figure 6. Sagebrush Ecosystem Program's map used to provide initial determination of areas of pinyon-juniper cover.

3RD ORDER: LOCAL SCALE



3rd Order: Local Scale

The purpose of measuring attributes at the local scale can be thought of as quantifying the extent to which the surrounding landscape affects the site's ability to perform up to its full potential.

1. Anthropogenic Disturbance
2. Habitat Suitability Index
3. Distance to Lek (Breeding)
4. Distance to Late Brood Rearing (Breeding)

3.3 LOCAL SCALE (3RD ORDER)

The significance of the effect of local conditions on the quality of any given area is an important consideration (Stiver et al. 2010; Connelly et al. 2011c). Habitat conditions within and surrounding a project site may affect sage-grouse seasonal habitat use, dispersal, local persistence, and overall population trend (Connell et al. 2011a, Connelly et al. 2011c). The HQT assesses habitat function at the local scale related to anthropogenic disturbance, habitat suitability as identified by the Habitat Suitability Index (HSI) and, for breeding habitat function, distance to nearest active lek and distance to nearest late brood-rearing habitat.

3.3.1 ANTHROPOGENIC DISTURBANCE

Indirect effects of anthropogenic disturbance are measured by applying scientifically-informed distance-decay curves to habitat around anthropogenic features. The cumulative aspect of the distance-decay curves accounts for the density effects of anthropogenic disturbance on habitat function (e.g., Doherty et al. 2010b, Harju et al. 2010). For each anthropogenic disturbance considered, both a distance over which the effect of the disturbance extends and a relative weight are assigned. Effects of distance from anthropogenic disturbances are generally well established (Manier et al. 2014) and are based on available literature and expert opinion (see Appendix D for a review of literature pertaining to the effects of anthropogenic disturbance on sage-grouse). Weights represent the relative degree of disturbance relative to the highest level of disturbance possible, and are based on literature and expert opinion. The magnitude of the effect at specific distances for anthropogenic disturbances is represented by an exponential decay curve, which associates the most significant impact close to the source and reflects a rapid decline in impact from the edge of the anthropogenic source. Scientific literature reports sage-grouse population response (e.g. lek attendance, nest selection) to anthropogenic disturbances (Holloran 2005, Blickley et al. 2012, LeBeau 2012) as well as raven population response to transmission lines (Coates et al. 2014b) is exponential in nature. The indirect effect relationship is established by a curve with the y-intercept the weight and the x-intercept the distance. Example distance-decay curves are provided in Figure 7.

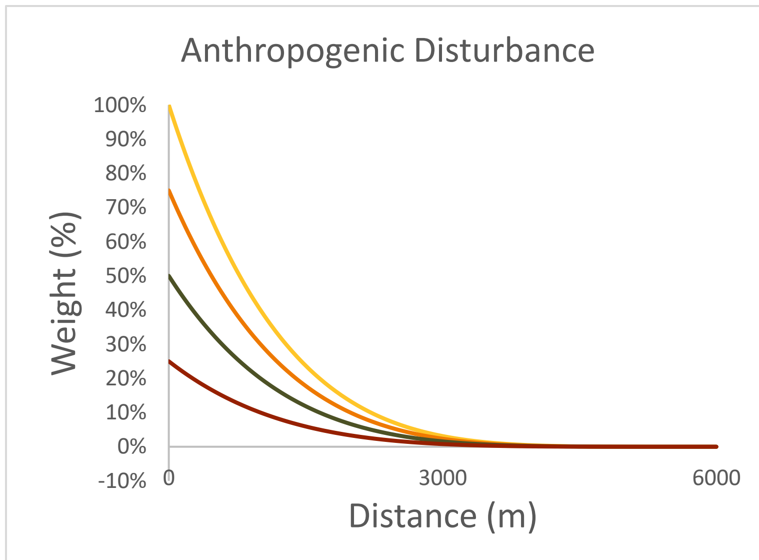


Figure 7: Example distance-decay curves with the y-intercept the weight and the x-intercept the distance associated with the anthropogenic disturbances.

Site-Specific Consultation-Based Design Features

Site-specific consultation-based design features (design features) are used to minimize impacts to sage-grouse and its habitat from indirect effects of anthropogenic disturbance. When quantifying the indirect effect of anthropogenic disturbance on sage-grouse habitat function (e.g., for a debit project), the use of design features may minimize the indirect effects of certain anthropogenic disturbances or minimize the indirect effects during certain times of the year. Distance-decay curves applied to habitats around the anthropogenic disturbance may be modified to more accurately reflect minimization of disturbances. See

Appendix A in the 2014 Nevada Greater Sage-grouse Conservation Plan for more information on the use of design features for newly proposed projects and modifications to existing projects.

Anthropogenic features considered by the Credit System, and their assigned weights and distances, are described in Table 2.

Table 2. Anthropogenic features considered by the Credit System with assigned weights and distances

DISTURBANCE TYPE	SUBTYPE*	WEIGHT (%)	DISTANCE (Miles (Kilometers))
Towers (cell, etc.)	Communications	75%	3.73 miles (6 km)
	Meteorological	75%	3.73 miles (6 km)
Power Lines[1]	Nest Facilitating	75%	3.73 miles (6 km)
	Non Nest Facilitating	25%	3.73 miles (6 km)
Mines	Active – Large (≥ 60 acres)	100%	3.73 miles (6km)
	Active - Med or small (< 60 acres)	100%	1.86 miles (3 km)
	Inactive – Large (≥ 60 acres)	50%	0.62 miles (1 km)
	Inactive - Med or small (< 60 acres)	10%	0.62 miles (1 km)
	Ancillary – Large	50%	1.86 miles (3 km)
	Ancillary – Med or Small	50%	0.93 miles (1.5 km)
Oil & Gas Wells	Producing	100%	1.86 miles (3 km)
	Inactive	0%	0
Urban, Suburban & Ex-urban Development[2]	Med-High	100%	3.73 miles (6 km)
	Low	75%	1.86 miles (3 km)
Roads	Interstate/4-lane	100%	3.73 miles (6 km)
	High Use – Paved or Improved; Commercial	100%	1.86 miles (3 km)
	Low Use – Improved; Local	25%	0.62 miles (1 km)
Renewable	Geothermal	100%	3.73 miles (6 km)
	Ancillary - Geothermal	50%	1.86 miles (3 km)
	Solar	25%	0.62 miles (1km)
	Wind	25%	3.73 miles (6 km)

Linear Rights of Way	LROW High	50%	0.62 miles (1 km)
	LROW Low	25%	0.31 miles (500 m)
Mineral Exploration[3]	Exploration	100%	0 miles (0 m)

*For precise definitions of each disturbance type and subtype, see the *Credit System User's Guide*

[1] The project proponent may request review and adjustment of the weight and distance criteria based upon powerline height, construction, perch deterrents or other site-specific factors. Any adjustments must be documented and scientifically defensible.

[2] The Urban Low classification includes landfills.

[3] Mineral exploration is a special case of impact type and includes exploration associated with CCS defined disturbance within Table 2, including mining, oil and gas, renewable, etc. Additional information is provided throughout this guide for this type of impact.

Calculation Method

1. To calculate anthropogenic disturbance, anthropogenic features are digitized within a GIS.
2. Distance to the nearest anthropogenic feature for each disturbance subtype is calculated to create a continuous surface raster representing the distance from each cell to the nearest feature.
3. For each raster, distances are translated into functional scores using inverted distance-decay curves (i.e., 80% weight on the distance-decay curve represents a 20% function score).
4. Each raster is multiplied together to produce a final raster, where values range from 0 (full impact) to 1 (no impact). Figure 7 depicts the indirect effects of anthropogenic disturbance on sage-grouse habitat in the form of a continuous surface raster.

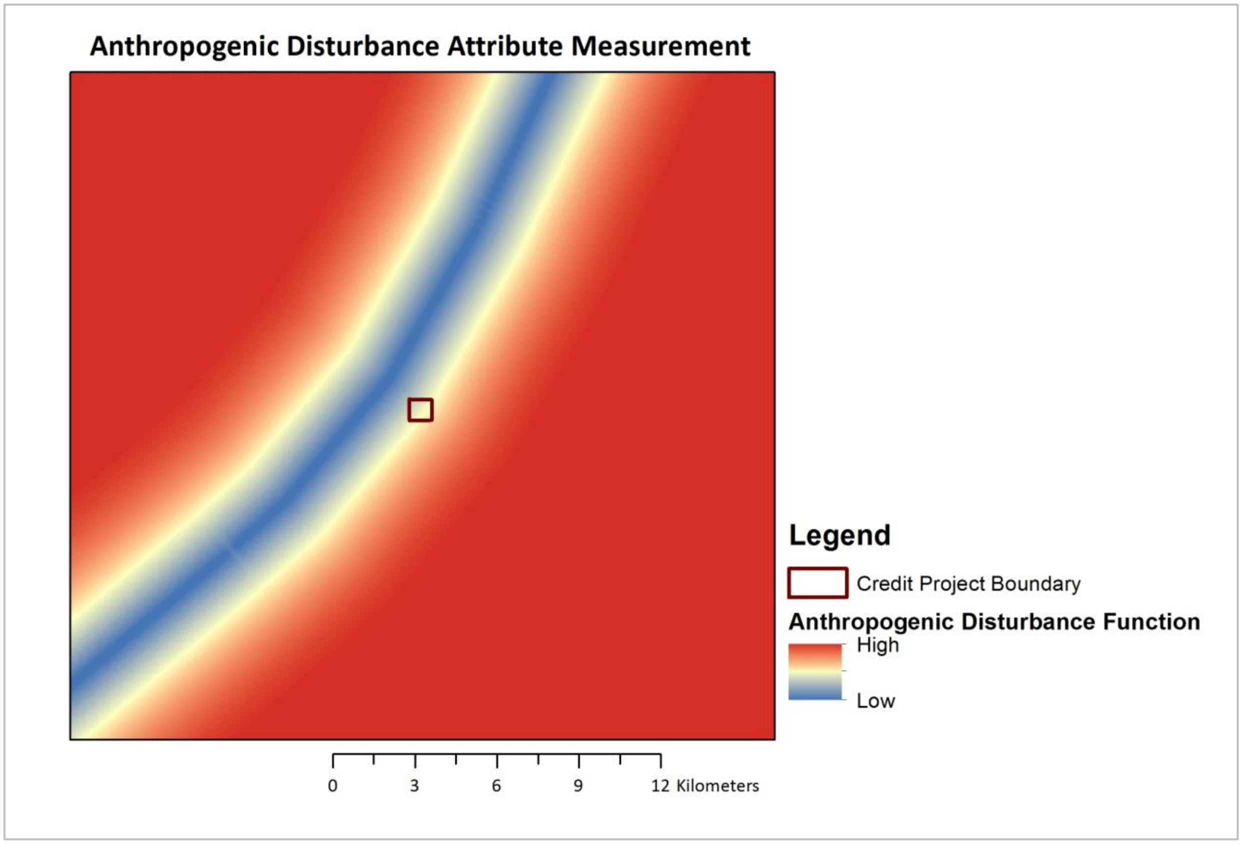


Figure 8: Habitat function due to the indirect effects of anthropogenic disturbance on sage-grouse habitat in the area surrounding an example credit project site

3.3.2 HABITAT SUITABILITY INDEX

The Habitat Suitability Index (HSI) is used as a local-scale modifier of habitat function. The HSI was generated based on model-averaged resource selection functions informed by more than 31,000 independent telemetry locations from more than 1,500 radio-marked sage-grouse across 12 project areas in Nevada and northeastern California collected during a 15-year period (1998–2013). Modeled habitat covariates included land cover composition, water resources, habitat configuration, elevation, and topography, each at multiple spatial scales that were relevant to empirically observed sage-grouse movement patterns (Coates et al. 2014a). The HSI is also used in the Sagebrush Ecosystem Program's Management Categories map, which determines management importance (see Section 3.2.2 Management Importance). However, the management categories value space use (i.e., modelled probability of sage-grouse occupancy) more highly than habitat suitability, and classifies the HSI into broad categories (high, moderate, low and non-habitat), whereas the HSI is used at the local scale at far higher resolution to evaluate habitats based on local context.

Four HSI maps were modeled to represent annual and seasonal (e.g. spring, summer, winter) habitat use of sage-grouse (Coates et al. 2016), which provided an updated product to the original 2014 HSI (Coates et al. 2014a). The original HSI values for each season are used as the scoring curve to assign habitat function, and no scaling or reclassification is applied to the seasonal HSI values. Each map unit within a credit or debit project is evaluated based on the averaged HSI scores for each season and the highest scoring seasonal habitat is used as the local-scale modifier when calculating habitat function.

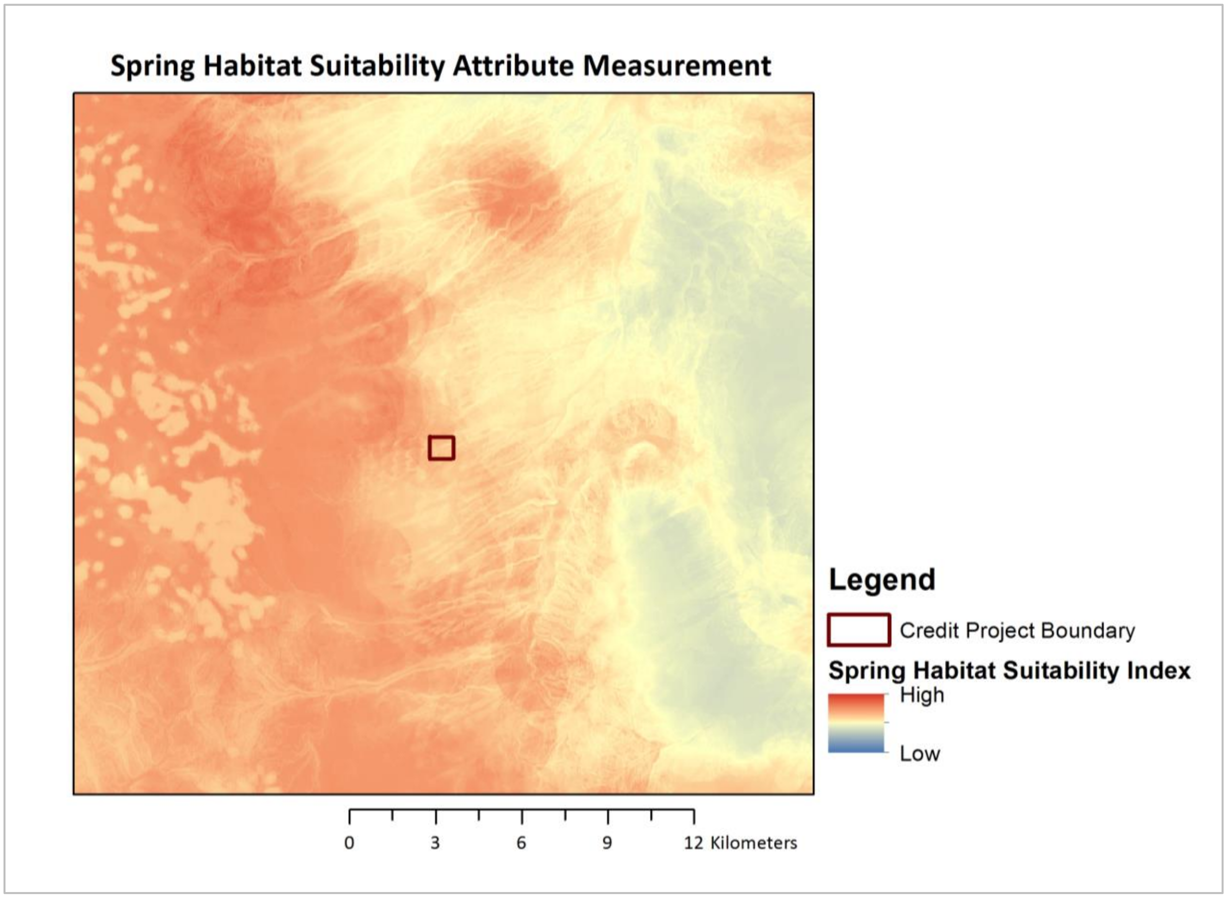
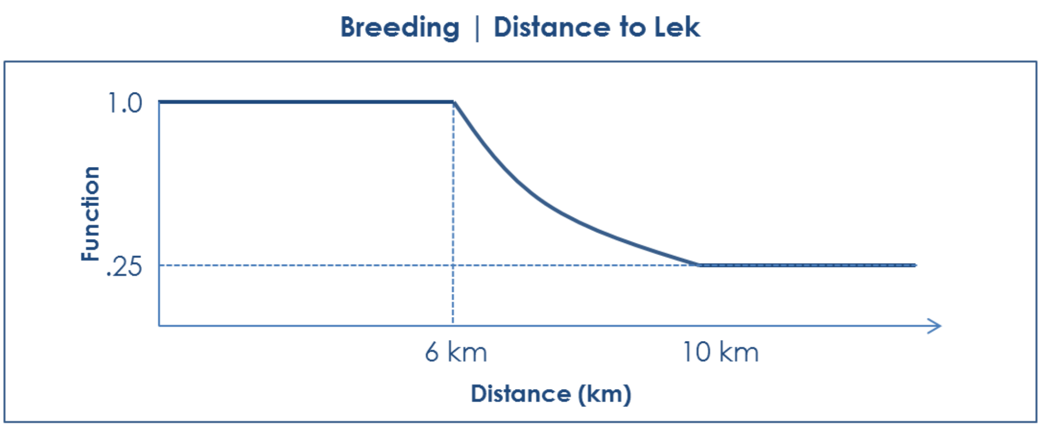


Figure 9. Habitat suitability related to the Spring HSI in the area surrounding an example credit project site

3.3.3 DISTANCE TO LEK (BREEDING)

Sage-grouse breeding habitat is spatially tied to lek locations; the majority of females breeding on a given lek nest within 3.73 miles (6 kilometers) of that lek (Colorado Greater Sage-grouse Steering Committee 2008). However, a portion of the female population will move farther than 3.73 miles (6 kilometers) from a lek to nest (Holloran and Anderson 2005, and see Doherty et al. 2011). The HQT therefore modifies breeding habitat function based on distance to closest known lek as follows: map units within 3.73 miles (6 kilometers) of a lek receive a score of 1.0 followed by a decline between 3.73 and 6.21 miles (6 and 10 kilometers) from a lek, map units farther than 6.21 miles (10 kilometers) from a known lek receive a score of 0.25 (Figure 10). The distance to lek score is multiplied by all other local-scale attribute scores to calculate overall local-scale habitat function for breeding habitat.



Distance (km)	<6	6 – <7	7 – <8	8 – <9	9 – <10	≥10
Score	1.0	0.80	0.60	0.40	0.30	0.25

Figure 10. Scoring curve and table for distance to lek attribute as modifier to breeding habitat function

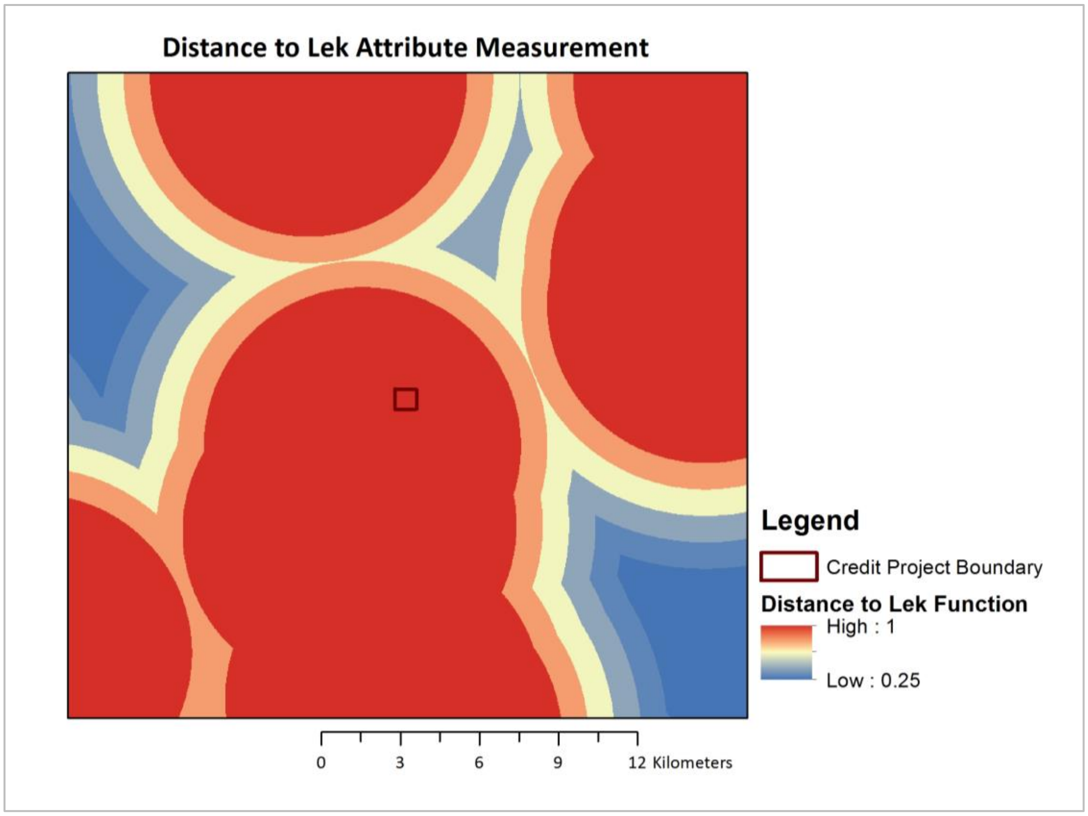
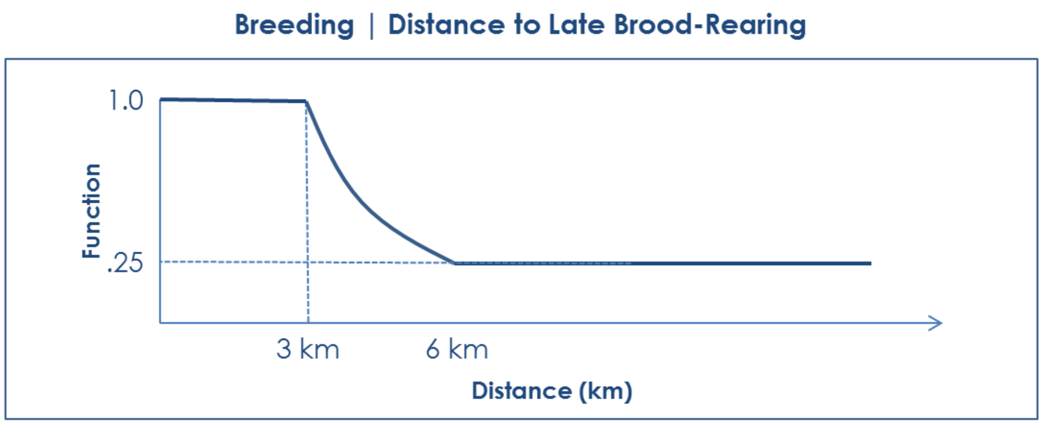


Figure 11. Effect of distance to the nearest lek on breeding habitat function for an example credit project

3.3.4 DISTANCE TO LATE BROOD-REARING HABITAT (BREEDING)

Research indicates chick survival drops significantly when broods are required to travel greater than 1.86 miles (3 kilometers) (Gibson et al. 2013). However, some broods successfully travel long distances to late brood-rearing habitat. Therefore, distance to late-brood rearing habitat is a modifier of breeding habitat function as follows: map units within 1.86 miles (3 kilometers) of late brood-rearing habitat receive a score of 1.0 followed by a decline between 1.86 and 3.73 miles (3 and 6 kilometers) from late brood-rearing habitat, map units farther than 3.73 miles (6 kilometers) from late brood-rearing habitat receive a score of 0.25 (Figure 12). The distance to late brood-rearing score is multiplied by all other local-scale attribute scores to calculate overall local-scale habitat function for breeding habitat.



Distance (km)	<3	3 – <4	4 – <5	5 – <6	≥6
Score	1.0	0.8	0.6	0.40	0.25

Figure 12. Scoring curve and table for distance to late brood-rearing habitat attribute as modifier to breeding habitat function

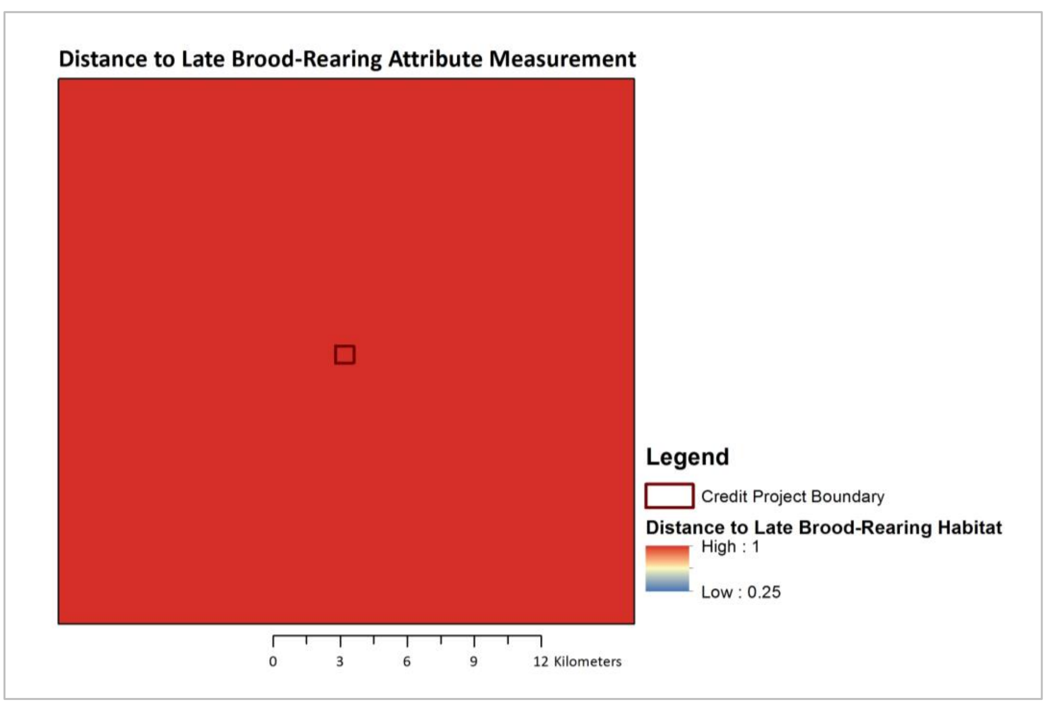


Figure 13. Effect of distance to late brood-rearing habitat on breeding habitat function for an example credit project

Box 2 | Example Map Unit Calculation (Local Scale)

Each local-scale attribute is measured either through direct digitization of high resolution aerial imagery or with geospatial layers in a GIS. Local-scale habitat function is calculated separately for each seasonal habitat type: breeding, late brood-rearing, and winter (Figure 13). Local-scale habitat function is measured to be 38% for breeding, 36% for late brood-rearing and 28% winter seasonal habitats for Map Unit 1.

	Management Category	Meadow Habitat	3rd Order Function	4th Order Function	**Overall Function**	Acres	**Functional Acres**
Breeding	PHMA	No Meadow	38%			18	
LBR	PHMA	No Meadow	36%			18	
Winter	PHMA	No Meadow	28%			18	

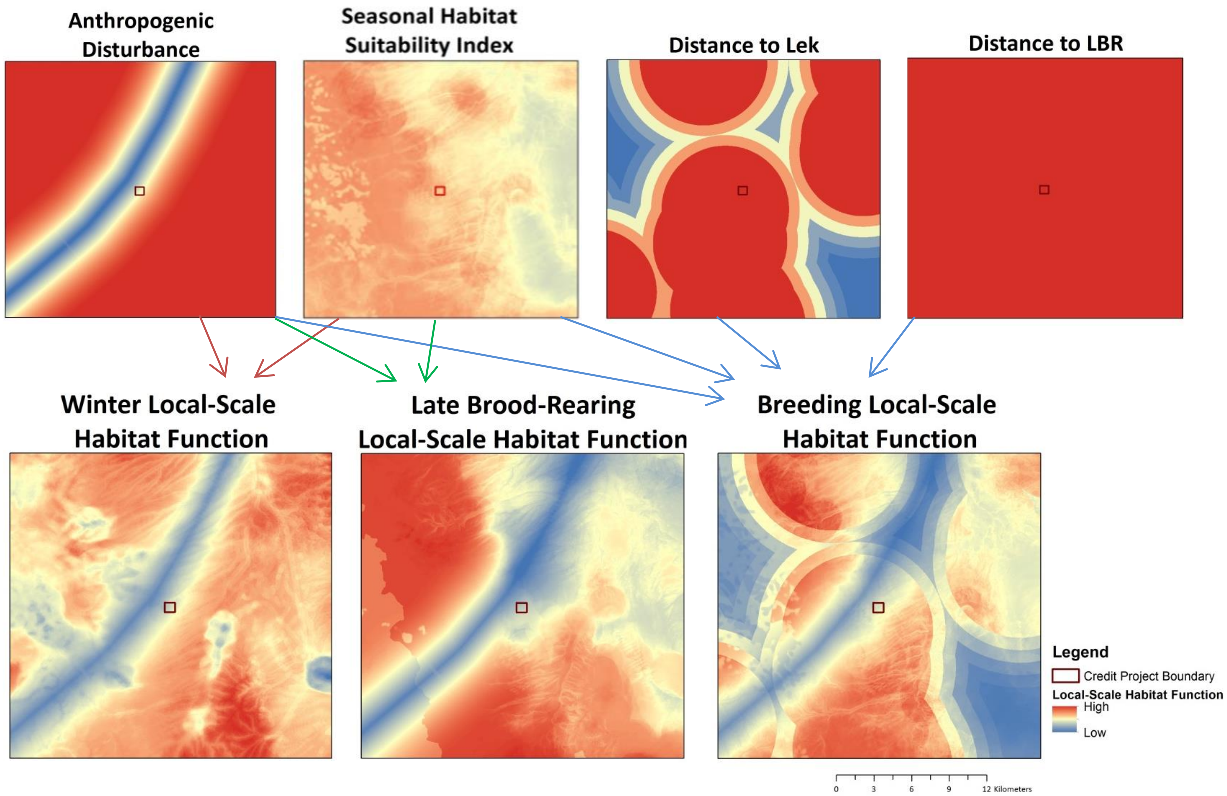
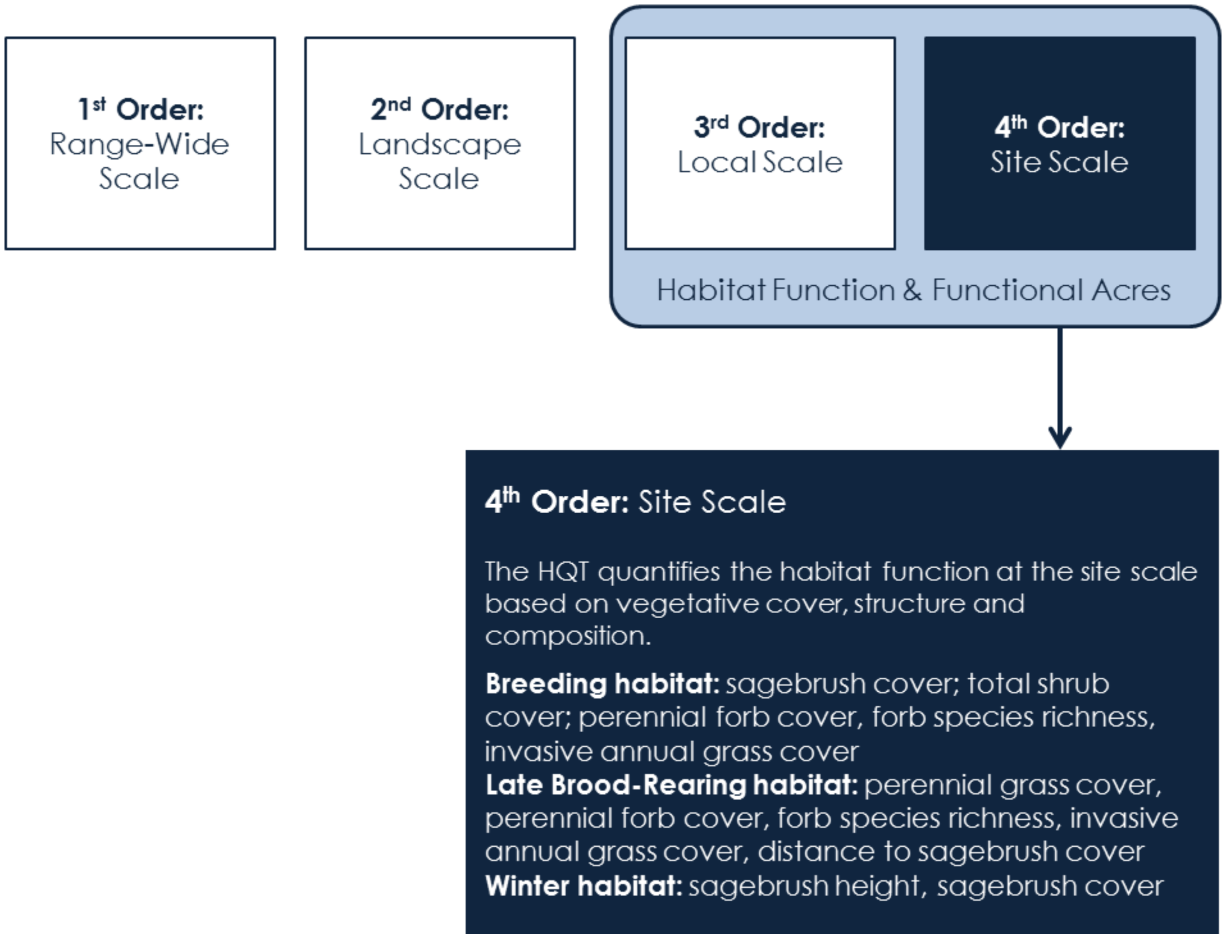


Figure 14. Local-scale attributes are measured in a GIS and combined to calculate local-scale habitat function for each seasonal habitat type.

4TH ORDER: SITE SCALE



3.4 SITE SCALE (4TH ORDER)

The HQT quantifies habitat function at the site scale based on vegetative cover, structure, and composition. Measurements include attributes that are indicative of habitat suitability and quality for sage-grouse, including conditions that support breeding, late brood-rearing, and winter habitats. Vegetation attributes are measured within each map unit and scored based on triggers, scoring curves and tables, and weighting. Modifiers of site-scale habitat function, including invasive annual grass and distance to sagebrush, are applied to habitat function for the appropriate seasonal habitat types.

The concept model below illustrates the conditions being measured at the site scale and the role they play in providing suitable breeding, late brood-rearing, and winter habitat (Figure 15).

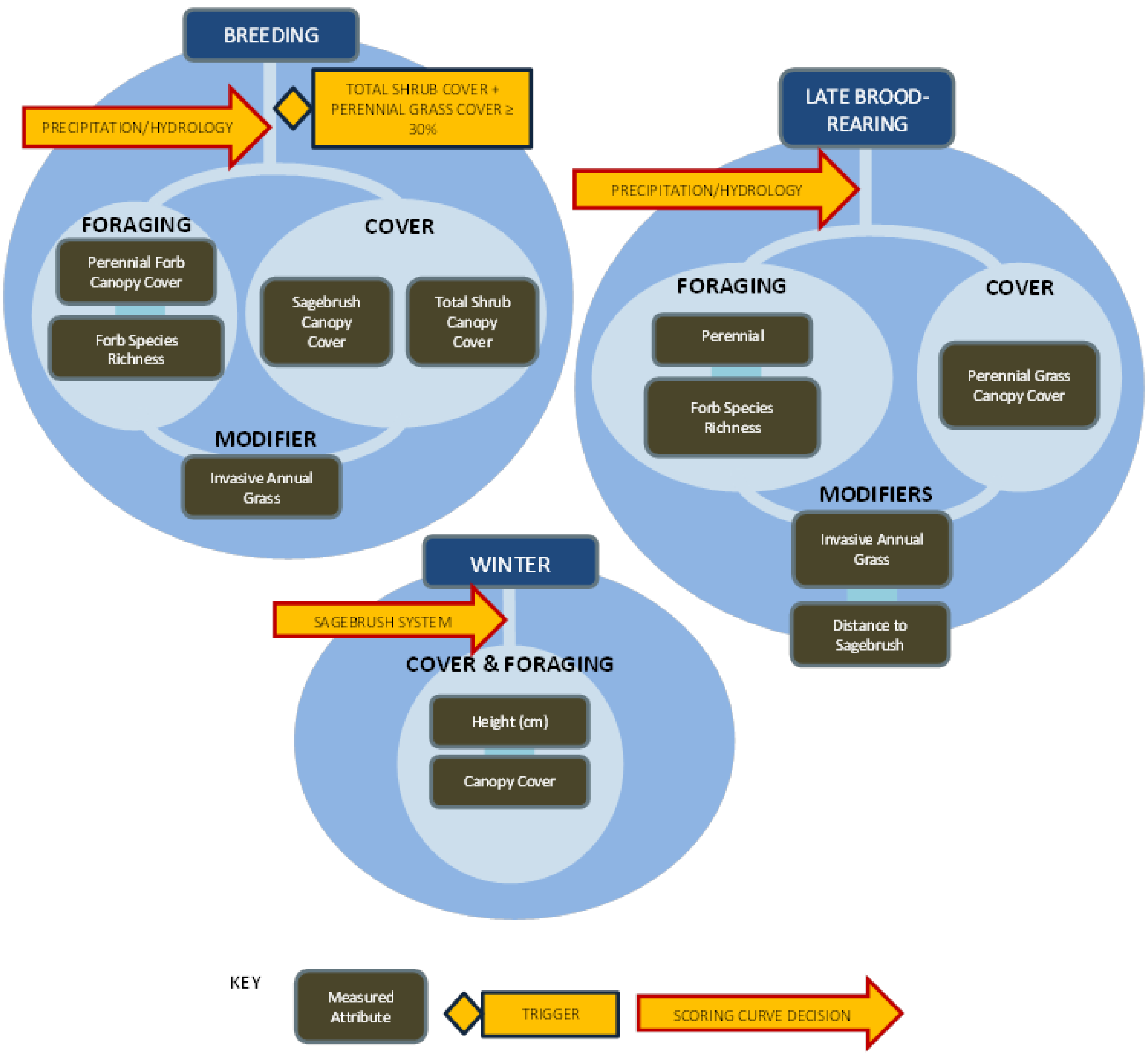


Figure 15. Conceptual model depicting sage-grouse life history requirements at the site scale (4th order)

3.4.1 TRIGGERS

For breeding habitat, when sagebrush cover is less than 25%, there should be at least 10% perennial grass cover (Coates et al. 2011; Coates and Delehanty 2010). However, the relationship is dynamic—as cover of sagebrush increases, perennial grass cover becomes less important. Further, any type of shrub can be used for cover. Therefore, a combined cover of 30% for total shrub cover and perennial grass cover is required for the map unit to be scored for breeding habitat function. Combined total shrub cover and perennial grass cover is a trigger to indicate that a map unit contains functional breeding habitat. If the trigger is met, the map unit is scored as usual for breeding habitat. If the trigger is not met, the map unit receives a breeding habitat score of zero. The map unit may still receive a score for other seasonal habitat types.

3.4.2 SCORING CURVES

A set of scoring curves has been developed by the TRG for each attribute measured to reflect an attribute's potential for supporting sage-grouse for a given measurement of that attribute, representing how a site's habitat function changes as the attribute measurements change. The scoring curves for all of the vegetation attributes measured are included in Appendix A. Scoring curves are used to score average measurements for each attribute within a map unit. Separate scoring curves are used for some attributes based on the map unit's mean annual precipitation, hydrologic system, and dominant sagebrush community.

Precipitation Regime & Hydrologic System

The wide geographic range of sage-grouse results in different vegetation potentials in different regions in Nevada. This may be due to variation in factors such as mean annual precipitation and the site's hydrology. Encouraging the identification of suitable and high quality habitat within each region of the state requires some flexibility in how attributes are scored. For example, vegetation height in lower precipitation areas may not attain the same levels as vegetation in wetter areas, even though the former area may otherwise be high quality habitat for sage-grouse.

The HQT addresses this potential for variability by using different scoring curves for sites in arid-shrub conditions, mesic-shrub conditions, and meadow systems.

- **Arid-shrub condition**: sites with mean annual precipitation of less than 10 inches (25.4 centimeters)
- **Mesic-shrub condition**: sites with mean annual precipitation of greater than or equal to 10 inches (25.4 centimeters)

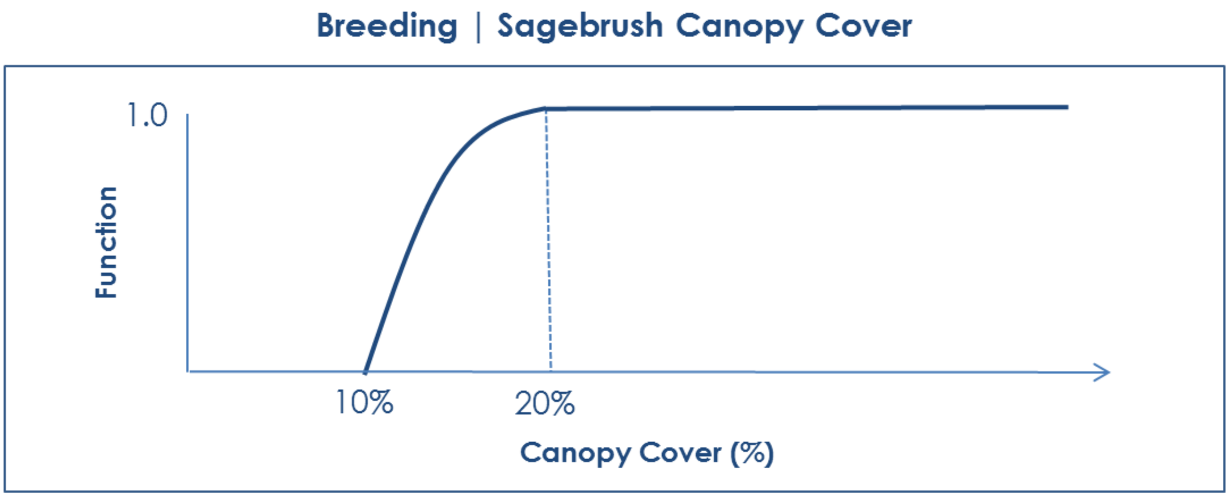
Note that annual precipitation changes (e.g., drought conditions) are different than mean annual precipitation as used by the HQT. Refer to PRISM Climate Group's "30-yr Normal Precipitation: Annual" for annual precipitation zones at http://prism.oregonstate.edu/normals/.

Dominant Sagebrush System

Different scoring curves for winter habitat function are used based on the dominant sagebrush community present. Sites dominated by Wyoming big sagebrush or mountain big sagebrush (*Artemisia tridentata* ssp.), which are typically taller and found where snow is deeper, are scored with different curves than sites dominated by low sagebrush (*Artemisia arbuscula* ssp.) or black sagebrush (*Artemisia* *nova*), which are typically shorter and found in areas where snow dissipates more quickly due to wind and solar radiation.

Application of Scoring Curves

After establishing the specific seasonal habitats to be scored and which scoring curves to use, the average measurement for each vegetation attribute in the map unit is scored using the appropriate scoring curve. For example, Figure 16 is the scoring curve and associated table for sagebrush canopy cover for scoring breeding habitat function.



Cover (%)	<10	10 – <12	12 – <14	14 – <16	16 – <18	18 – <20	≥20
Score	0	0.30	0.55	.75	.85	.93	1.00

Figure 16. Scoring curve and table for sagebrush canopy cover in breeding habitat

The scoring curve above establishes the relationship between sagebrush canopy cover and breeding habitat function, the shape of which is established from literature and expert opinion. The scoring curve establishes the habitat function of each site relative to fully-functioning conditions—from 0 (non-functioning) to 1.0 (fully-functioning canopy cover).

3.4.3 ATTRIBUTE WEIGHTING

The score for each attribute is then weighted as established in Table 3. The weights are based on expert opinion, are on a relative scale and add to 100%. See also Connelly et al. 2011c for a review of habitat requirements for sage-grouse habitat, and aforementioned literature citations (and the citations within) that describe sage-grouse habitat. The scores are multiplied by the weight, and the weighted scores across all attributes for that season are then added to generate a score for a map unit.

3.4.4 ATTRIBUTES MEASURED

The following attributes of site vegetation are measured (the following tables are adapted from Table 4-1 in Appendix B "Development Process and Justification for Habitat Objectives for Greater Sage-grouse in Nevada" in the Nevada State Plan). Attributes must be measured for each seasonal habitat type during the appropriate time of year, except for winter habitat attributes which can be measured at any time.

Table 3. Description of vegetation attributes measured and attribute weight

BREEDING (SAMPLE WINDOW APRIL 15 THROUGH JUNE 15)			
Cover	Sagebrush canopy cover	This serves as nesting horizontal overstory substrate. The presence of sagebrush in nesting habitat is an active variable in all studies of sage-grouse. (Connelly et al. 2000; Blomberg et al. 2012; Kolada et al. 2009a; Kolada et al. 2009b). Qualifying sagebrush species are defined in the Credit System User's Guide. This is estimated with line intercept.	20% Weight
	Total shrub canopy cover (includes sagebrush)	Shrub species such as rabbitbrush (*Chrysothamnus spp.*), antelope bitterbrush (*Purshia tridentata*), and horsebrush (*Tetradymia canescans*) are associated with higher nest success. Where sagebrush canopy cover is high, other brush species play a positive role. Total canopy cover of all species is a positive attribute for nest success (Coates and Delehanty 2010; Kolada et al. 2009b). This is estimated with line intercept.	30% Weight
Foraging	Perennial forb canopy cover	Forbs are an important food resource and is a primary habitat component affecting brood persistence (Casazza et al 2011). This is estimated along line transects within Daubenmire frames.	25% Weight
	Forb species richness	This is a measure of the number of forb species (excluding noxious weeds as designated in NAC 555.010), both perennial and annual, available across the early brood-rearing period. Data indicate there is a direct correlation between the number of forb species present and sage-grouse persistence (Casazza et al. 2011). Species are tallied within Daubenmire frames along line-transects.	25% Weight
Trigger	Perennial grass canopy cover	Combined perennial grass canopy cover and total shrub canopy cover must exceed 30% to be scored for breeding.	n/a

LATE BROOD-REARING (SAMPLE WINDOW APRIL 15 THROUGH JUNE 15)			
Cover	Perennial grass canopy cover	Perennial grass cover is higher (17.4% versus 12%) in selected sites than non-selected sites (Kirol et al. 2012). This is estimated along line transects within Daubenmire frames.	25% Weight
Foraging	Perennial forb canopy cover	Forbs are an important food resource and is a primary habitat component affecting brood persistence (Casazza et al 2011). This is estimated along line transects within Daubenmire frames.	37.5% Weight
	Forb species richness	This is a measure of the number of forb species (excluding noxious weeds as designated in NAC 555.010), both perennial and annual, available across the late brood-rearing period. Data indicate there is a direct correlation between the number of forb species present and sage-grouse persistence (Casazza et al. 2011). Species are tallied within Daubenmire	37.5% Weight

		frames along line transects.	

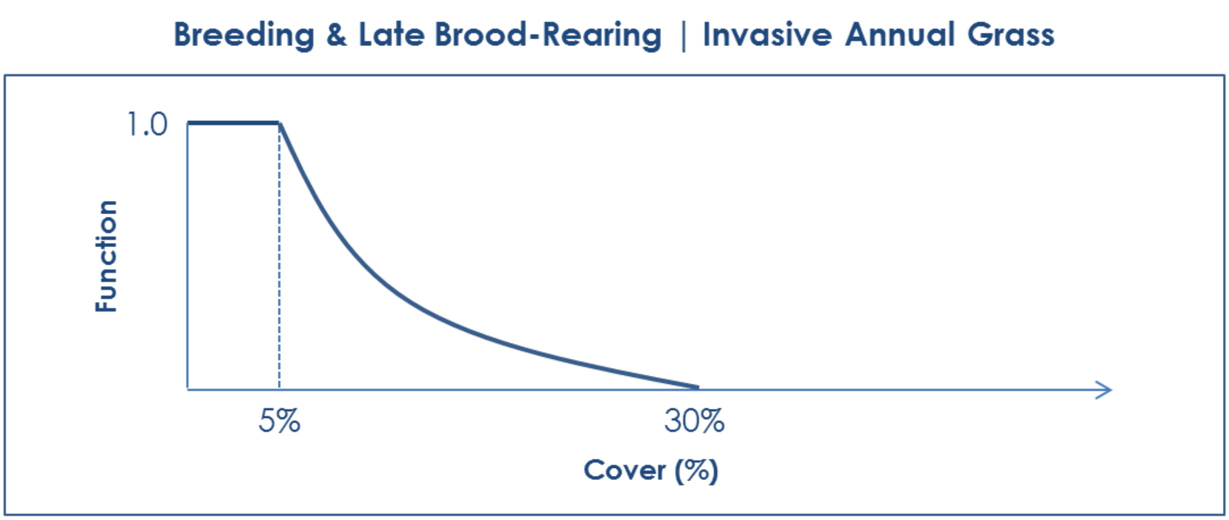
WINTER			
(SAMPLE ANYTIME)			
Cover & Foraging	Shrub canopy cover	During winter, sagebrush canopy cover serves as both food and cover for sage-grouse (Connelly et al. 2000). This is estimated with line intercept.	50% Weight
	Sagebrush height	Access to sagebrush during winter conditions is important (Connelly et al. 2000). This measures the average height of sagebrush. It is collected along line transects.	50% Weight

3.4.5 MODIFICATION OF SITE-SCALE HABITAT FUNCTION

Habitat function is modified at the site scale by invasive annual grass cover for breeding and late brood-rearing habitat function and distance to sagebrush cover for late brood-rearing habitat function. Scores associated with each modifier are multiplied by the pre-modified site-scale habitat function of the appropriate seasonal habitat types to calculate site-scale habitat function.

3.4.5.1 Invasive Annual Grass (Breeding & Late Brood-Rearing)

Invasive annual grass cover is a modifier for breeding and late brood-rearing habitat function, and is measured along line transects within Daubenmire frames (Figure 17). Invasive annual grass includes, but is not limited by, noxious weed grasses as designated in NAC 555.010.



Cover (%)	<5	5 – <10	10 – <15	15 – <20	20 – <25	25 – <30	≥30
Score	1.00	0.80	0.60	0.45	0.25	0.15	0

Figure 17. Scoring curve and table for invasive annual grass canopy cover as a modifier for breeding and late brood-rearing habitat

Big sagebrush ecosystems of the Intermountain West are especially vulnerable to invasions by annual exotic grasses such as cheatgrass, which can become dominant in the herbaceous understory community (Miller et al. 2011). Invasive plants, especially invasive annual grasses (e.g., cheatgrass, and medusahead) in sagebrush-steppe habitats, alter plant community structure, composition and productivity and may competitively exclude native plants important as cover and forage for sage-grouse (Vitousek 1990, Mooney and Cleland 2001, Rowland et al. 2010). The most pronounced negative consequence of invasive annual grass invasion into sagebrush habitats is the resulting change in fire frequency and intensity (Balch et al. 2013, Antonio et al 1992). Ultimately, invasive annual grasses promote fires and fires promote invasive annual grasses. Fire also facilitates the conversion of rangelands from perennial-dominated to annual-dominated systems by eliminating fire-intolerant species such as big sagebrush from these systems, rendering them permanently unsuitable to sage-grouse (Connelly et al. 2004, Epanchin-Niell et al. 2009, Davies et al. 2011). In central Nevada, recruitment of male sage-grouse to leks was consistently low in areas with high proportions of exotic grasslands interspersed in the landscape within 3.11 miles (5 kilometers) of a lek, even during years when climatic conditions resulted in substantial recruitment to leks in the region (Blomberg et al. 2012).

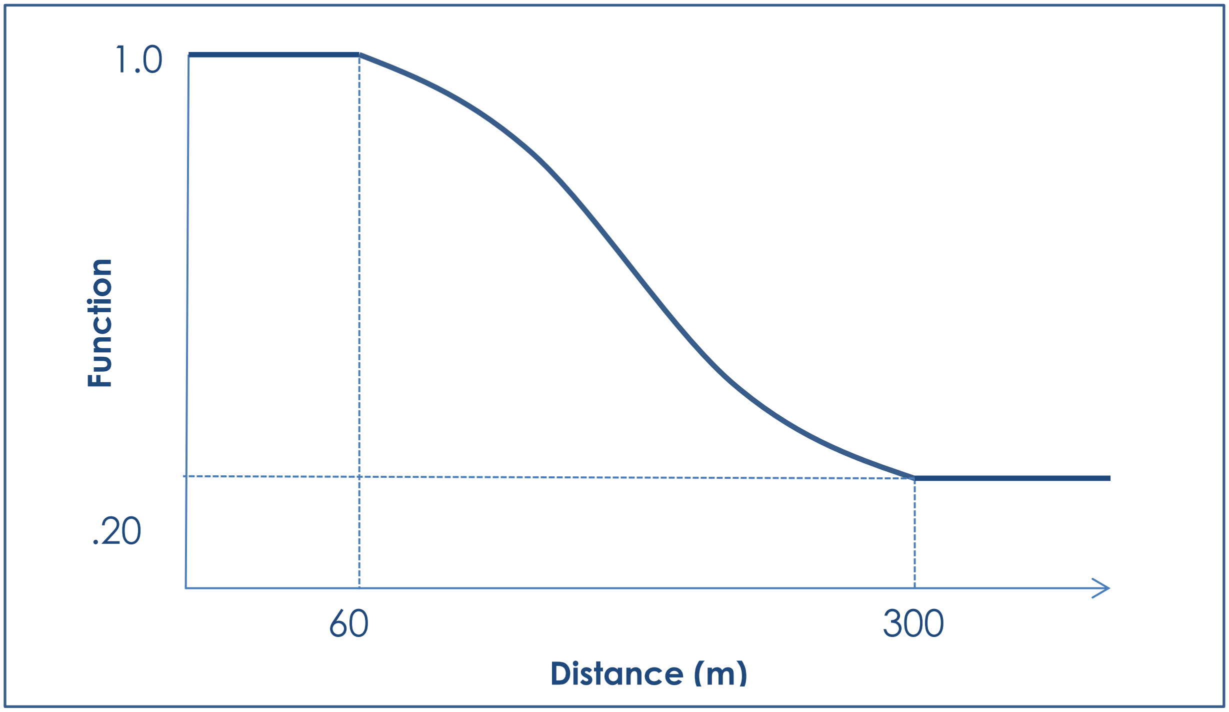
3.4.5.2 Distance to Sagebrush Cover (Late Brood-Rearing)

Late brood-rearing habitat that is classified as meadow is categorized as either unaltered or altered meadow. Unaltered meadows are defined as naturally occurring wetland complexes, dominated by wetland vegetation and soils (e.g. stringer meadows, springs, seeps) where the hydrology has been minimally altered or is currently not being managed. Altered meadows are defined as receiving either controlled irrigation, where the hydrology is currently being altered or managed (e.g. diversions, spreaders), or where the landscape is being functionally altered. Distance to sagebrush cover for altered meadow is a modifier of late brood-rearing habitat function as follows: map units within 196.9 feet (60 meter) of cover (defined as 10% cover and 11.8 inches (30 centimeters) height minimum over 98.4 feet (30 meter) x 98.4 feet (30 meter) area) of sagebrush or sagebrush mixed-shrub community (e.g., sagebrush, bitterbrush, rabbitbrush, serviceberry, broom snakeweed) receive a score of 1.0 followed by a decline between 196.8 feet (60 meter) and 984.3 feet (300 meter) to sagebrush or sagebrush mixed-shrub cover, map units farther than 984.3 feet (300 meter) from sagebrush or sagebrush mixed-shrub cover receive a score of 0.20 (Figure 18)

Distance (m)	<60	60 – <100	100 – <140	140 – <180	180 – <220	220 – <260	260 – <300	≥300
Score	1.00	.93	.80	.67	.54	.40	.27	.20

Figure 18. Distance to sagebrush or sagebrush mixed-shrub cover is measured from the 98.4 feet (30 meter) mark of every transect. Distance to sagebrush cover for unaltered meadow is a modifier of late brood-rearing habitat function that receives a score of 1.0 for any distance to sagebrush cover. The interface between the sagebrush and meadow edge is the most highly forb-productive area for sage-grouse and provides immediate available escape cover (Connelly et al. 2000). Based on the expert opinion of the TRG, sage-grouse may use specific areas (e.g., wet meadows) during the late brood-rearing season that do not have sagebrush within the perimeter of the meadow itself, as long as sagebrush is accessible to them. Scientific research also finds evidence for selection of riparian and grass cover by brood-rearing females at an 800m spatial extent (Westover el. al 2016). Meadows, riparian areas, other moist areas adjacent to sagebrush habitat and higher elevation sagebrush communities that maintain rich forb component later in summer can provide foraging areas during this season (Fischer et al. 1996a, Fischer et al. 1996b, Connelly et al. 2000, Connelly et al. 2011c).

Late Brood-Rearing | Distance to Late Brood-Rearing – Altered Meadow



Distance (m)	<60	60 – <100	100 – <140	140 – <180	180 – <220	220 – <260	260 – <300	≥300
Score	1.00	.93	.80	.67	.54	.40	.27	.20

Figure 18. Scoring curve and table for scoring late brood-rearing habitat based on distance to sagebrush cover

3.4.5.3 An Option for Debit Projects to Forego Onsite Sampling by Assuming Maximum Site-Scale Function

If a Debit Project Proponent prefers to not conduct field sampling, whether they are under a time constraint or developing an area with high anthropogenic disturbance, a site-scale habitat function of 100% could be assigned within the debit site-screening tool which would allow for the most conservative debit calculation possible. This would display the same function as if the field sampling determined pristine habitat. If this option is preferred over utilizing the complete HQT, it would create a systematic and consistent approach to calculating credit obligation for debit projects that would always yield a higher debit estimate than if field data were collected.

Box 3 | Example Map Unit Calculation (Site Scale)

The site-scale habitat function for each seasonal habitat type is multiplied by local-scale habitat function and the number of acres within the map unit to calculate functional acres.

	Management Category	Meadow Habitat	3rd Order Function	4th Order Function	**Overall Function**	Acres	**Functional Acres**
Breeding	PHMA	No Meadow	38%	61%	**23%**	18	4.2
LBR	PHMA	No Meadow	36%	70%	**25%**	18	4.5
Winter	PHMA	No Meadow	28%	64%	**18%**	18	3.2

Map Unit 1 is located in a mesic precipitation zone (i.e., more than 10 inches (25.4 centimeters) of precipitation per year) and contains dominantly mountain big sagebrush. The following measurements are obtained during the appropriate sampling period. Each measurement is scored using the appropriate scoring curves, the score is then weighted and the weighted scores are **summed** for each seasonal habitat type to calculate pre-modified site-scale habitat function.

The map unit is also assessed for invasive annual grass and distance to sagebrush. The map unit contains sagebrush within it, yielding a score of 100% for the distance to sagebrush modifier. Invasive annual grass cover is measured at 6% during the breeding assessment and 3% during the late brood-rearing assessment, yielding scores of 100% and 80%, respectively. Modifier scores are **multiplied** by the pre-modified site-scale habitat function for each seasonal habitat type in succession to calculate site-scale habitat function.

Breeding	**Average Measurement**	**Score***	**Weight**	**Weighted Score**
Sagebrush Canopy Cover	17%	85%	20%	17%
Total Shrub Canopy Cover	24%	75%	30%	23%
Perennial Forb Canopy Cover	4%	40%	25%	10%
Forb Species Richness	3 species	45%	25%	11%
		Pre-modified Site-Scale Breeding Function		**61%**
Invasive Annual Grass	3%	100%	n/a	100%
		Site-Scale Breeding Function		**61%**
Late Brood-Rearing				
Perennial Grass Canopy Cover	7%	64%	25%	16%
Perennial Forb Canopy Cover	12%	100%	37.5%	38%
Forb Species Richness	4 species	90%	37.5%	34%
		Pre-modified Site-Scale Late Brood-Rearing Function		**88%**
Invasive Annual Grass	6%	80%	n/a	80%
Distance to Sagebrush	0 m	100%	n/a	100%
		Site-Scale Late Brood-Rearing Function		**70%**
Winter				
Sagebrush Canopy Cover	17%	88%	50%	44%
Sagebrush Height	34 cm	40%	50%	20%
		Site-Scale Winter Function		**64%**

*See Appendix A for all scoring curves used to assess vegetation attributes at the site scale

4.0 PROJECT EXAMPLE

Tables 4, 5 and 6 illustrate the scoring process for the remainder of the map units in the example credit project (Figure 19). The process used to evaluate Map Unit 1, described in the previous section, is repeated for each map unit.

The scoring process requires both a desktop analysis and a field analysis. The desktop analysis measures attributes at the landscape and local scale. The field analysis measures vegetation attributes relevant at the site scale. Overall habitat function is a product of local-scale habitat function and site-scale habitat function. Functional acres are a product of habitat function and the acres within the map unit. Each map unit is assessed for each seasonal habitat type: breeding, late brood-rearing and winter.

For a complete, step-by-step description of the scoring process used by the HQT, please see the *Credits System User's Guide*.

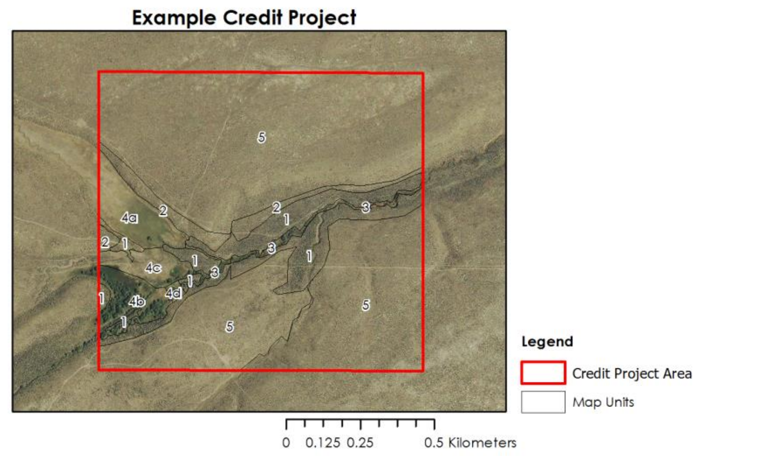


Figure 19. Example credit project and map units

Table 4. Attribute measurements, habitat function, and functional acre values for breeding habitat function

BREEDING HABITAT FUNCTION									
Map Unit	Acres	Precipitation Regime/ Hydrologic System	Dominant Shrub Community	Management Category	Meadow Habitat	Local-Scale Habitat Function	Site-Scale Habitat Function	Habitat Function	Functional Acres
1	18	Mesic	Big Sagebrush	PHMA	No Meadow	38%	61%	23%	4.1
2	6	Mesic	Big Sagebrush	PHMA	No Meadow	36%	46%	16%	1.0
3	2	Mesic	n/a	PHMA	Altered	38%	0%	0%	0.0
4a	6	Mesic	n/a	PHMA	Altered	35%	0%	0%	0.0
4b	5	Mesic	n/a	PHMA	Altered	37%	0%	0%	0.0
4c	4	Mesic	n/a	PHMA	Altered	36%	0%	0%	0.0
4d	0.5	Mesic	n/a	PHMA	Altered	35%	0%	0%	0.0
5	112	Mesic	Big Sagebrush	PHMA	No Meadow	38%	58%	22%	25.1

Table 5. Attribute measurements, habitat function, and functional acre values for late brood-rearing habitat function

LATE BROOD-REARING HABITAT FUNCTION									
Map Unit	Acres	Precipitation Regime/ Hydrologic System	Dominant Shrub Community	Management Category	Meadow Habitat	Local-Scale Habitat Function	Site-Scale Habitat Function	Habitat Function	Functional Acres
1	18	Mesic	Big Sagebrush	PHMA	No Meadow	36%	70%	25%	4.6
2	6	Mesic	Big Sagebrush	PHMA	No Meadow	35%	64%	23%	1.4
3	2	Mesic	n/a	PHMA	Altered	36%	92%	33%	0.7
4a	6	Mesic	n/a	PHMA	Altered	35%	29%	10%	0.6
4b	5	Mesic	n/a	PHMA	Altered	36%	64%	23%	1.2
4c	4	Mesic	n/a	PHMA	Altered	36%	24%	9%	0.3
4d	0.5	Mesic	n/a	PHMA	Altered	34%	58%	20%	0.1
5	112	Mesic	Big Sagebrush	PHMA	No Meadow	36%	11%	4%	4.4

Table 6. Attribute measurements, habitat function, and functional acre values for winter habitat function

WINTER HABITAT FUNCTION									
Map Unit	Acres	Precipitation Regime/ Hydrologic System	Dominant Shrub Community	Management Category	Meadow Habitat	Local-Scale Habitat Function	Site-Scale Habitat Function	Habitat Function	Functional Acres
1	18	Mesic	Big Sagebrush	PHMA	No Meadow	28%	64%	18%	3.3
2	6	Mesic	Big Sagebrush	PHMA	No Meadow	26%	53%	14%	0.8
3	2	Mesic	n/a	PHMA	Altered	29%	0%	0%	0.0
4a	6	Mesic	n/a	PHMA	Altered	24%	0%	0%	0.0
4b	5	Mesic	n/a	PHMA	Altered	26%	0%	0%	0.0
4c	4	Mesic	n/a	PHMA	Altered	25%	0%	0%	0.0
4d	0	Mesic	n/a	PHMA	Altered	25%	0%	0%	0.0
5	112	Mesic	Big Sagebrush	PHMA	No Meadow	29%	71%	20%	22.7

5.0 LIMITATIONS OF THE HQT

The HQT is the scientific underpinning of the Credit System. The credibility of the Credit System and its effectiveness hinges upon the quality of the science upon which it is based and the integrity with which it is applied. The HQT is based on the best available science and best professional judgment. However, there are aspects of its content and potential uses that can be improved as it is adaptively managed over time. These limitations should be considered when applying the HQT.

Linking to Population Outcomes

The ultimate objective of the Credit System is to contribute to conservation of the sage-grouse by providing net habitat benefits. However, these habitat benefits must ultimately lead to larger and more secure sage-grouse populations. Therefore, the Credit System must have a means of measuring aggregate cumulative habitat impacts and benefits, and relating the net contribution of habitat benefits achieved through the Credit System to populations.

To make this link, an estimate of population impacts from activities related to credit and debit projects is needed. Unfortunately, it is not currently possible to make this link directly through published literature and thus site-level management actions cannot be quantified for the number of sage-grouse "produced" or "eliminated." However, additional research could contribute to a greater understanding of how cumulative habitat changes contribute to population viability. Furthermore, as long as debits are offset by credits, and as credits accumulate beyond debits, the Credit System will have contributed to increases in high quality habitat that can help to sustain resilient populations over time. The State of Nevada will continue to monitor sage-grouse populations across the state.

Importance of Temporal Scale

Temporal scales must be taken into consideration when establishing a mitigation project, and as spatial scales of a project or evaluation area increase, so should temporal scales.

Temporal scales vary among ecological processes and may not be linear especially in varying environments (Wiens 1989). The time required for a vegetation community to respond to management practices or changes in habitat and its influence on sage-grouse vital rates varies by ecosystem, geography, climate, and land use. For sage-grouse, time lags of two to ten years have been observed for population response to infrastructure development (Holloran 2005; Harju et al. 2010; Walker et al. 2007) or even longer with changes in habitat structure (e.g., fire) (Connelly et al. 2011b). Temporal scale for sagebrush projects deserves especially close consideration given that recovery of sagebrush is an especially difficult and slow process due to abiotic variation, short-lived seedbanks, and long generation time of sagebrush; where soils and vegetation are highly disturbed, sagebrush restoration can be challenging if not impossible (Pyke et al. 2011, Monsen 2005).

The scoring approach used in the HQT does not include a short-term temporal aspect. Thus, it cannot detect short-term changes in impacts resulting from infrastructure. For example, a drilling rig may have more impact than a producing well. Due to this limitation, it scores the impact based on the primary level of activity the majority of the time the disturbance is present. In this example, it scores based on the impact of the active production phase, rather than the drilling rig phase, which may only last 60 days.

Anthropogenic Impacts Literature

Much of the literature used to estimate the distance effects and relative weights associated with anthropogenic disturbance is derived from analyses of the response of sage-grouse on leks (i.e., number of males occupying leks) to that infrastructure (see Appendix D) as leks are relatively easy to monitor and provide surrogate information for seasonal habitat quality in the vicinity of leks. As more studies become available that more explicitly quantify demographic impacts to sage-grouse during specific seasonal periods (i.e., breeding, summer and winter), weights and distances for each season may be developed to fine-tune the relative impacts by season from different types of anthropogenic activity.

Additionally, most of this literature relates to oil and gas development. Although currently in Nevada there is little oil and gas development, other energy and mineral facilities are assumed to have similar effects as oil and gas-related infrastructure. Where literature is available specific to a type of anthropogenic disturbance, that literature is used to determine indirect effect distances and weights.

Vegetation Sampling Protocol

The HQT currently relies on a standardized, site-specific vegetation sampling protocol to establish vegetation conditions. The methods established in the User's Guide are based on the same methods that were used in the research supporting the scoring curves developed for this process. Standardizing vegetation sampling protocols over space and time has its challenges, which could be problematic in situations where quantifying vegetation change is the objective of monitoring (Seefeldt and Booth 2006). Aerial imagery and other remotely-sensed information offer the opportunity for more objective measurement of vegetation across space and time, but in most instances the products derived from these data are too coarse to effectively detect small-scale changes in the vegetation (Seefeldt and Booth 2006). As remote-sensing platforms and sensors mature, spatial and temporal resolution are expected to improve and costs decrease, making it easier to effectively quantify change in relevant vegetation attributes for attributes that can be assessed with these technologies. The Science Committee, a group of sage-grouse experts and scientists convened to inform monitoring efforts across the Credit System, will stay abreast of advances in remote-sensing and image analysis software so that GIS-based monitoring protocols can be incorporated into the HQT as suitable to address the HQT objectives.

Seasonal Habitat Availability, Interspersion & Juxtaposition

The HQT uses the proportion of each seasonal range available to sage-grouse on the landscape within and surrounding a project site as a modifier of habitat quality. However, the interspersion, juxtaposition and availability of the differing cover types used by sage-grouse during an annual cycle influence the effectiveness of a given landscape to provide sage-grouse with useable and high quality habitat (Connelly et al. 2011c). Future iterations of the HQT could explore how to integrate interspersion and juxtaposition as modifiers of habitat function.

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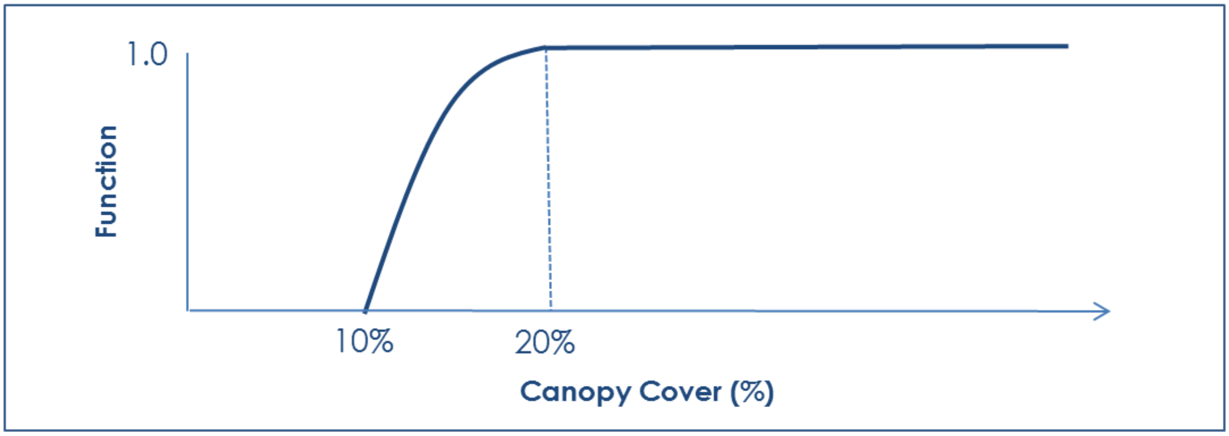
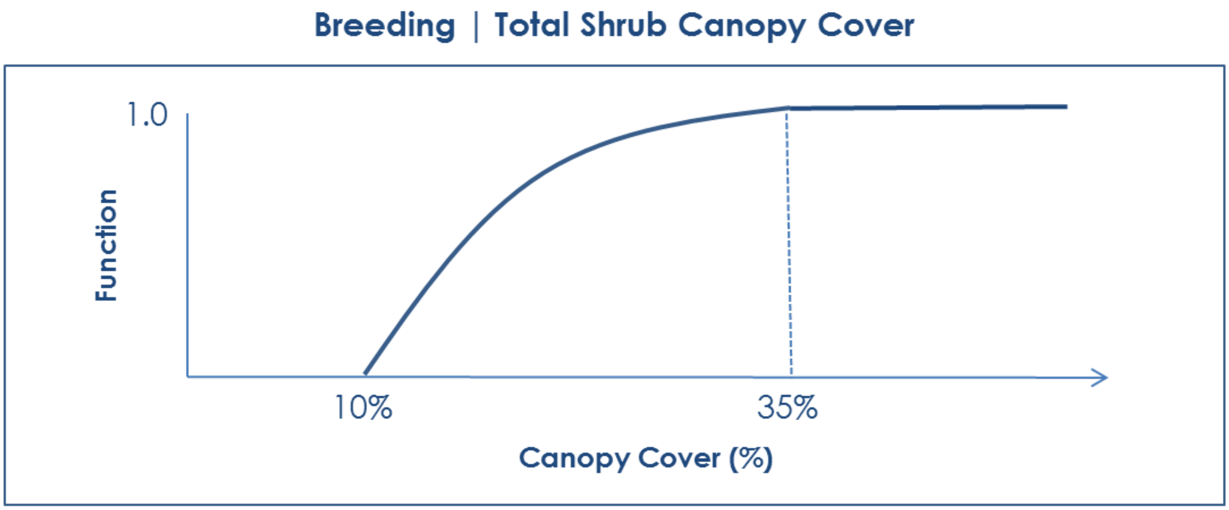
APPENDIX A: SCORING CURVES

Breeding | Sagebrush Canopy Cover



Cover (%)	<10	10 – <12	12 – <14	14 – <16	16 – <18	18 – <20	≥20
Score	0	0.30	0.55	.75	.85	.93	1.00

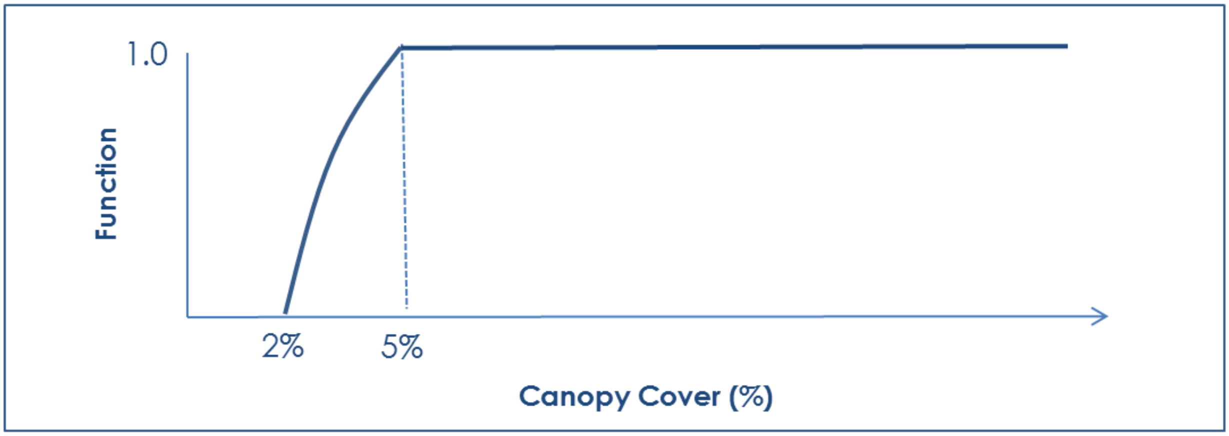
Reference: Modified from a curve created for the Colorado Greater Sage-Grouse Habitat Quantification Tool (2016), which used 20% as the starting value and 30% as the minimum fully functional value. TRG input subtracted 10% from the starting point to reflect Table 2-6 (BLM 2013 and references therein) and Kolada et al. 2009a and Kolada et al. 2009b.



Cover (%)	<10	10 – <14	14 – <20	20 – <25	25 – <30	30 – <35	≥35
Score	0	0.3	0.55	0.75	0.85	.93	1

Reference: Attribute included based on TRG input to reflect Table 2-6 (BLM 2013) and developed curve setting the minimum fully functional value at 35% based on Kolada et al 2009a, Coates and Delehanty 2010, and Lockyer et al. In Press. Further modified by TRG to reflect data from Gibson et al. 2013.

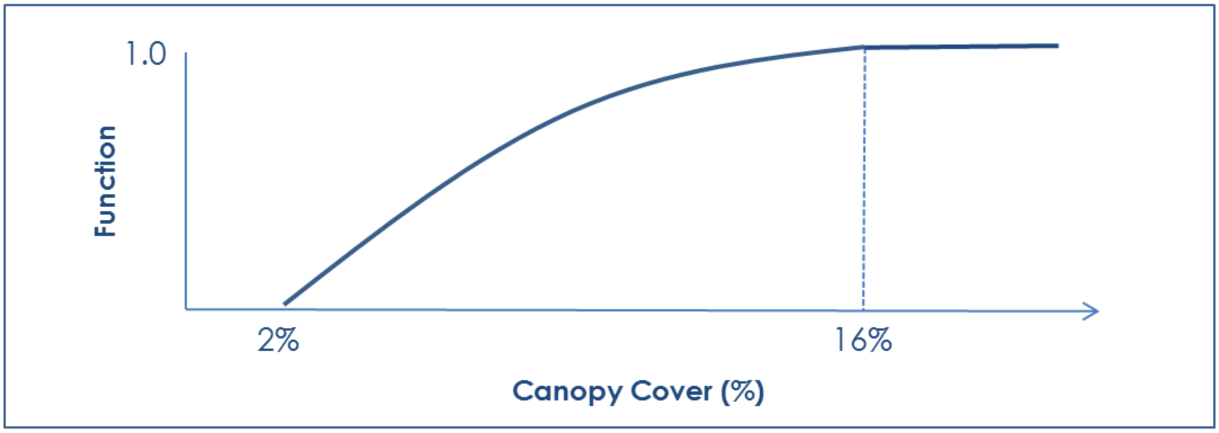
Breeding | Perennial Forb Canopy Cover (Arid Conditions)



Arid-Shrub Conditions	Cover (%)	<2	2 – <3	3 – <4	4 – <5	≥5
	Score	0	0.4	0.7	0.9	1

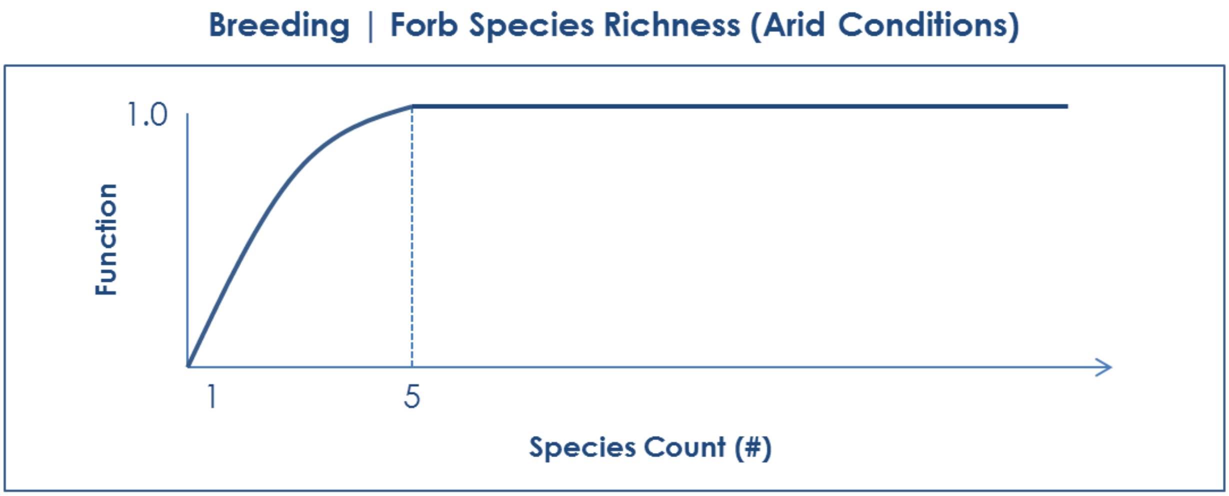
Reference: Modified from a curve created for the Colorado Greater Sage-Grouse Habitat Quantification Tool (2016), which used 20% as the minimum fully functional value and 0% as the starting value. Modified based on TRG input to reflect Table 2-6 (BLM 2013) to develop separate curves for arid-shrub conditions and mesic-shrub conditions/meadow systems. Based on Table 2-6 (BLM 2013), Casazza et al. 2011, and Lockyer et al. 2012 modified the minimum fully functional value set to 5%. Based on TRG input, the starting value was set at 2% as some canopy cover is needed to meet the needs of sage-grouse and reflects the ability for a site to recovery after a disturbance. Curve was modified to be more linear based on unpublished data provided by J. Sedinger that showed increased nest selection preference and success related to increased forb cover in an almost linear relationship.

Breeding | Perennial Forb Canopy Cover (Mesic-Shrub & Meadow Systems)



Mesic-Shrub & Meadow Systems	Cover (%)	<2	2 – <4	4 – <6	6 – <8	8 – <10	10 – <12	12 – <14	14 – <16	≥16
	Score	0	.2	.4	.55	.7	.79	.86	.93	1

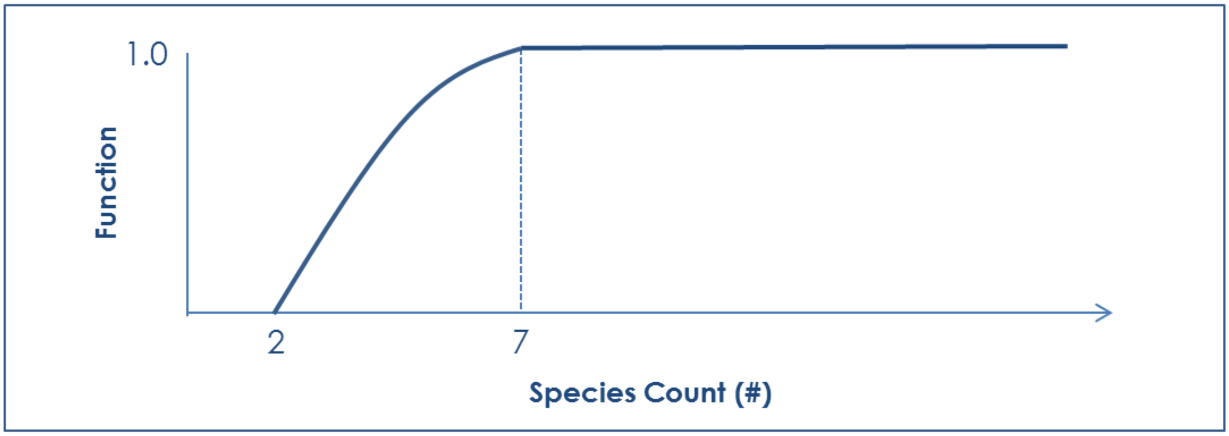
Reference: Modified from a curve created for the Colorado Greater Sage-Grouse Habitat Quantification Tool (2016), which used 20% as the minimum fully functional value and 0% as the starting value. Modified based on TRG input to reflect Table 2-6 (BLM 2013) to develop separate curves for arid-shrub conditions and mesic-shrub conditions/meadow systems. Based on Table 2-6 (BLM 2013), Casazza et al. 2011, and Lockyer et al. In Press, and TRG input modified the minimum fully functional value set to 16%. Based on TRG input, the starting value was set at 2% as some canopy cover is needed to meet the needs of sage-grouse and reflects the ability for a site to recovery after a disturbance. Curve was modified to be more linear based on unpublished data provided by J. Sedinger that showed increased nest selection preference and success related to increased forb cover in an almost linear relationship.



Arid-Shrub Conditions	Species (#)	<1	1 – <2	2 – <3	3 – <4	4 – <5	≥5
	Score	0	.3	.6	.75	.9	1

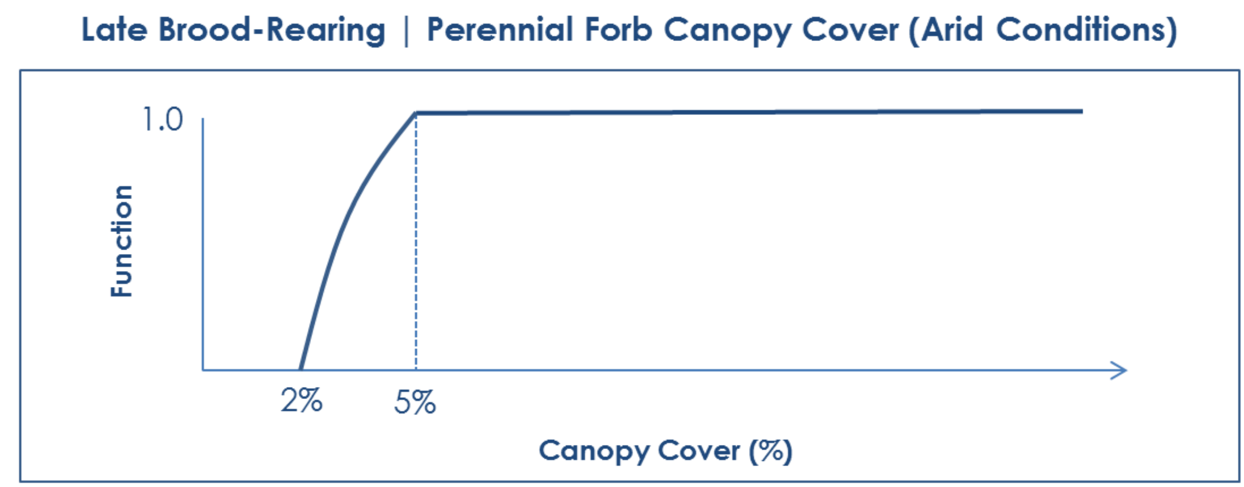
Reference: Modified from a curve created for the Colorado Greater Sage-Grouse Habitat Quantification Tool (2016), which set 8 species as the minimum fully functional value and 0 species as the starting value. Adjusted based on Casazza et al. 2011, Lockyer et al. 2012, and TRG input changing starting value to be 1 forb species as having no forbs has no value and reduced the minimum fully functional value to 5 species due to lower general forb abundance in Nevada.

Breeding | Forb Species Richness (Mesic-Shrub & Meadow Systems)



Mesic-Shrub & Meadow Systems	Species #	<2	2 – <3	3 – <4	4 – <5	5 – <6	6 – <7	≥7
	Score	0	.25	.45	.65	.8	.92	1

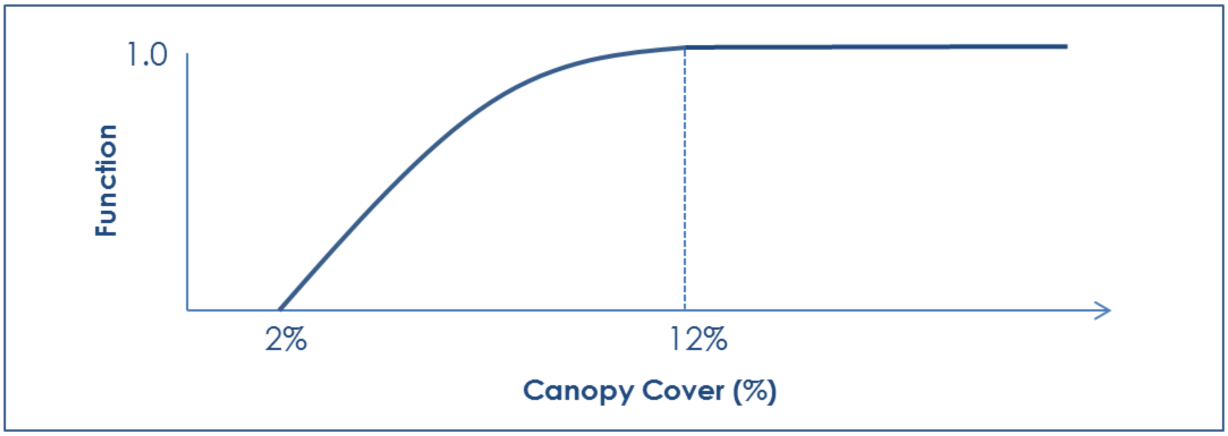
Reference: Modified from a curve created for the Colorado Greater Sage-Grouse Habitat Quantification Tool (2016), which set 12 species as the minimum fully functional value and 0 species as the starting value. Adjusted based on Casazza et al. 2011, Lockyer et al. 2012, and TRG input changing starting value to be 2 forb species as having no forbs has no value, but expectation that mesic sites should have more species than arid, and reduced minimum fully functional value to 7 due to lower general forb abundance in Nevada.



Arid-Shrub Conditions	Cover (%)	<2	2 – <3	3 – <4	4 – <5	≥5
	Score	0	0.34	0.62	0.84	1

Reference: Modified from a curve created for the Colorado Greater Sage-Grouse Habitat Quantification Tool (2016), which used 20% as the minimum fully functional value and 0% as the starting value. Modified based on TRG input to reflect Table 2-6 (BLM 2013) to develop separate curves for arid-shrub conditions and mesic-shrub conditions/meadow systems. Based on Table 2-6 (BLM 2013), Casazza et al. 2011, and Lockyer et al. 2012 modified the minimum fully functional value set to 5%. Based on TRG input, the starting value was set at 2% as some canopy cover is needed to meet the needs of sage-grouse and reflects the ability for a site to recovery after a disturbance. Curve was modified to be more linear based on unpublished data provided by J. Sedinger that showed increased nest selection preference and success related to increased forb cover in an almost linear relationship.

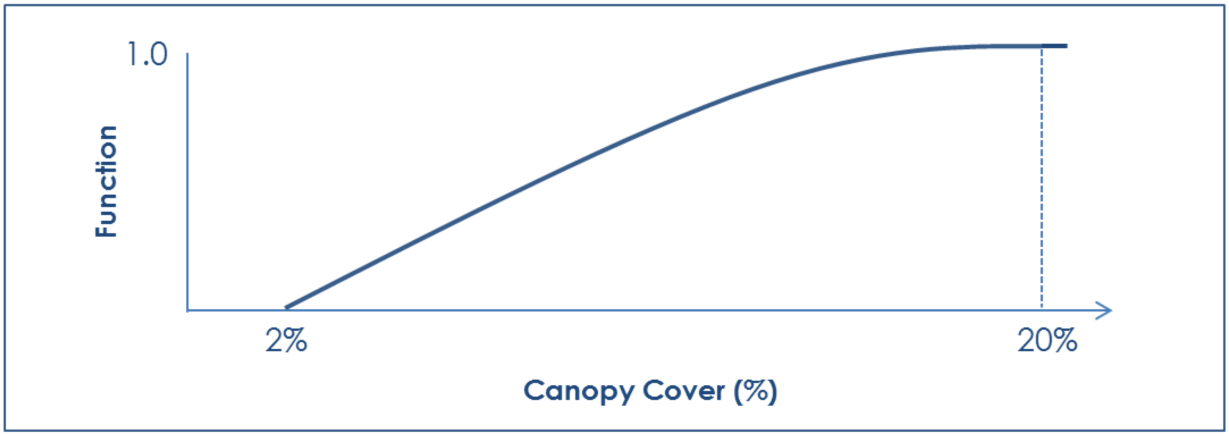
Late Brood-Rearing | Perennial Forb Canopy Cover (Mesic-Shrub Systems)



Mesic-Shrub Systems	Cover (%)	<2	2 – <4	4 – <6	6 – <8	8 – <10	10 – <12	≥12
	Score	0	.25	.45	.64	.78	.9	1

Reference: Modified from a curve created for the Colorado Greater Sage-Grouse Habitat Quantification Tool (2016), which used 20% as the minimum fully functional value and 0% as the starting value. Modified based on TRG input to reflect Table 2-6 (BLM 2013) to develop separate curves for arid-shrub conditions and mesic-shrub conditions/meadow systems. Based on Table 2-6 (BLM 2013), Casazza et al. 2011, and Lockyer et al. 2012, and TRG input modified the minimum fully functional value set to 12%. Based on TRG input, the starting value was set at 2% as some canopy cover is needed to meet the needs of sage-grouse and reflects the ability for a site to recovery after a disturbance. Curve was modified to be more linear based on unpublished data provided by J. Sedinger that showed increased nest selection preference and success related to increased forb cover in an almost linear relationship.

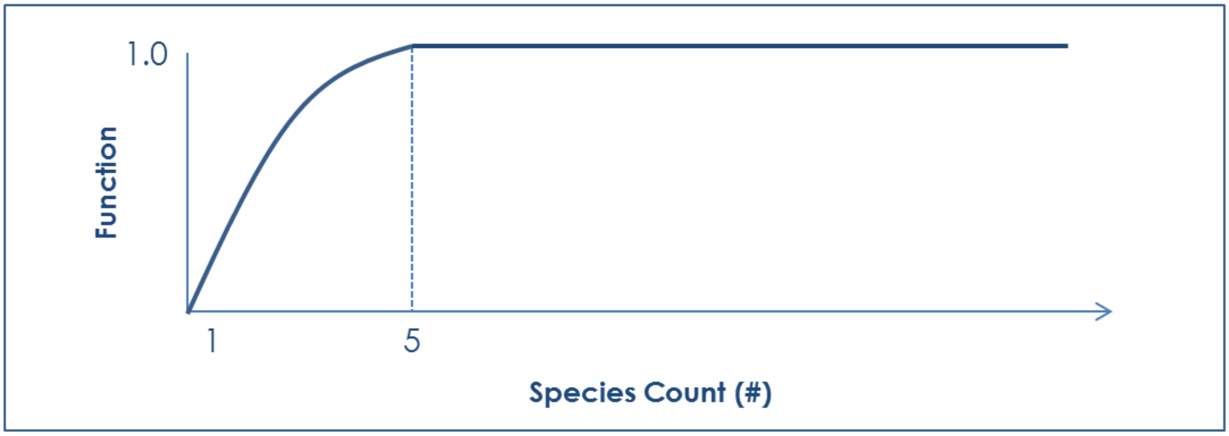
Late Brood-Rearing | Perennial Forb Canopy Cover (Meadow Systems)



Meadow Systems	Cover (%)	<5	5 – <8	8 – <10	10 – <14	14 – <16	16 – <20	≥20
	Score	0	.25	.45	.64	.78	.9	1

Reference: Modified from a curve created for the Colorado Greater Sage-Grouse Habitat Quantification Tool (2016), which used 20% as the minimum fully functional value and 0% as the starting value. Modified based on TRG input to reflect Table 2-6 (BLM 2013) to develop separate curves for arid-shrub conditions and mesic-shrub conditions/meadow systems. Based on curves for Late Brood Rearing – Perennial Forb Canopy Cover (arid-shrub and mesic-shrub conditions) and increased productivity in meadow site, TRG modified the minimum fully functional value to 20%. Based on TRG input, the starting value was set at 2% as some canopy cover is needed to meet the needs of sage-grouse and reflects the ability for a site to recovery after a disturbance. Curve was modified to be more linear based on unpublished data provided by J. Sedinger that showed increased nest selection preference and success related to increased forb cover in an almost linear relationship.

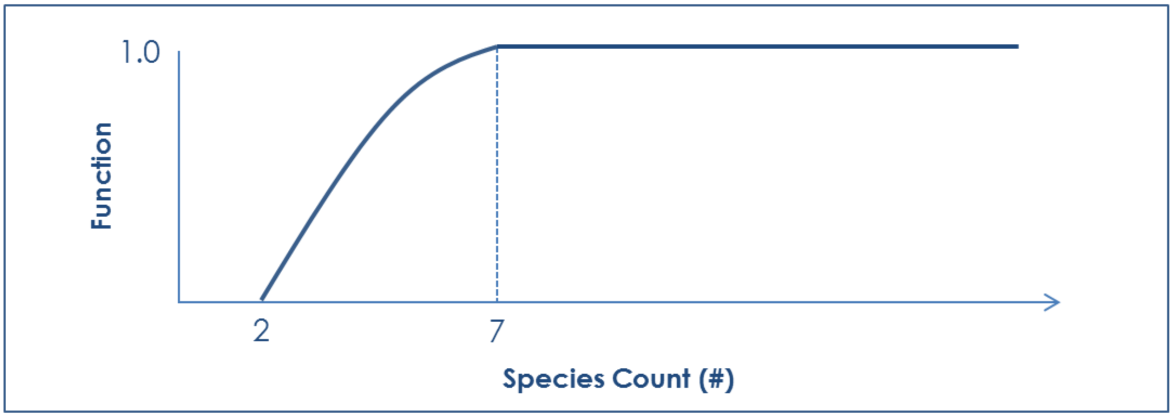
Late Brood-Rearing | Forb Species Richness (Arid Conditions)



Arid-Shrub Conditions	Species (#)	<1	1 – <2	2 – <3	3 – <4	4 – <5	≥5
	Score	0	.3	.6	.75	.9	1

Reference: Modified from a curve created for the Colorado Greater Sage-Grouse Habitat Quantification Tool (2016), which set 8 species as the minimum fully functional value and 0 species as the starting value. Adjusted based on Casazza et al. 2011, Lockyer et al. 2012, and TRG input changing starting value to be 1 forb species as having no forbs has no value and reduced the minimum fully functional value to 5 species due to lower general forb abundance in Nevada.

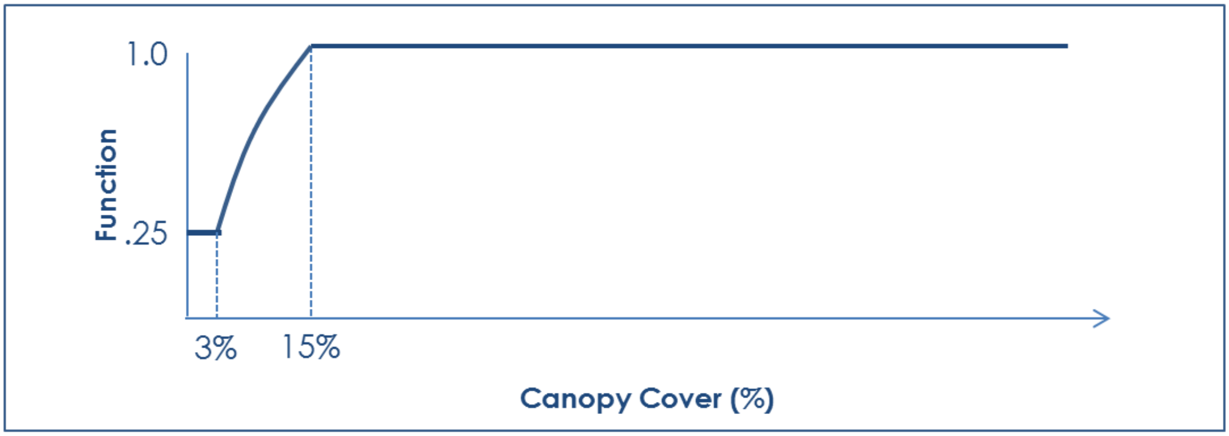
Late Brood-Rearing | Forb Species Richness (Mesic-Shrub & Meadow Systems)



Mesic-Shrub & Meadow Systems	Species #	<2	2 – <3	3 – <4	4 – <5	5 – <6	6 – <7	≥7
	Score	0	.25	.45	.65	.78	.92	1

Reference: Modified from a curve created for the Colorado Greater Sage-Grouse Habitat Quantification Tool (2016), which set 12 species as the minimum fully functional value and 0 species as the starting value. Adjusted based on Casazza et al. 2011, Lockyer et al. 2012, and TRG input changing starting value to be 2 forb species as having no forbs has no value, but expectation that mesic sites should have more species than arid, and reduced minimum fully functional value to 7 due to lower general forb abundance in Nevada.

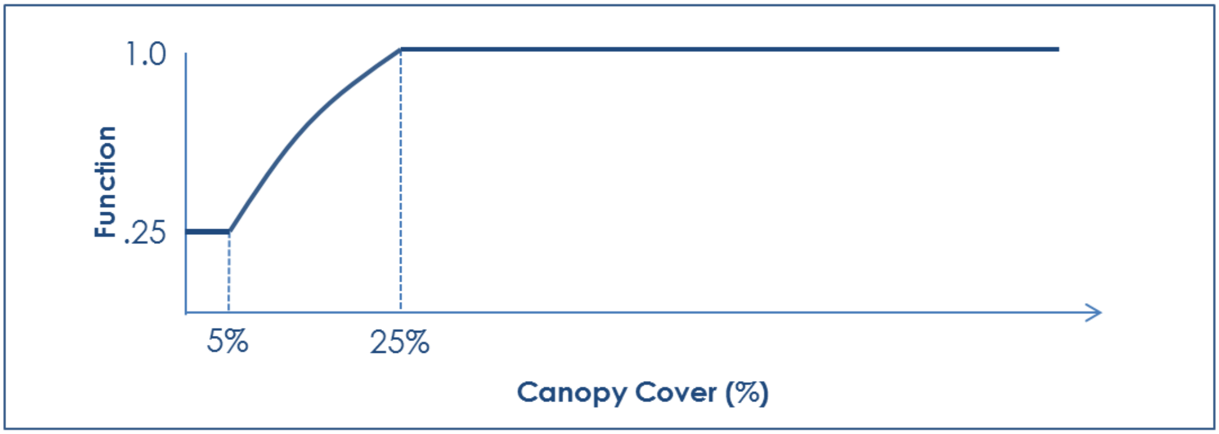
Late Brood-Rearing | Perennial Grass Canopy Cover (Arid Conditions)



Arid-Shrub Conditions	Cover (%)	<3	3 – <6	6 – <9	9 – <12	12 – <15	≥15
	Score	.25	.45	.64	.78	.92	1

Reference: Attribute included based on TRG input to reflect Table 2-6 (BLM 2013) and curved based on Connelly et al. 2000 and Hagen et al. 2007 which provided support for 15% as the minimum fully functional value. The late brood-rearing perennial grass canopy cover curve was further informed by Kirol et al. 2012, which found perennial grass cover was 17.4% in selected sites, and 12% in non-selected sites.

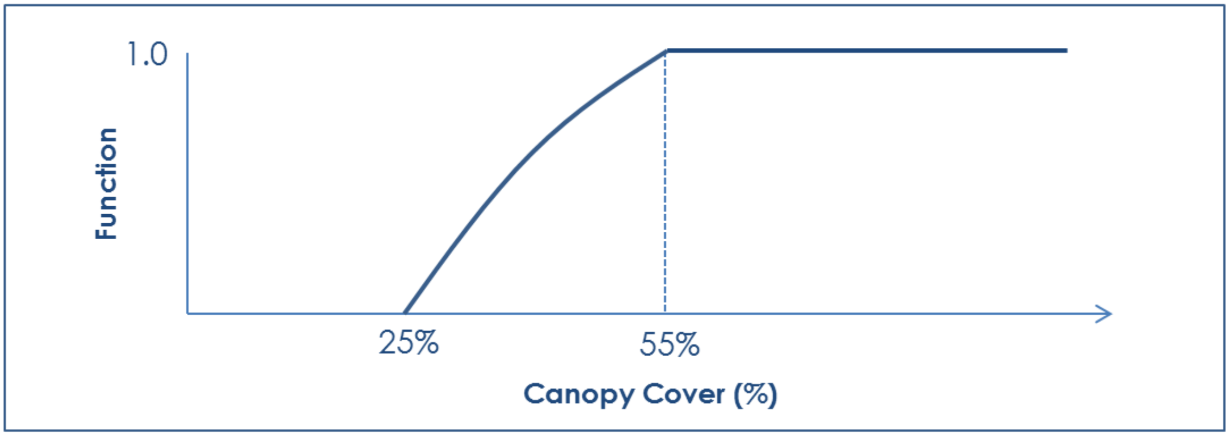
Late Brood-Rearing | Perennial Grass Canopy Cover (Mesic-Shrub Systems)



Mesic-Shrub Systems	Cover (%)	<5	5 – <10	10 – <15	15 – <20	20 – <25	≥25
	Score	.25	.45	.64	.78	.92	1

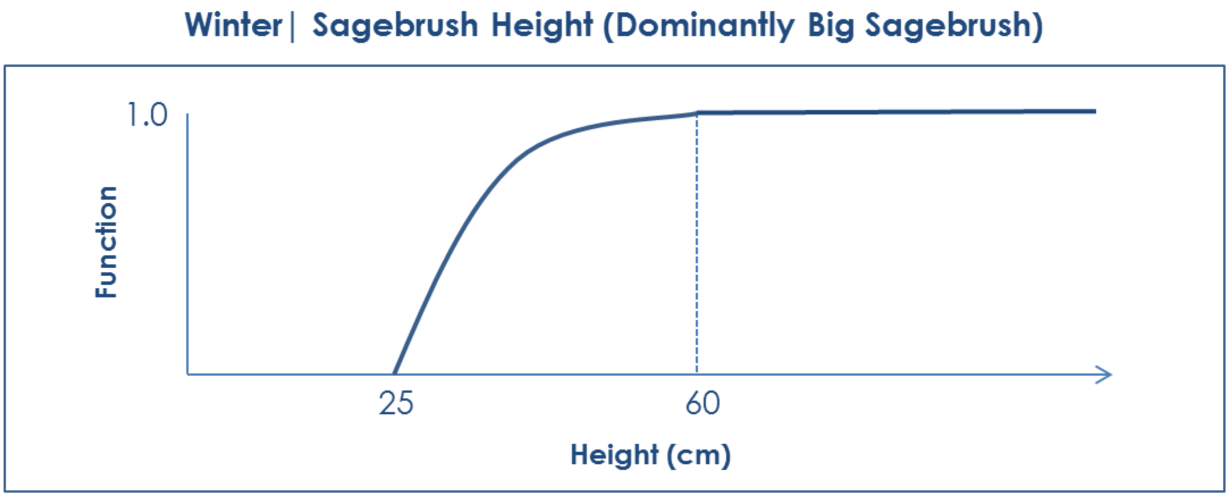
Reference: Attribute included based on TRG input to reflect Table 2-6 (BLM 2013) and curved based on Connelly et al. 2000 and Hagen et al. 2007 which provided support for 15% as the minimum fully functional value for arid sites. TRG recommended different curves for arid-shrub conditions, mesic-shrub conditions and meadow systems. Starting and minimum fully functional values for mesic-shrub conditions were increased to 25% due to higher levels of productivity.

Late Brood-Rearing | Perennial Grass Canopy Cover (Meadow Systems)



Meadow Systems	Cover (%)	<25	25 – <30	30 – <35	35 – <40	40 – <45	45 – <50	50 – <55	≥55
	Score	0	.23	.42	.58	.7	.82	.94	1

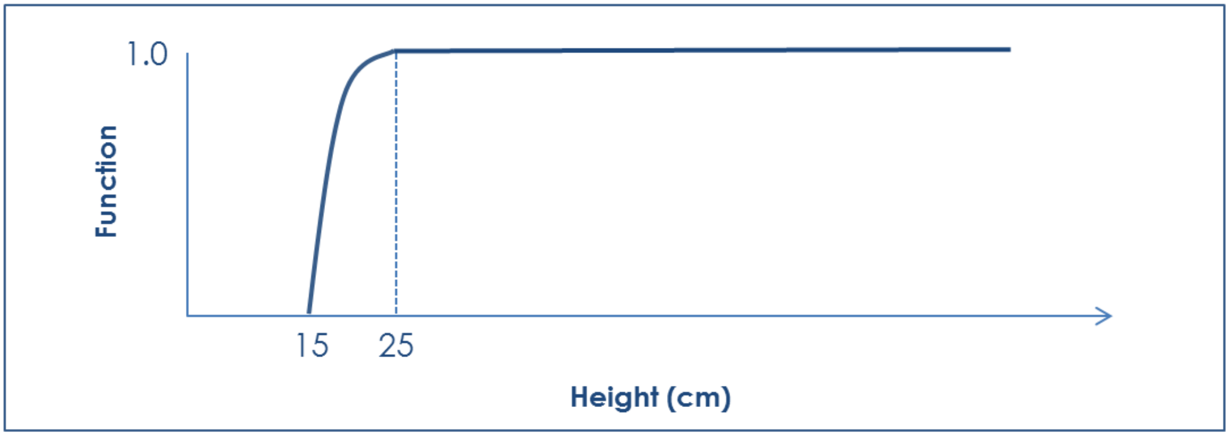
Reference: Attribute included based on TRG input to reflect Table 2-6 (BLM 2013) and curved based on Connelly et al. 2000 and Hagen et al. 2007 which provided support for 15% as the minimum fully functional value for arid sites. TRG recommended different curves for arid-shrub conditions, mesic-shrub conditions and meadow systems. Starting and minimum fully functional values for mesic-shrub conditions were increased to 55% due to higher levels of productivity.



Dominantly Big Sagebrush	Height (cm)	<25	25 – <30	30 – <35	35 – <40	40 – <45	45 – <50	50 – <55	55 – <60	≥60
	Score	0	.2	.4	.55	.62	0.68	.84	.92	1

Reference: Modified from a curve created for the Colorado Greater Sage-Grouse Habitat Quantification Tool (2016), which set the minimum fully functional value at 15.7 inches (40 centimeters) and the starting point at 7.87 inches (20 centimeters) for slope < 5%, and 7.87 inches (20 centimeters as the minimum fully functional value and 3.94 inches (10 centimeters) as the starting point for slope > 5%. TRG input developed different curves for different sagebrush systems (big sage versus low/black sage), instead of differentiating by slope and aspect and mesic vs. arid, as this is less complicated to determine and likely to be more reflective of sagebrush heights snow levels given different inherent size of sagebrush species and snow depths relative to sagebrush/ species communities. For big sagebrush species, TRG modified the minimum fully functional value to 23.6 inches (60 centimeters) to focus conservation of winter sites in areas that are key during heavy winters and that Connelly et al. 2000 recommendation of 9.84 inches (25 centimeters) *above snow level*, but that measurements for the Nevada Credit System will be occurring when there is no snow.

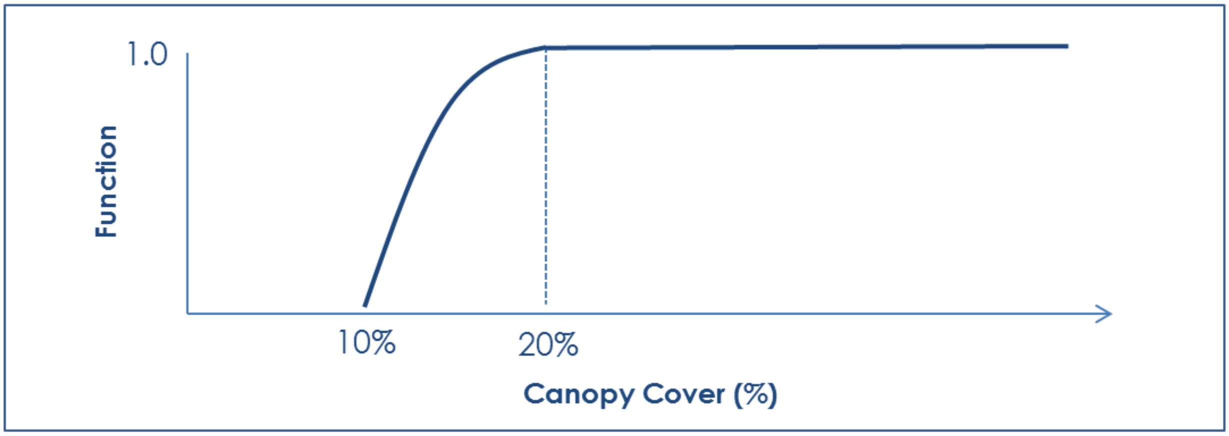
Winter | Sagebrush Height (Dominantly Low or Black Sagebrush)



Dominantly Low or Black Sagebrush	Height (cm)	<15	15 – <17	17 – <19	19 – <21	21 – <23	23 – <25	≥25
	Score	0	.25	.45	.6	.75	.9	1

Reference: Modified from a curve created for the Colorado Greater Sage-Grouse Habitat Quantification Tool (2016), which set the minimum fully functional value at 15.7 inches (40 centimeters) and the starting point at 7.87 inches (20 centimeters) for slope < 5%, and 7.87 inches (20 centimeters) as the minimum fully functional value and 3.94 inches (10 centimeters) as the starting point for slope > 5%. TRG input developed different curves for different sagebrush systems (big sage versus low/black sage), instead of differentiating by slope and aspect and mesic vs. arid, as this is less complicated to determine and likely to be more reflective of sagebrush heights snow levels given different inherent size of sagebrush species and snow depths relative to sagebrush/ species communities. This is lower than big sagebrush communities curve because of the inherently shorter stature of low/black sagebrush communities and that snow generally does not last as long (wind, solar radiation) in these communities as in big sagebrush communities.

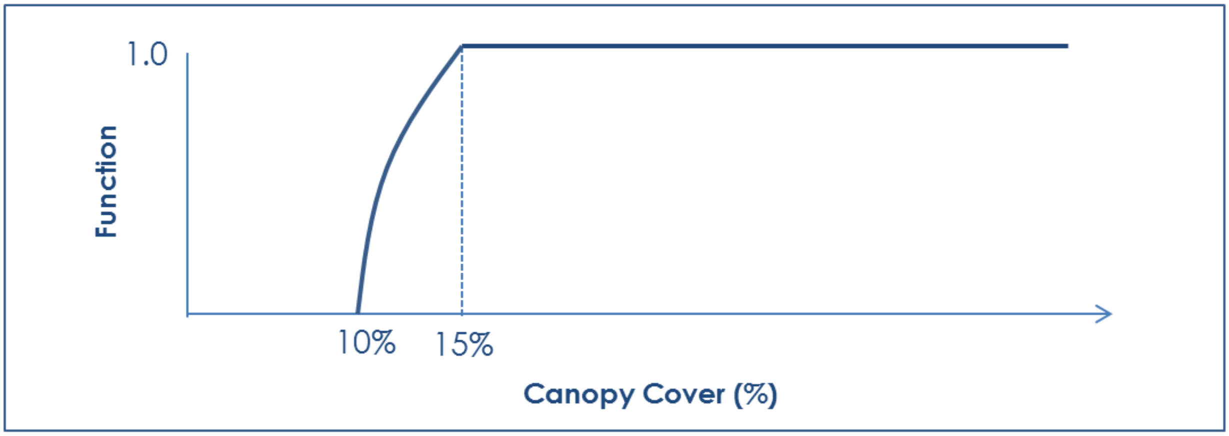
Winter | Sagebrush Canopy Cover (Dominantly Big Sagebrush)



Dominantly Big Sagebrush	Cover (%)	<10	10 – <12	12 – <14	14 – <16	16 – <18	18 – <20	≥20
	Score	0	.3	.55	.75	.88	.95	1

Reference: Modified from a curve created for the Colorado Greater Sage-Grouse Habitat Quantification Tool (2016), which set the minimum fully functional value at 30% and the starting value at 20%. TRG input developed different curves for different sagebrush systems (big sage versus low/black sage), instead of differentiating by slope and aspect and mesic vs. arid, as this is less complicated to determine and likely to be more reflective of sagebrush canopy cover above snow levels given different inherent size of sagebrush species and snow depths relative to sagebrush/ species communities. For big sagebrush species, TRG input kept same value as Colorado Habitat Exchanged and justified that based on Connelly et al. 2000 recommendation of 10% *above snow level*, but that measurements for the Nevada Credit System will be occurring when there is no snow.

Winter | Sagebrush Canopy Cover (Dominantly Low or Black Sagebrush)



Dominantly Low or Black Sagebrush	Cover (%)	<10	10 – <11	11 – <12	12 – <13	13 – <14	14 – <15	≥15
	Score	0	.3	.55	.75	.88	.95	1

Reference: Modified from a curve created for the Colorado Greater Sage-Grouse Habitat Quantification Tool (2016), which set the minimum fully functional value at 30% and the starting value at 20%. TRG input developed different curves for different sagebrush systems (big sage versus low/black sage), instead of differentiating by slope and aspect and mesic vs. arid, as this is less complicated to determine and likely to be more reflective of sagebrush canopy cover above snow levels given different inherent size of sage species and snow depths relative to sage species communities. For low/black sagebrush species, TRG input moved the minimum fully functional value to 15% based on Connelly et al. 2000 recommendation of 10% *above snow level*, but that measurements for the Nevada Credit System will be occurring when there is no snow. This is lower than big sagebrush communities curve because in low/black sagebrush communities snow generally does not last as long (wind, solar radiation) as in big sagebrush communities.

APPENDIX B. MONITORING AND ADAPTIVE MANAGEMENT

This section is divided into two subsections: Tool Evaluation and Credit System Management System. The descriptions provided here represent only guidelines for monitoring and adaptive management and not a *plan* for carrying out these activities. Monitoring should be highly coordinated with federal land agency monitoring efforts.

TOOL EVALUATION

Tool evaluation is defined as collection and analysis of data that pertains to the functionality and performance of the HQT. In particular, tool evaluation is concerned with: 1) Accuracy of the scores in measuring real and expected outcomes; 2) Utility (ease of use, efficiency, and cost) for a variety of users; 3) Repeatability of scores from one user to the next; and 4) Reliability of scores over time.

CREDIT SYSTEM MANAGEMENT SYSTEM

The Credit System Management System is a formal, structured programmatic adaptive management approach to dealing with uncertainty in natural resources management, using the experience of management and the results of research as an ongoing feedback loop for continuous improvement. The Credit System Management System requires an ongoing flow of information from 1) research and monitoring activities conducted by scientists, 2) the practical experiences of Credit Developers and Buyers, and 3) changing context from stakeholders to inform Credit System improvements. A systematic and transparent decision making process ensures that improvements to the Credit System do not cause uncertainty for participants. Figure 20 provides an overview of the Credit System Management System steps[4].

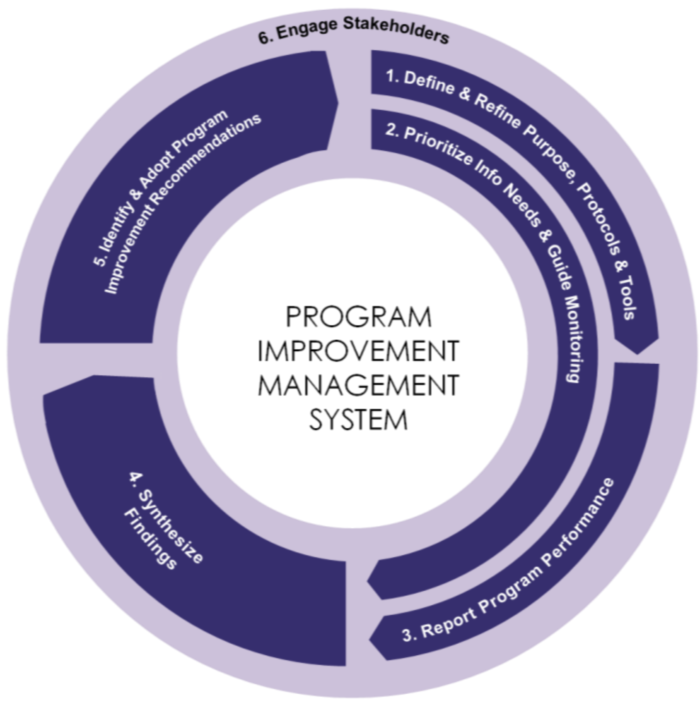


Figure 20. Steps in the Credit System Adaptive Management Process

Adaptive management is used in the Credit System Management System to refine and update the HQT over time. In other words, none of the content or components of the HQT are meant to be static in time, rather the HQT is intended to evolve over time as needed according to new science and monitoring. The

[4] This management process has been adapted from The Conservation Measures Partnership's Open Standards for the Practice of Conservation, which can be found at www.conservationmeasures.org. Significant changes were made to adapt the Open Standards to 1) a market context where individual projects are selected and implemented by individual market participants and 2) be a formally governed process that balances the needs for improvements with the needs to limit market uncertainty for all participants.

goal of adaptive management for the HQT is to make periodic changes that keep it up to date with the current state of ecological knowledge.

As specified in the Credit System Manual, the Credit System Administrator performs the day-to-day functions to manage the Credit System. The Administrator is accountable to the Oversight Committee (Sagebrush Ecosystem Council), which approves all changes to the Credit System Manual, HQT and other tools.

The Administrator convenes a Science Committee consisting of expert scientists to inform the development and revisions of technical decisions, products and tools, like the HQT. The Science Committee meets periodically to review and evaluate new information including new research on the species biology or ecology, new or changing threats to the species, recent substantial gains or losses of habitat for the species, and the establishment of new protected areas. The Science Committee then makes recommendations to the Credit System Administrator, based on the best-available science regarding the greater sage-grouse and sagebrush ecosystems. This review and evaluation process is also used to assess the overall status of the covered species, Credit System implementation and progress, and whether any adjustments are needed to the products and tools in order to further ensure conservation benefits to the species.

The Administrator decides whether any specific modifications are necessary according to Science Committee recommendations, and then the Administrator makes a recommendation regarding such modifications to the Oversight Committee. The Oversight Committee confers about the Science Committee's findings and Administrator's recommendations. Any modifications to the HQT are not applied retroactively.

APPENDIX C. HQT DEVELOPMENT AND REVIEW

The HQT is the scientific underpinning of the Credit System. It is the approach to measure impacts and benefits, and is based on science. Science-related elements of the Credit System that are not entirely based on science (e.g. mitigation ratio factor related to the proximity of credits and debits) are defined in the Credit System Manual. The credibility of the Credit System and its effectiveness in generating net benefit for the species hinges upon the quality of the science upon which it is based and the integrity with which it is applied. It is therefore important to maintain the scientific integrity of the HQT over time as new science and implementation monitoring becomes available.

The HQT is not static. It is a working document that changes over time through the development and review processes outlined below as new scientific information becomes available. Transparent, fair, and consistent review processes are essential to ensure that the best and most recent scientific information is used incorporated over time.

Like any significant change to the Credit System, and changes to the HQT are under the control of the Oversight Committee, and the Administrator according to Credit System Management System . As such, the Administrator oversees the process of development and review, and the Oversight Committee approves all changes to the HQT.

INTERNAL DEVELOPMENT AND REVIEW

Internal Development

Internal development of the HQT is conducted by the Administrator in collaboration with consultants. Tasks associated with development include reviewing and compiling scientific information, developing concept models and scoring curves, and writing the HQT documents. While the HQT is in the development stage, decision-making and control over the content of the HQT is the responsibility of the Administrator. Members of the Administrator should declare any real or perceived conflict of interest with stakeholders, including offers or acceptance of funding.

Internal Review

Internal review is conducted by official members of the Technical Review Group. During internal review, members of the Technical Review Group are given the first opportunity to provide comments on the HQT. Internal review comments from the Technical Review Group adhere to the following format and principles:

- Confidential – internal reviewers may not share the draft HQT with any non-official members of the group at this stage, unless those persons are experts or consultants within their own organizations.
- Constructive, practical, and cooperative – we expect comments to come from a positive spirit of cooperation, to improve the potential for the Credit System to meet its goals in a practical manner.
- Documented – all comments must be referenced and supported by scientific support (e.g. peer-reviewed research), independent analysis, expert opinion with a citation of "personal communication," and/or a thorough, clear rationale. Reviewers clearly state the source of documentation they are using. General preferences and opinions are useful and welcomed, but may not be sufficient for incorporation into the HQT. All committee participants are listed by name unless they request to remain anonymous, in which case they are acknowledged as an "anonymous reviewer."

Annual Improvement

Annual improvement of the HQT is conducted by the Administrator with the Sagebrush Ecosystem Council. The Sagebrush Ecosystem Council will determine, with suggestion from the Sagebrush Ecosystem Technical Team, whether the TRG is needed to develop changes to the HQT. Tasks associated with annual improvement include reviewing and compiling newly published scientific information, conducting research and monitoring, and revising HQT documents. While the HQT is in the annual improvement stage, decision-making and control over the content of the HQT is the responsibility of the Administrator. Members of the Administrator should declare any real or perceived conflict of interest with stakeholders, including offers or acceptance of funding.

APPENDIX D. SAGE-GROUSE RESPONSE TO ANTHROPOGENIC DISTURBANCE LITERATURE REVIEW

DISTANCE TO ENERGY DEVELOPMENT

Researchers have reported indirect effects associated with the infrastructure of energy fields whereby sage-grouse on leks are negatively influenced to a greater extent if infrastructure is placed near the lek, with the response diminishing as distances from lek to infrastructure increase (Manier et al. 2013). Additionally, the distance-effect of infrastructure with higher levels of human activity may be larger than that of infrastructure with lower levels of activity. Harju et al. (2010) reported that impacts to lekking sage-grouse of well pads located at shorter distances to leks were more consistently observed across energy fields compared to well pads at longer distances. There was a consistent pattern whereby the presence of well pads within smaller radii buffers (< 0.99 – 1.24 miles (<1.6 - 2 kilometers)) around leks in extensively developed areas was associated with 35-76% fewer sage-grouse males on leks compared to leks with no well pads within these radii (Harju et al. 2010). Walker et al. (2007) found a strong negative effect of infrastructure within 0.50 and 1.99 miles (0.8 and 3.2 kilometers) of leks on lek persistence, with lesser impacts to lek persistence apparent at 3.98 miles (6.4 kilometers). Holloran (2005) reported that impacts of development to the number of males occupying leks were greatest when infrastructure was located near the lek and attendance declined approximately 75% within 1 km of a major haul road, but that impacts were discernable to 1.86 miles (3 kilometers) for lower activity sites (producing well pads) and 3.73 miles (6 kilometers) for higher activity sites (drilling rigs). Johnson et al. (2011) reported negative lek trends for leks within approximately 2.49 miles (4 kilometers) of a producing well pad across the range of the species. Additionally, distance effects of infrastructure have been noted for other seasonal periods. Carpenter et al. (2010) found that sage-grouse avoided habitats within 1.18 miles (1.9 kilometers) of infrastructure during the winter. Holloran et al. (2010) reported that yearling females avoided nesting within 3,116.8 feet (950 meter) of well pads. Annual survival of sage-grouse chicks reared near gas field infrastructure was lower than those reared away from infrastructure, and the probability of male chicks reared near infrastructure establishing a breeding territory as a yearling was half that of male chicks reared away from infrastructure (Holloran et al. 2010). Dzialak et al. (2011) reported that the closer a nest was to a natural gas well (that existed or was installed in the previous year), the more likely it was to fail. LeBeau et al. (*In Press*) reported that the risk of a nest or a brood failing decreased by 7.1% and 38.1%, respectively, with every 0.62 mile (1 kilometer) increase in distance from the nearest wind turbine; however, no variation in female survival was detected relative to wind energy infrastructure.

Manier et al. 2014 completed a synthesis analysis that identified literature minimum and maximum distance effects for six categories of anthropogenic land use and activity. From these they developed interpreted ranges that indicate a generalized effect area that are capped by diminishing gains analysis. For energy development, the literature minimum is 3.2 km (2 mi) (Naugle et al. 2011), literature maximum is 20 km (12.4 mi) (Johnson et al. 2011), and interpreted range is 5 km (3.1 mi) to 8 km (5 mi).

DENSITY OF ENERGY DEVELOPMENT

Substantial amounts of research suggest that increased infrastructure densities around leks will negatively influence sage-grouse. Harju et al. (2010) reported that well pad densities of 4 and 8 pads/section (square mile) within 5.28 miles (8.5 kilometers) of leks were associated with lek count declines ranging from 13-74% and 77-79%, respectively. Doherty et al. (2010a) reported that impacts to leks were indiscernible at well pad densities at or below 1 pad/section within 1.99 miles (3.2 kilometers) of leks, but that lek loss and declines in numbers of males on leks increased at greater pad densities. Holloran (2005) reported that well densities exceeding 1 well/section within 1.86 miles (3 kilometers) of leks negatively influenced male lek attendance. Hess and Beck (2012) reported 0% probability of lek occurrence in areas with well pad densities exceeding 6.5 pads/section within 0.62 miles (1 kilometer). Tack (2009) reported that larger leks (>25 males) did not occur in areas where well pad densities exceeded 2.5 pads/section within 7.64 miles (12.3 kilometers) of a lek. Johnson et al. (2011) found a generally negative trend in lek counts as numbers of producing wells increased within 3.11 and 11.18 miles (5 and 18 kilometers) of leks. Kirol (2012) reported that females avoided nesting and rearing broods in areas with increased numbers of visible wells within a 0.62 square mile (1 square kilometer) area. Aldridge and Boyce (2007) reported that chick survival decreased with increasing numbers of visible wells within 0.62 mile (1 kilometer) of brood-rearing locations. Doherty et al. (2008) found that sage-grouse were 1.3 times more likely to occupy suitable winter habitats with no gas field infrastructure within a 2.49 square mile (4 square kilometer) area compared to areas with 12.3 pads (8 pads/section).

MINING

The specific impacts of mining on sage-grouse and their habitat have not been studied in the peer reviewed literature (Manier 2013). However, mining and its associated facilities and infrastructure result in habitat fragmentation, direct habitat loss, and indirect impacts decreasing the suitability of otherwise suitable habitat (USFWS 2013). Manier et al. 2014 found for surface disturbances a literature minimum of 3.2 km (2 mi) (Holloran and Anderson 2005), literature maximum is 20 km (12.4 mi) (Johnson et al. 2011), and interpreted range is 5 km (3.1 mi) to 8 km (5 mi). For activities, the literature minimum is 400 m (0.12 mi) (Blickley et al. 2012), literature maximum is 4.8 km (3 mi) (Nevada Governor's Sage-grouse Conservation Team 2010), and interpreted range is 400 m (0.12 mi) to 4.8 km (3 mi).

The magnitude of the impacts of mining activities on sage-grouse and sagebrush habitats is largely un-quantified (Braun 1998). Development of surface mines and associated infrastructure (e.g., roads and power lines), noise and human activity negatively impact sage-grouse numbers in the short term (Braun 1998). The number of displaying sage-grouse on two leks within 1.24 miles (2 kilometers) of active coal mines in northern Colorado declined by approximately 94% over a 5-year period following an increase in mining activity (Remington and Braun 1991). However, Braun (1998) reports that studies in Montana, Wyoming and Colorado suggest that some recovery of populations occurred after initial development and subsequent reclamation of mine sites, although populations did not recover to pre-development sizes. Additionally, population re-establishment may take upwards of 30 years (Braun 1998).

NOISE

Blickley et al. (2012) report that peak male attendance (i.e., abundance) at leks experimentally treated with noise recorded at roads in a natural gas field decreased 73% relative to paired controls. The authors reported that the intermittent nature of noise from roads impacted male sage-grouse to a greater degree than more constant noise as that from a drilling rig; peak male attendance at leks treated with noise from natural gas drilling rigs decreased 29% relative to paired controls (Blickley et al. 2012).

Noise is not directly addressed in the HQT. However, the potential differential effects of noise on sage-grouse relative to activity levels associated with infrastructure are accounted for in the indirect effects, and associated response curves, used to establish the anthropogenic disturbances distances and weights.

ROADS

Sage-grouse avoidance of high-activity roads is well documented. Connelly et al. (2004) found that no leks occurred within 1.24 miles (2 kilometers) of interstate 80, there were fewer leks within 4.66 miles (7.5 kilometers) than within 9.32 miles (15 kilometers) of the interstate, and there were higher rates of decline in lek counts between 1970 and 2003 on leks located within 4.66 miles (7.5 kilometers) compared to beyond 4.66 miles (7.5 kilometers) of the interstate. Knick et al. (2013) reported that high habitat suitability was associated with <0.62 miles/square mile (<1.0 kilometers/square kilometer) of secondary roads, 0.03 miles/square mile (0.05 kilometers/square kilometer of highways, and 0.0062 miles/square mile (0.01 kilometers/square kilometer of interstate highways within 3.1 miles (5-kilometer) radius areas. LeBeau (2012) found that sage-grouse avoided nesting and summering near major roads (e.g., paved secondary highways). Tack (2009) found negative relationships with more roads around leks at all levels of lek attendance, but impacts were greatest for larger leks (>25 males); the probability of occurrence of a large lek was 50% with road densities of approximately 15.5 miles (25 kilometers) of road within 1.99 miles (3.2 kilometers) of a lek. Dzialak et al. (2012) documented sage-grouse during the winter avoiding haul roads associated with natural gas development. In contrast, Johnson et al. (2011) found negative trends in counts of males on leks throughout the range of the species with increasing distance to interstate highway—although few leks occurred near interstates; relatively consistent slight negative trends in lek counts with distance to highways; and no relationship between distance to secondary roads and lek trends. Road densities within 3.1 miles (5 kilometers) radii of leks suggested similar relationships by road category (Johnson et al. 2011).

Manier et al. 2014 found for linear features a literature minimum of 400 m (0.25 mi) (Blickley et al. 2012), literature maximum is 18 km (11.2 mi) (Johnson et al. 2011), and interpreted range is 5 km (3.1 mi) to 8 km (5 mi).

TRAFFIC

Remington and Braun (1991) reported that the upgrade of a haul road accessing a coal mine was correlated with a 94% decline in the number of sage-grouse on leks <1.24 miles (<2 kilometers) from the road over a 5-year period; traffic speed was not measured but the potential for increased speed was inferred from upgraded road surface. Holloran (2005) reported that declines in lek counts on leks within 1.86 miles (3 kilometers) of roads were positively correlated with increased traffic volumes and that vehicle activity on roads within 1.86 miles (3 kilometers) of leks during the time of day sage-grouse were present on leks influenced the number of males on leks more negatively than leks where roads within 1.86 miles (3 kilometers) had no vehicle activity during the strutting period. Lyon and Anderson (2003) reported that traffic disturbance (1 to 12 vehicles/day) within 1.86 miles (3 kilometers) of leks during the breeding season reduced nest-initiation rates and increased distances moved from leks during nest site selection of female sage-grouse breeding on those leks. Blickley et al. (2012) report that peak male attendance (i.e., abundance) at leks experimentally treated with noise recorded at roads in a natural gas field decreased 73% relative to paired controls; the authors found that the intermittent nature of noise from roads impacted male sage-grouse to a greater degree than more constant noise, such as that from a drilling rig.

TRANSMISSION AND POWERLINES

Results of sage-grouse research related to the development of the 345 kV Falcon to Gonder (FG) transmission line in Eureka County, NV has recently been synthesized and published (Gibson et al., 2018). This is the only study on sage-grouse to focus exclusively on powerlines and no previous study that has assessed impacts of powerlines has controlled for confounding effects of environmental variability, which was achieved due to the 10 year study period, large sample sizes of sage-grouse locations and habitat measurement sites, and statistical analyses that isolated transmission line effects from other variables (e.g. habitat quality). The conclusions of this study tie an increase in ravens in the study area as causal factor related to avoidance of powerlines and decreased sage-grouse vital rates in the study area. The greatest driving factor behind the effects of powerlines is raven abundance. In years with more ravens (increased over time), the response was stronger. Nests located 12.5 km from the line had 0.06 to 0.14 higher probabilities of hatching compared to nests within 1 km of the line during years of average to high raven abundance. Gibson et al. (2018) also found that leks located 5 km from the line had a 0.02 to 0.16 higher rates of population growth compared to leks within 1 km of the line in years of average to high raven abundance. In addition, there was also support for downward trends in other vital rates including pre-fledgling chick survival, male survival, per capita recruitment, and population growth. Habitat avoidance from any power line was observed within 10 km and demographic suppression from the 345 kV Falcon-Gondor (FG) line was observed up to 12.5 km; these effects combined ultimately resulted in an overall negative association between the FG line and population growth rates to at least 5 km from the line.

Increases in raven abundance have been well documented across the west in relation to anthropogenic subsidies (i.e. landfills, road kill) and infrastructure, including transmission lines (Engel et al., 1992, Knight and Kawashima 1993, Knight et al. 1995, Kristan and Boarman 2007, Steenhof et al. 1993, Webb et al. 2004). Recent studies have provided additional support for the influence of transmission lines on raven occupancy and abundance. Coates et al. (2014b) found that the probability of a raven nesting on anthropogenic structures was 80%, which consisted of transmission lines (53%), cooling towers, single radio-communication and cell towers (16.5%), and nesting platforms (4.1%). Bui et al. (2010) observed the probability of nesting ravens across two study sites in Wyoming ranged from 78% - 98% (90% average) within 400m of oil development, urban areas, and roads. Coates et al. (2014c) observed effects of raven abundance in relation to powerlines out to 27 km; however the probability of raven occurrence in relation to transmission lines had the most significant effect within approximately 2km of transmission lines, after which the impact was reduced substantially.

Ravens have also been identified as the primary nest predator of sage-grouse using nest videography in Nevada (Coates and Delehanty 2010, Coates et al. 2008, Lockyer et al. 2013). Bui et al. (2010) determined that sage-grouse nest survival in a Wyoming study was more affected by raven occupancy (e.g. resident nesting, territorial pairs) than raven density (e.g. non-territorial, nomadic individuals). These results suggest that breeding resident ravens were responsible for the majority of sage-grouse nest depredations and negatively affected local breeding population productivity in this study.

Knick et al. (2013) reported that leks were absent from 3.11 miles (5 kilometers) radius areas where transmission line and major power line densities exceeded 0.124 miles/square mile (0.20 kilometers/square kilometer). Wisdom et al. (2011) found that the mean distance to transmission lines using historical sage-grouse locations in extirpated range was approximately 6km compared to 15km for historical locations in currently occupied range. In other words, historical sage-grouse locations within 6km of transmission lines are now extirpated. LeBeau (2012) reported that sage-grouse avoided habitats within 2.92 miles (4.7 kilometers) of transmission lines during brood-rearing, and that the probability of nest success and probability of female survival increased as distance to transmission line increased; but it is worth noting that the author found that brood-rearing and nesting sage-grouse selected habitats nearer transmission lines in the control study area. Walker et al. (2007) reported that the probability of lek persistence decreased with proximity to power lines and with increasing proportion of power lines within a 3.98 miles (6.4 kilometers) window around leks; but it is worth noting that distances to power line and power line densities as covariates were highly correlated with other gas development infrastructure covariates examined on the study site, and were not as good as predictors as gas wells. Dinkins et al. (2012) found evidence that female sage-grouse selected nest sites that had lower densities of ravens and raptors compared to random locations.

Other cited studies that may provide evidence of impacts of tall structures on sage-grouse include the following: Braun (1998) reported that sage-grouse avoided habitats within 1,968.5 feet (600 meters) of transmission lines, but results were based on unpublished pellet survey data; Gillian et al (2013) observed sage-grouse avoidance within 600m of transmission lines; and Hansen et al. (2013) showed that sage-grouse winter home ranges were negatively influenced by the presence of high voltage (345-500kv) transmission lines. Beck et al. (2006) reported that collisions with power lines accounted for 33% of juvenile sage-grouse winter mortality, but only 2 juvenile grouse were killed by running into power lines. Gibson et al. 2013 and Gibson et al. (*In Review*) reported a negative effect of transmission line proximity on nest success for nests in high quality habitats and a negative effect of proximity to the line on female survival for females with generally lower survival. They did not find an avoidance of transmission lines by either males or females, but did find demographic effects.

Manier et al. 2014 found for surface disturbances a literature minimum of 1 km (0.6 mi) (Howe et al. 2014), literature maximum is 18 km (11.2 mi) (Johnson et al. 2011), and interpreted range is 3.3 km 2 mi) to 8 km (5 mi). This synthesis did not include the results of Gibson et al. (*In Review*).

Data from Wells Rural Electric Association (WREA) has provided data to allow further categorization of powerline subtypes. WREA data included nest observations associated with pole types (e.g. single pole, one cross arm, double cross arm, single or three phase, etc). The SETT was able to compile average number of nests per km of line within the WREA service area. WREA services 1,123 miles of single and three phase line and recorded 236 nests on those lines. An analysis of nests per structure type resulted in 11.2 nests per 100 miles of line for single phase and 34.7 nests per 100 miles of line for three phase, which is a 210% increase in frequency of nests on three phase compared to single phase. Single phase lines are all single poles with no cross arms (excluding transformers associated with single phase).

When three phase lines were further divided by structure type, there were differences among cross arm types. Single cross arm poles had a total of 9.6 nests per 100 miles of line and double cross arm poles had 24.7 nests per 100 miles of line. Single cross arm poles actually had a lower nesting frequency than single phase; however, all of single phase includes transformers, which attract nesting raptors and ravens. The double cross arm design had a 158% increase in nesting frequency compared to the single cross arm structure.

TOWERS

Despite low numbers of communication towers across the sagebrush biome, sage-grouse lek trends across the range of the species generally decreased with distance to nearest communication tower and generally decreased with increasing numbers of towers within 3.11 miles (5 km) and 11.18 miles (18 kilometers) of leks (Johnson et al. 2011). The authors surmised that the response of sage-grouse to communication towers may be correlative with human development in general as these types of towers tend to be concentrated along major roadways and near urban centers; however, with the increase in these types of structures throughout the sagebrush biome (e.g., meteorological towers at proposed wind developments), it is worth considering the documented effects. Wisdom et al. (2011) found that the mean distance to cell towers using historical sage-grouse locations in extirpated range was approximately 12km compared to 21km for historical locations in currently occupied range.

In addition, more evidence indicates that impacts on sage-grouse from tall structures such as powerlines and other human infrastructure is due to predation from ravens and level of impact is relative to raven abundance (Bui et al. 2010, Coates and Delehanty 2010, Dinkins et al. 2012, Coates et al. 2014b, Gibson et al., 2016).

URBAN DEVELOPMENT

Urban areas by themselves remove habitat and present inhospitable environments for sage-grouse, but the physical boundaries of cities are small relative to the total sagebrush area. However, people in cities require resources from surrounding areas, and the connecting roads, railways, power lines and communications corridors exert a greater influence on sagebrush habitats (Connelly et al. 2004). Additionally, recreation, including hiking, hunting and fishing, and off-highway vehicle use in areas surrounding urban centers can negatively influence sage-grouse through habitat loss and fragmentation, facilitation of exotic plant spread, animal displacement or avoidance, establishment of population barriers, or increased human-wildlife encounters that increase wildlife mortality (Connelly et al. 2004). Across the sage-grouse range, lek count trends were lower when human-footprint scores exceeded 2 at leks, or when median scores exceeded 3 within either 3.11 miles (5 kilometers) or 11.2 miles (18 kilometers) of a lek (Johnson et al. 2011). The human-footprint index was a measure of the totality of direct anthropogenic features – including human habitation, highways and roads, railroads, power lines, agricultural lands, campgrounds, rest stops, landfills, oil and gas developments, and human-induced fires – on a landscape expressed on a 1 to 10 scale (Johnson et al. 2011). Wisdom et al. (2011) reported that human density was 26 times lower in occupied sage-grouse range compared to historically occupied but currently extirpated range. Aldridge and Boyce (2007) found that brood-rearing females avoided habitats associated with a high density of urban developments; it is worth noting that "urban" was defined as towns, farmsteads, and energy infrastructure in this study, however it is not the case in the Program.

Landfills are an important anthropogenic disturbance category; disturbances associated with landfills include traffic, equipment operation, etc., that produces noise and activity similar to what can be expected within urban areas. Landfills also can attract large concentrations of ravens. Ravens are very successful nest predators of sage-grouse, and anthropogenic food and perching subsidies such as landfills have been shown to attract large concentrations of ravens which can lead to increases in juvenile survival and local populations (Webb et al. 2004, Kristan and Boarman 2007, Peebles and Conover 2017; see Transmission and Powerlines section above for additional references). Due to the relatively close proximity of existing landfills and transfer stations to towns and communities and similar impacts to urban areas, this disturbance type is included within the Urban – Low disturbance category.

LINEAR RIGHTS OF WAY

Other than transmission lines and roads, there is little science directly on how some linear features, such pipelines or buried transmission lines, affect sage-grouse populations. However, looking at the components of what we would expect to find for pipelines, buried transmission lines, and other linear features, we would anticipate similar direct and indirect effects as the literature has shown roads and tall structures to have. There is direct surface area loss of habitat from the linear feature itself, whether above or below ground, as well as other infrastructure associated with the linear feature. Ground disturbance and potential for invasive species establishment and spread can be significant depending on the extent of ground disturbance, existing soil types, local environmental conditions, and other factors. In addition to direct impacts, there are potential indirect impacts from spread of invasive species into surrounding habitat, operation or traffic noise from maintenance of the linear feature, as well as from ravens and other birds of prey that may use above ground infrastructure for perching or nesting. Ravens and raptors may have more opportunities to use infrastructure that is accessible for either perching or nesting. Ravens are intelligent, visually cued predators that select edge-dominated or fragmented areas with changes in vegetation, particularly non-native vegetation (Coates et al., 2014); ravens therefore may be more likely to use linear ROW corridors that have either perching infrastructure or have significant ground disturbance that is largely removed of vegetation as well as cheatgrass establishment that provides access and opportunities for hunting and scavenging.