Montana Mitigation System
Habitat Quantification Tool Technical Manual
For Greater Sage-Grouse

Version 1.0

October 2018

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ACKNOWLEDGEMENTS

The Montana Mitigation System Habitat Quantification Tool Technical Manual for Greater Sage-grouse was developed by the Montana Mitigation Stakeholder Team, hosted by the Montana Sage Grouse Conservation Program. This collaborative group met from September 2016 through June 2017 and provided significant input from a wide diversity of organizations and individuals, but does not represent the consensus opinions of that Team or the approval of any group or individual involved. Participants included:

ABS Legal	Montana Fish, Wildlife, and Parks
Browning, Kaleczyc, Berry & Hoven	Montana Land Reliance
Cloud Peak Energy	Montana Petroleum Association
Denbury Resources	Montana Rangeland Resources Committee
Diane Ahlgren (MSGOT)	Montana Sage Grouse Conservation Program
Environmental Defense Fund	Montana Stockgrowers Association
Great Northern Properties	Natural Resource Conservation Service
HC Resources	Renewable Northwest
Mike Lang (MSGOT and Montana Senate)	The Nature Conservancy
Montana Association of Land Trusts	Theodore Roosevelt Conservation Partnership
Montana Audubon	Treasure State Resources
Montana Coal Council	Trout Headwaters
MT Dept. of Natural Resources & Conservation	US Bureau of Land Management
Montana Electric Cooperatives' Association	US Fish and Wildlife Service
Montana Farm Bureau Federation	US Forest Service

SWCA Environmental Consultants provided technical support and led development of the Habitat Quantification Tool. Sara O'Brien and Bobby Cochran at Willamette Partnership provided facilitation and technical support for the Stakeholders Team's work on the companion Montana Mitigation System *Policy Guidance Document*. In addition, many individuals and organizations provided essential guidance, insight, and support to ensure that the document is consistent with Montana state policy and the needs of key constituents and is a viable means for species conservation

This content was created in part through the adaptation of procedures and publications developed by SWCA Environmental Consultants, but is not the responsibility or property of this entity.

CONTENTS OF THIS DOCUMENT

The Montana Mitigation System Habitat Quantification Tool (HQT): Technical Manual for Greater Sage Grouse defines the processes and information necessary to quantify gains and/or losses of greater sage-grouse (*Centrocercus urophasianus*) habitat caused by development, and alternatively to estimate conservation benefits resulting from activities which restore, enhance or preserve sage grouse habitat. The results of the HQT are expressed as Functional Acres gained or lost, and is reported as a Raw HQT Score. All other entities engaged in the Montana Mitigation System are expected to apply these processes, methods, standards and criteria when creating, buying, or selling credits in Montana.

The primary audiences of the Montana HQT Technical Manual are the Montana Sage Grouse Habitat Conservation Program, the Montana Sage Grouse Oversight Team (MSGOT), state regulatory agencies, federal land management agencies, current and potential credit providers and project developers, and any third parties engaged in Greater Sage-Grouse mitigation in Montana.

To further assist the reader, the document is organized into stand-alone sections to quickly locate information specific to their purpose. Appendix A describes the technical development of the Montana HQT Basemap and Appendices B through I include relevant supporting literature and technical methods of the variables incorporated in calculating the Raw HQT Score specific to various disturbance types for new projects. Credit Providers can focus on Section 3 for the HQT process specific to conservation actions. Append J is also relevant for Credit Providers by explaining the technical methodologies used for assessing Preservation, Restoration, or Enhancement projects. Project Developers can focus on Section 4 for the HQT process specific to Debit Projects. Depending on the primary project type. Appendices B through I are also relevant for Project Developers by describing relevant literature and the technical methodologies of the variables incorporated in calculating the Raw HQT Score specific to various project types. Appendix K describes habitat recovery from a Debit Project through the Reclamation process, Appendix L describes unsuitable and suitable land cover types, and Appendix M is a list of acronyms used in the Technical Manual.

This document is organized into ten major Sections, as follows.

Habitat Quantification Tool Technical Manual		
Section 1:	**Introduction**	Introduces the purpose of, the need for, and the goals of a multi-agency, multi-disciplinary, citizen-based approach to sage grouse mitigation; summarizes the processes for calculating functional acres and describes the HQT development process
Section 2:	**Overview of the Montana HQT**	Describes the framework for quantifying habitat function and summarizes the Functional Acre approach. Outlines the authority and HQT process and how it works
Section 3:	**Montana HQT Basemap**	Describes the process for the creation of the HQT Basemap, and how GIS is used to combine sage grouse population and habitat variables with existing anthropogenic disturbances
Section 4:	**HQT Calculation Process for Credit Providers**	Describes how the HQT calculates Functional Acres gained for Preservation, Restoration or Enhancement projects, and how the Basemap is incorporated into the calculations; outlines hypothetical credit project examples
Section 5:	**HQT Calculation Process for Developers**	Describes how the HQT calculates Functional Acres lost and quantifies Direct and Indirect Impacts for development/debit projects, and how the Basemap is incorporated into the calculations; outlines hypothetical debit project examples
Section 6:	**Adaptive Management and Monitoring**	Describes the Adaptive Management approach and how HQT components may be revised, replaced, changes, or updated
Section 7:	**Limitations of the Montana HQT**	Describes the capabilities and limitations of the HQT for application to the Montana Mitigation System process; explains how the HQT is policy-neutral and is based on the continued incorporation of the best available science for sage grouse ecology and habitat
Section 8:	**Glossary**	Defines the terms used in this HQT Technical Manual
Section 9:	**References**	Lists the references used and relied upon by the Mitigation Stakeholders Group and cited in the HQT Technical Manual
Section 10:	**Appendices**	The Appendices describe the HQT calculations in detail for the Basemap and anthropogenic disturbances, and provides the reader with information to effectively use the Technical Manual. Appendix A describes the Montana HQT Basemap. Appendices B – I describe Anthropogenic Variables applied to Oil & Gas, Tall Structures, Transmission Structures, Wind Facilities, Roads & Railways, Buried Utilities, Agriculture & Mines, and Compressor Stations & other Noise Sources. Appendix J describes habitat Preservation, Restoration and Enhancement for credit projects. Appendix K describes post-project habitat recovery through Reclamation. Appendix L lists land cover designations as unsuitable/suitable. Appendix M is a list of acronyms used in the HQT Technical Manual

1.0 INTRODUCTION

The State of Montana and a multi-agency, multi-disciplinary, citizen-based stakeholder group (hereafter Stakeholder Group) has developed a Habitat Quantification Tool (HQT) for purposes of quantifying gains and/or losses of greater sage-grouse (*Centrocercus urophasianus*, hereafter GRSG) habitat caused by development, and alternatively to estimate conservation benefits resulting from activities which restore, enhance or preserve sage grouse habitat.

The HQT considers the biophysical attributes of GRSG seasonal habitats to provide a measure of habitat function across multiple scales. These measures of Habitat Function expressed as Functional Acres (Raw HQT Score), are used for calculating conservation benefits (i.e., credits) from mitigation projects as well as project impacts (i.e., debits) from development projects (Figure 1. 1). These Functional Acres provide a common "habitat currency" that can be used for both credit and debit projects to ensure accurate accounting of habitat gains and losses. The HQT will be conducted for all debit producing projects, such as those seeking to undertake a new land use or activity, in sage grouse habitat on state lands and private and federal lands in GRSG habitat that receive state funding or are subject to state agency review, approval, or authorization (unless otherwise directed by Montana Sage Grouse Oversight Team [MSGOT] and described in the accompanying Montana Mitigation System Policy Guidance Document for Greater Sage-Grouse [hereafter *Policy Guidance Document*]). The Raw HQT Score results may be subsequently adjusted, as discussed in the *Policy Guidance Document*, to incentivize or disincentivize conservation or development practices.

This Technical Manual 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 Raw HQT Score based on the measurements for a specific project type is also described.

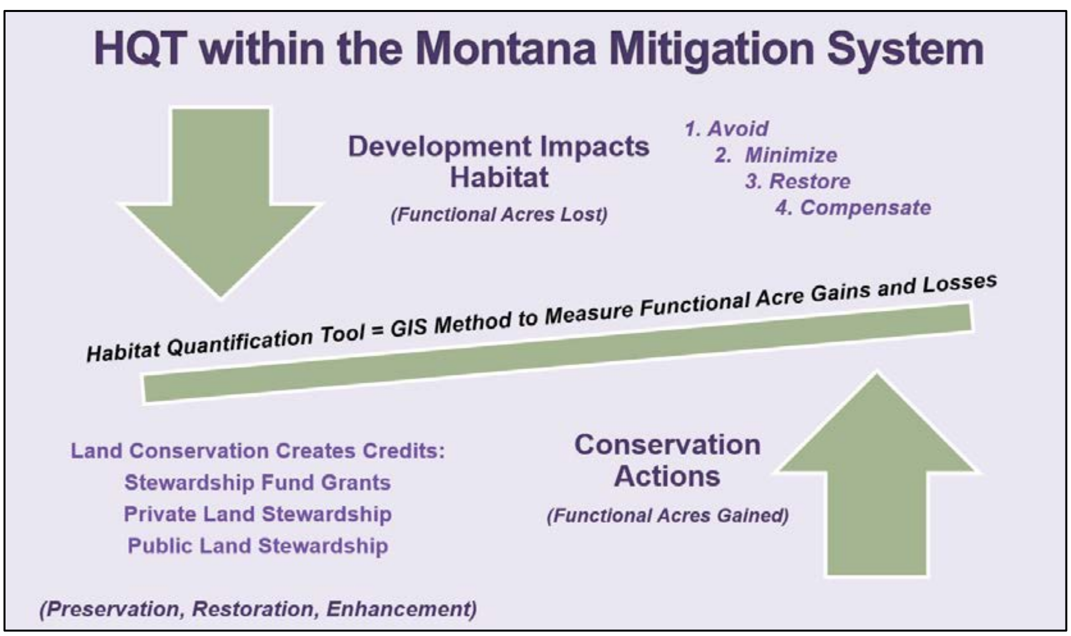

Figure 1. 1. The HQT supports the Montana Mitigation System by providing a scientific method for measuring impacts to habitat from development and improvements to habitat from conservation actions.

Users and Uses

The primary audiences of the Montana Mitigation System Habitat Quantification Tool Technical Manual for Greater Sage-grouse are the Montana Sage-Grouse Habitat Conservation Program (hereafter Program), MSGOT, regulatory agencies, current and potential Credit Providers (entities generating credits as compensatory mitigation for impacts to sage grouse habitat) or Project Developers (entities proposing an action that will result in a debit), and any third parties engaged in GRSG mitigation in Montana.

Development Process

The Montana HQT was first developed by the Stakeholder Group, with the first draft release of the technical document in May 2017. The technical document was revised based on stakeholder feedback and developed into The Montana Mitigation System Habitat Quantification Tool Technical Manual for Greater Sage-grouse (Montana HQT). It is based on the latest available peer-reviewed science related to GRSG and its habitat in Montana.

The Montana HQT incorporates elements from Nevada, Wyoming, and Oregon's Greater Sage-Grouse Habitat Quantification Tool Scientific Methods Documents and Wyoming Governor Mead's Compensatory Mitigation Framework. As new peer-reviewed science and agency information becomes available, the Montana HQT will be updated by the Program to reflect new understanding of GRSG and its habitat in Montana (see Section 6.0 on Adaptive Management and Monitoring).

2.0 OVERVIEW OF THE MONTANA HQT

The Montana HQT is a scientific approach for assessing Habitat Function and conservation outcomes for GRSG in Montana (Figure 2. 1). The purpose of the Montana HQT is to quantify Habitat Function for a given location with respect to GRSG needs. The Montana HQT uses a set of measurements and methods, applied at multiple spatial scales, to evaluate criteria related to GRSG Habitat Function. Estimates of Habitat Function in the Montana HQT are calculated using a multi-level assessment process (Figure 2. 2).

The First Level Assessment determines whether a project is located within currently defined boundaries of State-designated GRSG habitat and within the State's core, general, and connectivity habitat boundaries and U.S. Bureau of Land Management (BLM) or the U.S. Forest Service (USFS) Priority Habitat Management Areas (PHMA), General Habitat Management Areas (GHMA), and Restoration Habitat Management Areas (RHMA) where outside of state boundaries.

The Second Level Assessment is carried out for projects located within the habitat boundaries determined through the First Level Assessment. The Second Level Assessment is conducted in a geospatial platform to facilitate initial estimates of expected losses or gains of Habitat Function.

The Third Level Assessment is a field-based habitat assessment to confirm or adjust Second Level Assessment results and provide final estimates of GRSG Habitat Function. The Third Level Assessment is required for credit projects and voluntary for debit projects, although the Program may require it on debit projects in some cases.

The Montana HQT quantifies gains and/or losses of Habitat Function across multiple project milestones (e.g., baseline, construction, operation, reclamation) and spatial scales that may occur over the life of a project. Differences between Habitat Function before a project (baseline conditions) and the Habitat Function during each project milestone are quantified and summed to calculate the total habitat losses or gains that would result from project implementation. Estimated gains and/or losses of Habitat Function that result from a project, expressed as Functional Acres, become the base value from which final credits and/or debits can be calculated.

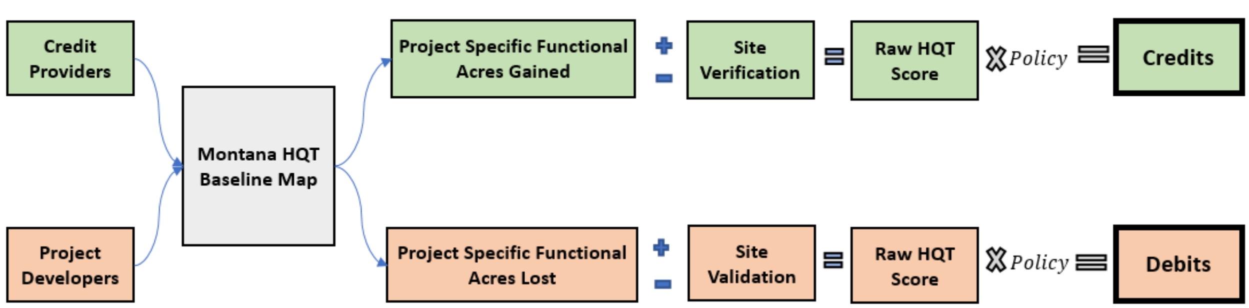

Figure 2. 1. General flow of events for determining the number of credits produced and the number of debits accrued during the life of a given project.

2.1. FRAMEWORK FOR QUANTIFYING HABITAT FUNCTION

The Montana HQT consists of a three-level assessment of GRSG habitat that incorporates many of the concepts and scales associated with multi-level assessments of habitat use and selection (Johnson 1980). The First Level Assessment evaluates the availability of GRSG habitat across all of Montana and incorporates many aspects of the first level (broad-scale) and second level (mid-scale) assessments described in other GRSG habitat assessment frameworks (Boyd et al. 2014, Nevada Natural Heritage Program and the Sagebrush Ecosystem Technical Team [NNHP and SETT] 2014, Stiver et al. 2015, EDF 2015a, EDF 2015b). Similar multi-level approaches have also been used to evaluate GRSG habitat use and quality in Montana (Montana Sage Grouse Work Group [FWP] 2005, Doherty 2008).

The Montana HQT Second Level Assessment is completed in a geospatial platform. The geospatial layers represent the functionality of habitat, incorporate many aspects of Johnson's (1980) fine-scale habitat assessments, and also incorporate aspects of multi-level site-scale assessments. In the Montana Mitigation System, the field-based Third Level Assessment measures and quantifies site-specific habitat characteristics and will be used to confirm and/or adjust estimates of gains and losses of Habitat Function that are generated in the Second Level Assessment.

In all three levels of the Montana HQT, Habitat Function is quantified using scores ranging in value from 0 (unsuitable) to 100 (optimal). To receive a functional value of 100, habitat would be required to fall within the boundaries of the First Level Assessment area (core, general, or connectivity habitats or federal lands) and have habitat characteristics as quantified in the second and Third Level Assessment processes that are optimal for GRSG in Montana.

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 2. 2).

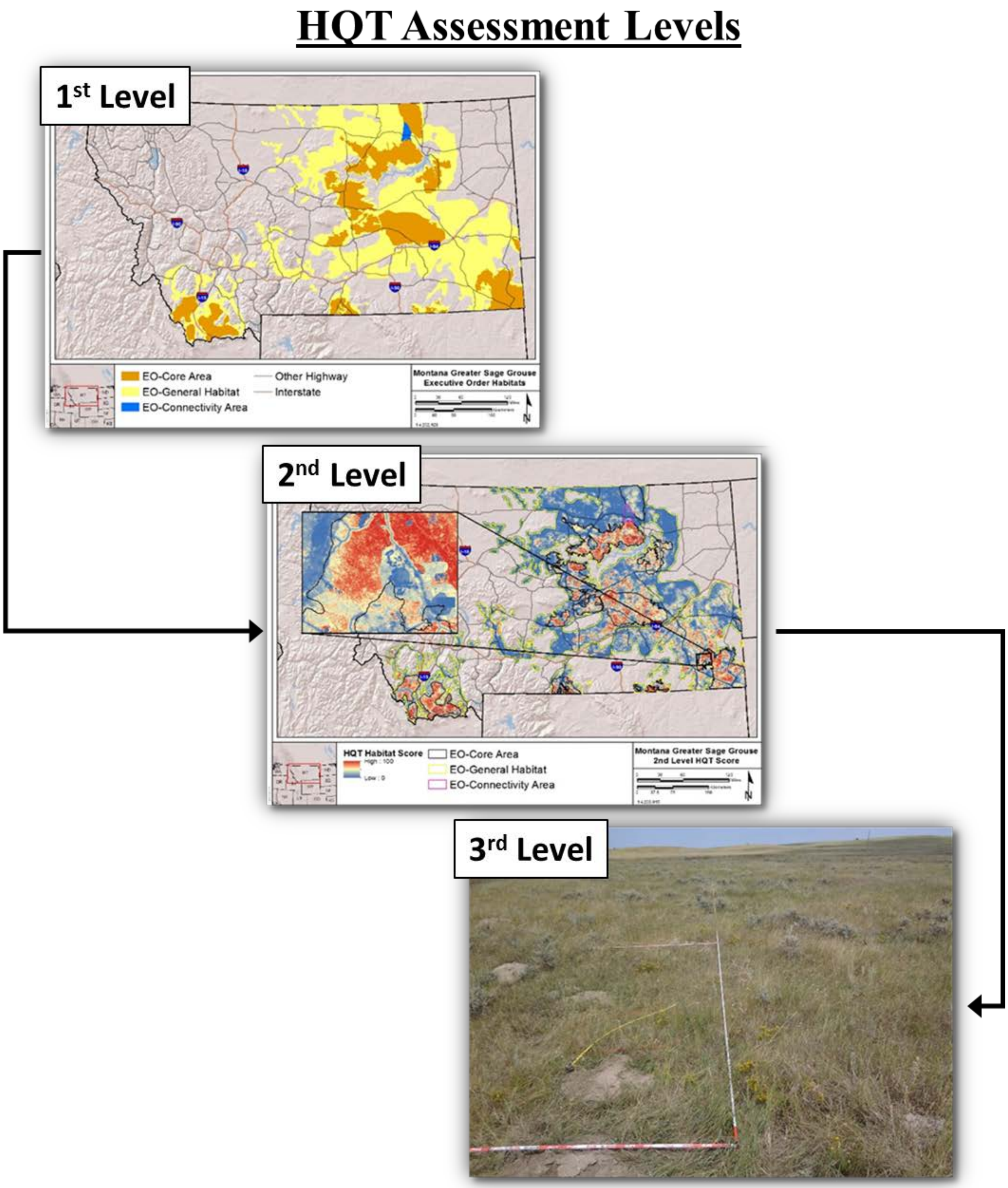

Figure 2. 2. Illustration of the three levels of assessment included in the Montana HQT.

2.2. FUNCTIONAL ACRE APPROACH

The HQT measures the quantity and quality of habitat at a site for GRSG in terms of Functional Acres. Habitat Function refers to the quality of the habitat for meeting life history requirements (reproduction, recruitment, and survival) for GRSG at multiple spatial scales. Functionality includes Direct and Indirect Impacts of existing and proposed anthropogenic disturbances on and surrounding a given site.

Functional Acres are a product of the site-scale Habitat Function, the local-scale Habitat Function, and the area assessed. Landscape scale policy adjustments are brought into the quantification of credits and debits through mitigation defined in the *Policy Guidance Document*.

The Functional Acre approach has several advantages:

- **Establishes a common currency.** Functional Acres serve as the basis of the currency of the Montana Mitigation System: credits and debits. Functional Acres account for the quantity and quality of the habitat at multiple spatial scales and temporal intervals. 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.

- **Provides full accounting of impacts.** Functional Acres account for both Direct and Indirect Impacts of anthropogenic disturbance as well as how those effects may change during the life of the project. Accounting for Indirect Impacts provides a more accurate representation of the full biological impact of a disturbance on GRSG. It also provides a strong incentive for targeting debit projects to the most appropriate places on the landscape, clustering development where it will have the least species impact. Mitigation obligations will be lowest when the fewest Functional Acres are impacted (i.e., the lowest Raw HQT Score).

- **Provides full accounting of benefits of conservation actions.** Functional Acres for credit projects account for the direct effects of the conservation actions. The Functional Acre approach allows for the full biological benefit of the conservation actions on GRSG to be quantified. Through this quantification, Credit Providers will directly be able to focus their efforts where they will have the greatest benefit across the landscape and to measure the success of their conservation actions. Conservation benefits will be highest when the most Functional Acres are conserved, restored, or enhanced (i.e., the highest Raw HQT Score).

- **Focuses on outcomes.** Rather than rewarding the completion of management actions or practices that may or may not succeed, the Montana Mitigation System focuses the activities of developers, ranchers, and conservationists on what matters most to GRSG – 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 Acres approach of the HQT enables the Montana Mitigation System to provide strong incentives to achieve habitat benefits at the multiple scales relevant to GRSG.

- **Tracks the contribution of the Montana Mitigation System to species habitat and population goals in Montana over time.** The use of Functional Acres allows for a simple metric to measure the overall performance of the Montana Mitigation System, which aims to incorporate mitigation as one tool among many in Montana's GRSG Conservation Strategy so that listing under the federal Endangered Species Act is never warranted.

2.3. AUTHORITY OF THE HQT AND HOW IT WORKS

The Montana Greater Sage Grouse Stewardship Act establishes direction to the Program in implementing its mitigation responsibilities under the Act and relevant Executive Orders. The Act provides for creation of an HQT, which is an objective scientific method used to evaluate vegetation and environmental conditions related to the quality and quantity of sage grouse habitat and to quantify and calculate the value of credits and debits in a mitigation marketplace setting such as a habitat exchange.

Montana Executive Order No. 21-2015 identifies GRSG Core Areas and General Habitat in Montana. Montana Executive Order No. 12-2015 (hereafter, EO, EO 12-2015, or Order) requires that all new activities be regulated to maintain existing levels of suitable GRSG habitat in Core Areas to ensure the maintenance of GRSG abundance and distribution in the state. Stipulations for new activities are specified in the EO and are specific to various activity types. The EO is a regulatory mechanism for purposes of addressing identified threats to sage grouse and analyzing whether listing under the federal Endangered Species Act is warranted (Figure 2. 3).

The BLM and USFS have designated PHMA, GHMA, and RHMA within Montana through their agencies respective management Plans. The Program will conduct the HQT for projects located within federally designated sage grouse management areas through a memorandum of understanding. This approach is expected to provide a consistent and integrated approach to fulfilling mitigation requirements for impacts to sage grouse habitat on all private, state, and federal lands in Montana.

The Montana HQT is designed to work in concert with the *Policy Guidance Document* in accordance with the rules and regulations of the state of Montana and federal land management agencies. All projects using the Montana Mitigation System will ultimately be governed by these rules and regulations.

The Montana Mitigation System recognizes the full mitigation hierarchy (avoidance, minimization, restoration, and compensation). The HQT quantifies the change in quantity and quality of GRSG habitat resulting from new activities (Figure 2. 3). Quantified results equally measure impacts and/or benefits of a new activity in order to evaluate the Functional Acres gained for credit purposes and/or the Functional Acres lost for debit purposes.

The HQT is defined as the scientific method "used to evaluate vegetation and environmental conditions related to the quality and quantity of sage grouse habitat and to quantify and calculate the value of credits and debits" [MCA§ 76-22-103(9) (2017)]. The output of the HQT is a measure of the existing quality of the habitat relative to optimal conditions (Figure 2. 3). Quality is measured first by assessing the existing habitat conditions, including existing anthropogenic variables

(Montana HQT Basemap) on a particular credit (conservation) or debit (development) project location. The quality of the given site is then modified by the project-specific anthropogenic variables. Variables include project attributes such as: size, type, location, and duration. The result then becomes the Raw HQT Score expressed as "Functional Acres," which then becomes the "currency" whereby "debits" accrued as a function of actions that decrease habitat quality are offset by "credits" that accrue as a function of actions that preserve or increase habitat quality. One Functional Acre gained is the equivalent of 1 credit. One Functional Acre lost is the equivalent of 1 debit. Credits and debits are exchanged in a mitigation marketplace which is further discussed in the *Policy Guidance Document*.

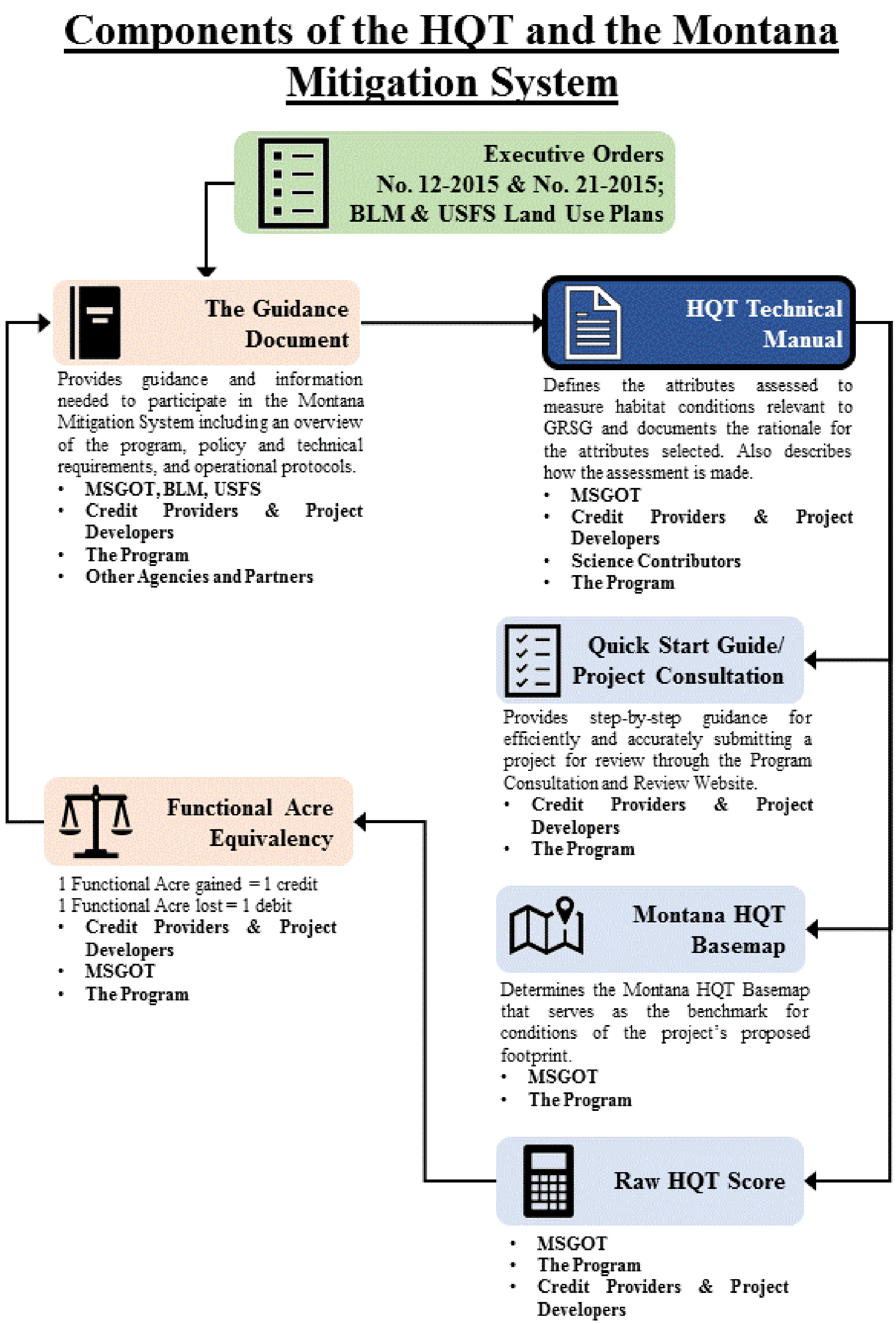

Figure 2. 3. Various components included in the Montana HQT and Montana Mitigation System Strategy.

3.0 MONTANA HQT BASEMAP: VARIABLES AND METHODS

The Montana HQT Basemap is used to provide the Program with a benchmark of existing Habitat Function that incorporates biological attributes important for GRSG. Existing Anthropogenic Surface Disturbance has been mapped by the Program and is incorporated into the Montana HQT Basemap. Examples of existing Anthropogenic Surface Disturbance include cultivation, highways, and existing rights-of-way. The Montana HQT Basemap is developed using the First and Second Level Assessments. Because Third Level Assessments are site-specific and the Montana HQT Basemap is statewide, Third Level Assessments were not incorporated in the Montana HQT Basemap, though may be permitted in the future as funding and Program needs allow.

3.1. First Level Assessment to Determine Map Extent and Applicability for Designated Sage Grouse Habitat

The State has already completed the First Level Assessment of habitat in Montana. The First Level Assessment Area consists of the distribution of GRSG in Montana ("currently defined occupied habitat", Montana Fish, Wildlife, & Parks [MTFWP] 2015) and is confirmed by the boundaries of general habitat, core habitat, and connectivity habitat areas for GRSG (Montana EOs 12-2015 and 21-2015).

On federal lands, the BLM and the USFS GRSG habitats are delineated in the agency's respective land use plans, and do not align with some areas of the Montana GRSG habitat areas (i.e., Core Areas, General Habitat, Connectivity Area). Therefore, the Montana HQT Basemap is computed for Montana state GRSG habitat boundaries, as well as within the boundaries of the BLM or USFS PHMA, GHMA, and RHMA areas.

3.2. Second Level Assessment to Determine Habitat Functionality and Estimate Functional Acres

The Second Level Assessment for the Montana HQT Basemap is the level at which the HQT quantifies Functional Habitat to provide a benchmark of GRSG Habitat Functionality for a specific credit or development project. It is computed using a geospatial platform (e.g., ArcGIS) using scores developed for selected Population and Habitat Variables associated with GRSG habitat selection and use.

The Population and Habitat Variables and scoring processes are similar to and consistent with multiple other habitat assessment frameworks for GRSG (Boyd et al. 2014, NNHP and SETT 2014, Stiver et al. 2015, EDF 2015a, EDF 2015b) but consider Montana-specific data and literature, when available. Selection of variables and scores were based on peer-reviewed literature, as well as those identified by the Stakeholder Group as being important for GRSG in Montana. Scores for each variable were developed by conducting a thorough review of available scientific information and using the following hierarchy in order of descending importance:

- Peer-reviewed literature, theses, and dissertations specific to GRSG habitat selection and use in Montana.

- Agency management reports or datasets specific to GRSG habitat selection and use in Montana.

- Peer reviewed literature, theses, and dissertations specific to GRSG habitat selection and use across the range of the species, with a greater emphasis on literature for the eastern, Rocky Mountain portion of the range (i.e., less reliance on literature from the Great Basin portion of the range).

- Professional judgment of the species' experts and habitat managers in the Stakeholder Group.

The ecological results presented in publications and extracted from datasets related to GRSG habitat suitability varied depending on geographic and climatic factors such as elevation, precipitation zone, and ecological site potential. To account for this variability, multiple datasets or literature sources were used or averaged to develop variable scores for the Montana HQT when possible.

Variable selection considered habitat requirements across all GRSG seasonal periods of use (nesting and breeding, brood-rearing and summer, and winter combined). For each of the selected variables, a Habitat Score ranging from 0.0 (unsuitable) to 100.0 (optimal) was assigned. Variables and variable scores were also developed to account for their effects on GRSG habitat through incorporation of Anthropogenic Variables. Scoring Population and Habitat Variables as well as Anthropogenic Variables are critical steps in the HQT process. Such scoring provides a way to quantitatively measure the quality of specific Habitat Functions.

Unsuitable Land Cover types (Appendix L) are removed from the HQT geospatial layers during the Second Level Assessment. Unsuitable Land Cover types are assigned a score of 0.0, which produces a Habitat Score of 0.0 for the given pixel and effectively removes those pixels from land cover datasets and subsequent calculations. See Section 3.2.1 and Appendix A for a complete description of Unsuitable Land Cover Types and as it pertains to the EO.

Scores for each variable (Population and Habitat Variables and Anthropogenic Variables) were combined in a geospatial (i.e., raster-based GIS) platform to quantify estimates of Habitat Function. Each pixel within the layers representing each variable receive a score between 0.0 and 100.0 based on the scores developed for that variable. The data layers for all variables are combined to develop a landscape-scale model representing Habitat Function in all Core Areas, General Habitat, and Connectivity Area and federal PHMA, GHMA and RHMA for GRSG. The Montana HQT Basemap is then used to compute the Raw HQT Score for projects proposed by credit providers and project developers to calculate the Functional Acres gained or lost, respectively, that equate directly to credits or debits. See Appendix A for the technical methods used to develop the Montana HQT Basemap. See the Policy Guidance Document for more information on how the total of credits and debits associated with projects are calculated and managed.

3.2.1. Spatial Resolution of the Montana HQT

Scores for each variable (Population and Habitat Variables and Anthropogenic Variables) were combined using raster-based GIS methods to quantify estimates of Habitat Function. Original data layers obtained and used to develop the Scores varied in the degree of spatial resolution, or pixel size, at which they were available; most data layers were available at 30-m resolution. To more accurately represent existing disturbance and balance computational demands of a state-wide modeling process, the Montana HQT Basemap is computed at a 7.5-m spatial resolution.

Because the HQT operates in a raster-based GIS platform, vector spatial data submitted for proposed projects will be converted to raster at a 3.75-m spatial resolution. Based on the Program's experience to date, many new projects are being proposed with finer and more detailed spatial features, which merit the selection of the finer 3.75-m resolution. This finer spatial resolution will better preserve the integrity of project footprints when converted to a raster data layer than achieved with coarser spatial resolutions. The spatial resolution selected during vector to raster conversion process alters the size and location of the Direct Impact area, consequently altering the Raw HQT Score. The degree of alteration is likely to decrease with increasing spatial resolution. Scores may be overestimated or underestimated due to the 1) inclusion of extra areas from pixels extending beyond the vector-defined perimeters or 2) the exclusion of areas if the project footprint is not adequately preserved through the conversion process from vector to raster.

The Program compared three spatial resolutions and the resulting physical area (in acres and m^2) retained through the vector to raster conversion process (Table 3. 1) for three linear projects that varied in degree of curvature (Figures 3. 1A, 3. 2A, 3. 3A). The 30-m spatial resolution resulted in rasters that presented a discontinuous Direct Impact area by capturing the entire Direct Impact area in 6-8 discrete pixels for all three linear projects (Figures 3. 1B, 3. 2B, 3. 3C). This essentially excluded relatively large sections of the Direct Impact area from the HQT analysis. Concurrently, the 30-m spatial resolution rasters included areas outside of the Direct Impact area delineated in the submitted vector spatial data for all three linear projects. This resulted in overestimating the Direct Impact area by 125-m^2, 1614-m^2, and 205-m^2 for the straight, slightly curved, and highly curved linear projects, respectively (Table 3. 2). The 7.5-m spatial resolution overestimated the Direct Impact area by 13-m^2 (Figure 3. 1C) and 93-m^2 (Figure 3. 3C) for the straight and highly curved linear projects, respectively, but underestimated the area by 16-m^2 (Figure 3. 2C) for the slightly curved linear project. The 3.75-m spatial resolution resulted in the lowest amount of Direct Impact area overestimated (11-m^2; Figure 3. 1D, Table 3. 2) for the straight linear project and slightly underestimated the Direct Impact area for the slightly curved and highly curved linear projects by 102-m^2 (Figure 3. 2D, Table 3. 2) and 119-m^2 (Figure 3. 3D, Table 3. 2), respectively. Ultimately, when converting to a raster with a 3.75-m spatial resolution, more of the Direct Impact area delineated by the submitted vector spatial data is captured by the pixels and the least amount of area outside of the Direct Impact area is included in the Direct Impact area that moves forward to the HQT analysis. Thus, the impacts from spatial errors associated with data type conversions may be decreased by increasing the spatial resolution. However, the Program did not consider a higher spatial resolution than 3.75-m due to computational demands.

The spatial errors associated with conversion processes are unavoidable artifacts of spatial data processing and analyses conducted in a geospatial platform. However, the propagation of those errors may be moderated by diligently selecting an appropriate spatial resolution for the analysis. The selection of the 3.75-m spatial resolution was the best spatial resolution of the three resolutions compared as it retained the best representation of the physical area within the Direct Impact area delineated in the vector spatial data.

Due to the extreme computational demands exhibited at the 3.75-m resolution when operating at a statewide extent, the Montana HQT Basemap was computed at the 7.5-m resolution. Resampling to 3.75-m resolution was then conducted on the HQT Basemap to be compatible with the resolution selected for computing the Raw HQT Scores. Any existing disturbance not adequately captured in the Montana HQT Basemap may be accounted for during the Third Level Assessment for proposed projects.

Table 3. 1. Three spatial resolutions compared to determine which resolution best retained the Direct Impact area when converting from vector to raster.

Spatial Resolution in Meters (Pixel Size)	3.75	7.5	30
Square Meters/Pixel	14.06	56.25	900
Physical Acres/Pixel	0.003	0.014	0.222

Table 3. 2. Comparison examples of converting vector spatial data (blue) to raster at three spatial resolutions (in meters; 30-m [red rows], 7.5-m [orange rows], 3.75-m [yellow rows]). Converting the Example Linear Projects' vector spatial data to a raster with a pixel size of 3.75-m produced the closest results for the Direct Impact area without overestimating for curved projects and the closest result for straight linear projects by minimally overestimating.

Spatial Data			Linear Project		
			Straight	Slight curvature	High curvature
Vector		Square Meters	5,274.72	5,585.22	5,194.88
Vector		Physical Acres	1.30	1.38	1.28
Raster	30-m spatial resolution	Number of Pixels	6	8	6
Raster	30-m spatial resolution	Square Meters	5,400.00	7,200.00	5,400.00
Raster	30-m spatial resolution	Difference	+125.08	+1,614.78	+205.12
Raster	30-m spatial resolution	Physical Acres	1.33	1.78	1.33
Raster	30-m spatial resolution	Difference	+0.03	+0.40	+0.05
Raster	30-m spatial resolution	*Trend*	*Overestimates*	*Overestimates*	*Overestimates*
Raster	7.5-m spatial resolution	Number of Pixels	94	99	94
Raster	7.5-m spatial resolution	Square Meters	5,287.50	5,568.75	5,287.50
Raster	7.5-m spatial resolution	Difference	+12.58	-16.47	+92.62
Raster	7.5-m spatial resolution	Physical Acres	1.31	1.38	1.31
Raster	7.5-m spatial resolution	Difference	+0.01	-0.003	+0.03
Raster	7.5-m spatial resolution	*Trend*	*Overestimates*	*Underestimates*	*Overestimates*
Raster	3.75-m spatial resolution	Number of Pixels	376	390	361
Raster	3.75-m spatial resolution	Square Meters	5,286.56	5,483.40	5,075.66
Raster	3.75-m spatial resolution	Difference	+11.64	-101.82	-119.22
Raster	3.75-m spatial resolution	Physical Acres	1.31	1.35	1.25
Raster	3.75-m spatial resolution	Difference	+0.01	-0.03	-0.03
Raster	3.75-m spatial resolution	*Trend*	*Overestimates*	*Underestimates*	*Underestimates*

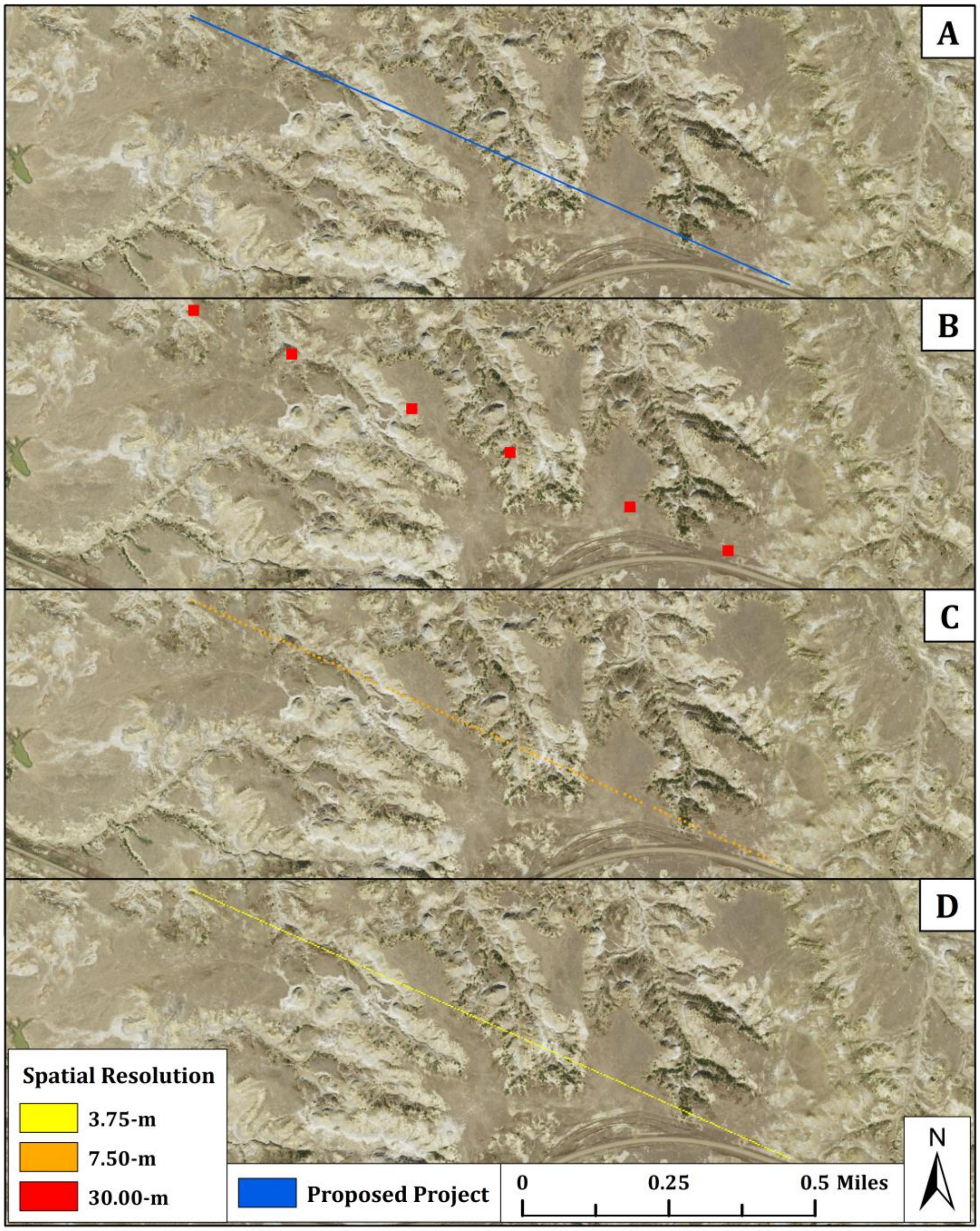

Figure 3. 1. Example of a proposed linear project showing the Direct Impact area (direct footprint; A) in blue covering approximately 1.30-acres. When converted to a raster data type with a 30.0-m (red; B) spatial resolution, the area for the HQT analysis increases to approximately 1.33-acres and covers areas outside of the project footprint, as well as excludes entire portions of the proposed project footprint. The amount of area missing decreases when converting to rasters with 7.50-m (orange; C) or 3.75-m (yellow; D) spatial resolutions, where the Direct Impact area for the HQT analysis very minimally increases by 0.003-acres for both resolutions.

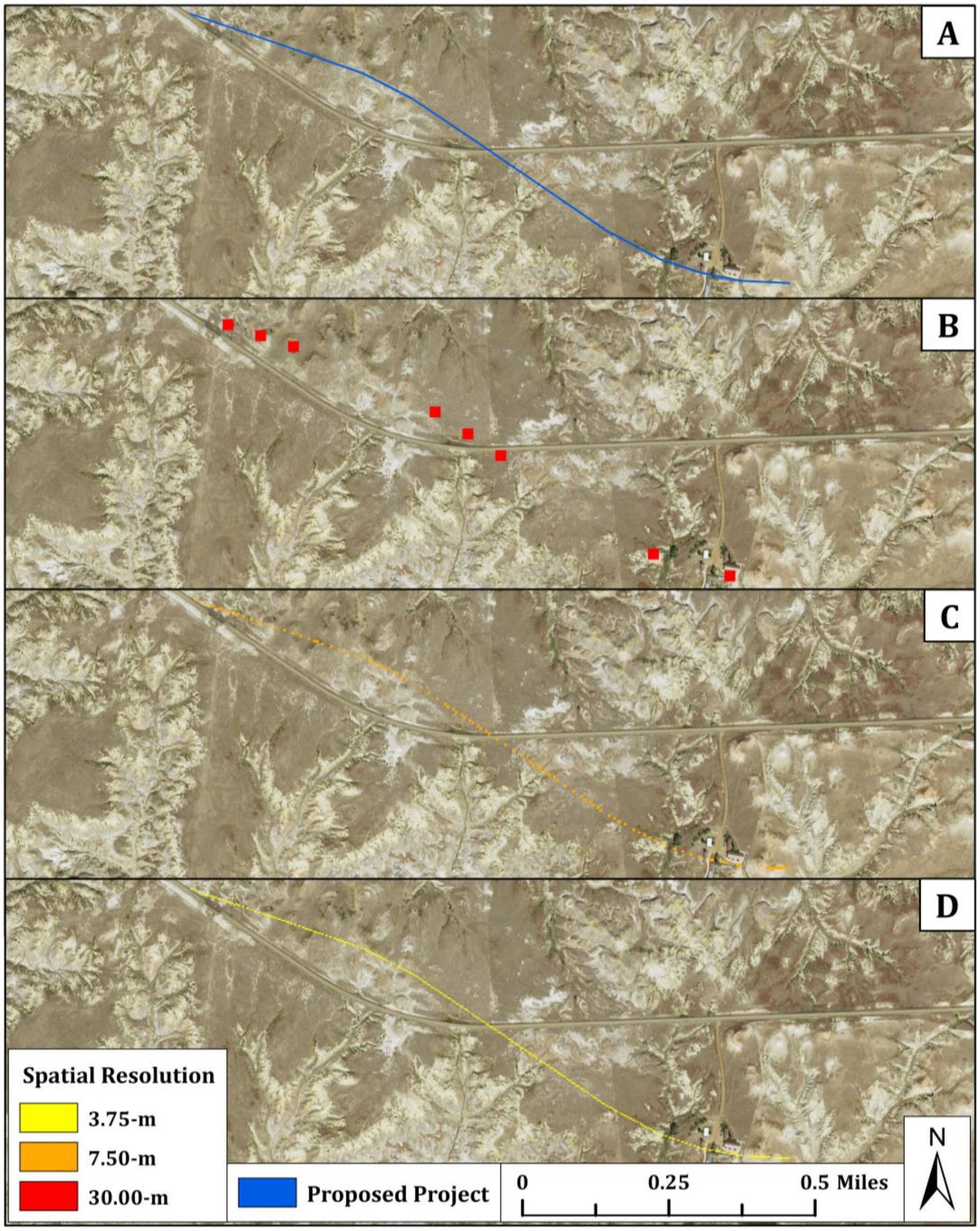

Figure 3. 2. Example of a proposed linear project that contains some degree of curvature showing the Direct Impact area (direct footprint; A) in blue covering approximately 1.38-acres. When converted to a raster data type with a 30.0-m (red; B) spatial resolution, the area for the HQT analysis increases to approximately 1.78-acres and covers areas outside of the project footprint, as well as excludes entire portions of the proposed project footprint. The amount of area missing decreases when converting to rasters with 7.50-m (orange; C) or 3.75-m (yellow; D) spatial resolutions, where the Direct Impact area for the HQT analysis is 1.38-acres and 1.35-acres, respectively.

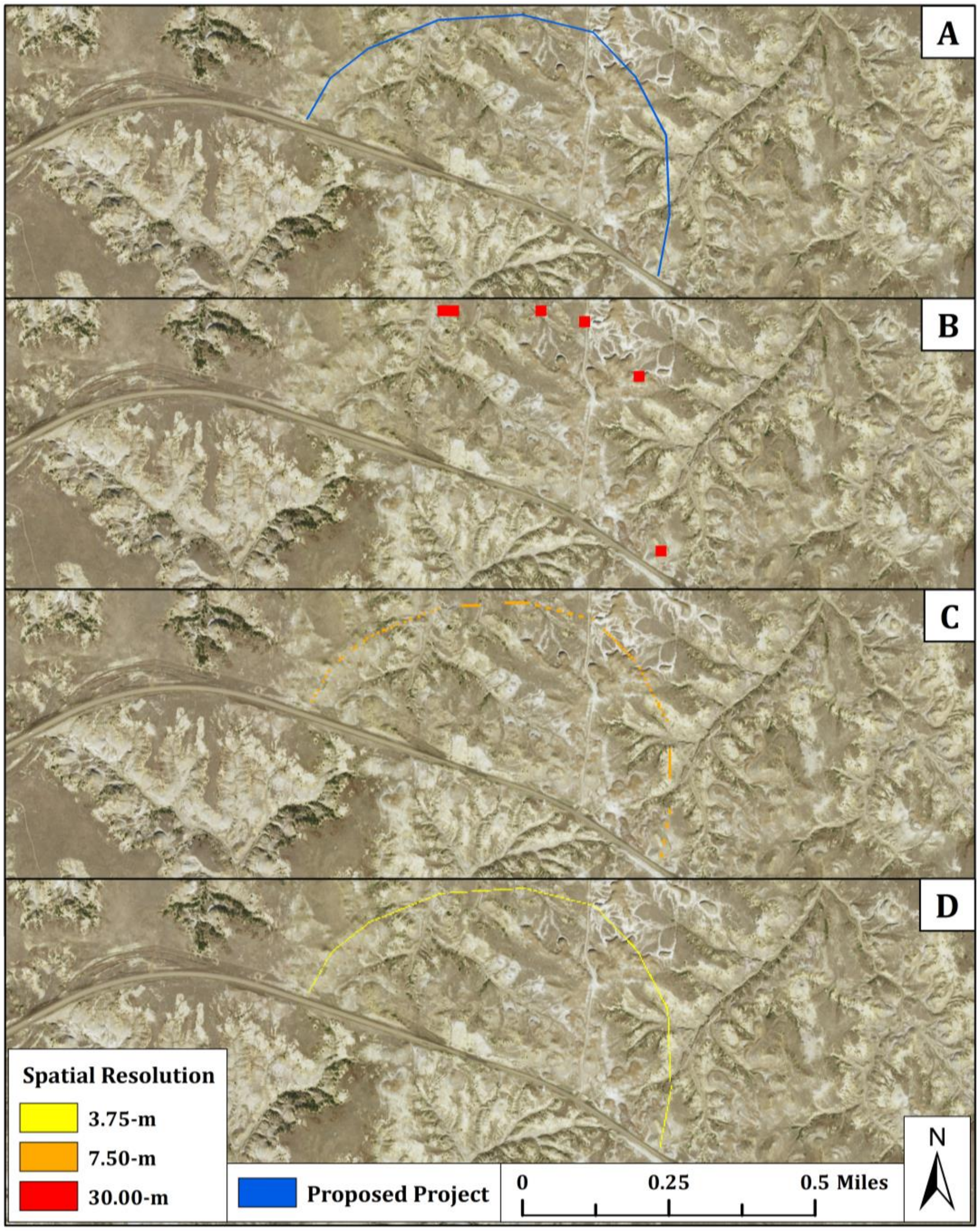

Figure 3. 3. Example of a proposed linear project that contains a high degree of curvature showing the Direct Impact area (direct footprint; A) in blue covering approximately 1.28-acres. When converted to a raster data type with a 30.0-m (red; B) spatial resolution, the area for the HQT analysis increases to approximately 1.33-acres and covers areas outside of the project footprint, as well as excludes entire portions of the proposed project footprint. The amount of area missing decreases when converting to rasters with 7.50-m (orange; C) or 3.75-m (yellow; D) spatial resolutions, where the Direct Impact area for the HQT analysis is 1.31-acres and 1.25-acres, respectively.

Montana HQT Basemap Flowchart

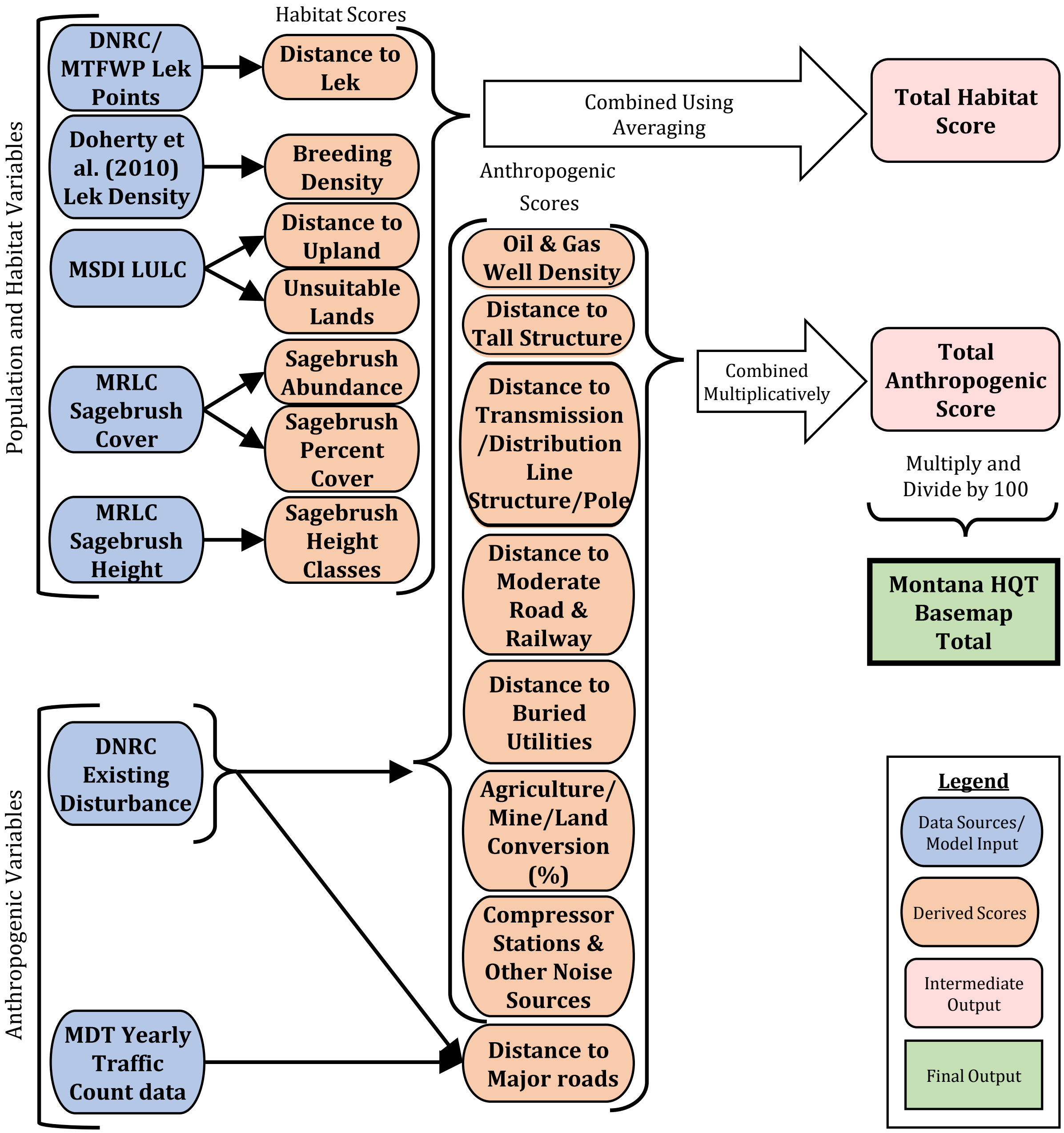

Figure 3. 4. The flowchart for the development of the Montana HQT Basemap.

3.2.2. Population and Habitat Variables Used to Create the Montana HQT Basemap

Habitat Function in the Second Level Assessment is calculated using Population and Habitat Variables to produce the Montana HQT Basemap. The Habitat Variables were developed to represent and account for impacts to winter, breeding, and nesting habitats specific to upland and mesic landscapes. Early and late summer brood-rearing habitats that are specific to mesic landscapes were also included (see Table A. 10 for the detailed list of datasets and land cover types used to define Mesic areas).

Selection of the Population and Habitat Variables considered best available scientific information for GRSG habitat in Montana as well as the public availability of datasets and GIS layers to inform variable scores and resulting geospatial models of Habitat Function (See Appendix A for specific input data sources used).

Each Population and Habitat Variable listed in Appendix A is scored based on its Habitat Function value derived from the Habitat Variables, ranging from 0.0 (no value) to 100.0 (maximum value). Detailed descriptions of Population and Habitat Variables and their scoring are provided in Appendix A of this document. Score ranges were assigned based on the best available scientific information and peer-reviewed scientific literature using the hierarchy described in Section 3.2. When possible, Montana-specific data and information were used to establish and/or adjust scores to better match known patterns of GRSG habitat use in Montana.

The Total Habitat Score is calculated by averaging all the Habitat Scores specific to the Population and Habitat Variables. Given that habitats outside the sage grouse occupied range and non-habitats (i.e., unsuitable lands; see Appendix L for a complete list of land cover types designated as suitable or unsuitable lands in the model) are masked from scoring, an averaging approach (as compared to a multiplicative approach) provides a method where potential habitat cannot be zeroed out by a single vegetation or population variable. This is important for considering the mosaic of habitat conditions important for sage grouse through their annual life cycle.

The Total Habitat Score is a single continuous GIS layer that quantifies the important Population and Habitat Variables for GRSG within the First Level Assessment Area. The Total Habitat Score is then combined with the output of the Total Anthropogenic Score that affect GRSG Habitat Function to produce the final Montana HQT Basemap (a continuous GIS layer; see Section 3.2.2). The following sections describe the scoring process that was used for each Population and Habitat Variable used to calculate the Total Habitat Score.

3.2.2.1. Distance to Lek

Scores for this variable were developed using the MTFWP lek location database and associated geospatial layers. Leks classified by MTFWP as "confirmed active", "unconfirmed", and "confirmed inactive" were used to develop scores for this Population and Habitat Variable. Leks classified as "never confirmed active" or "confirmed extirpated" were not included in the scoring process for this variable. The distance to lek Population and Habitat Variable will be updated annually to reflect newly discovered leks, lek status changes, and leks removed from the MTFWP lek database.

Current GRSG habitat management guidance uses "active" leks as focal points for breeding and nesting habitat management (Connelly et al. 2000, Connelly et al. 2011); therefore, distance to lek was used as a variable in the upland habitat calculations. This variable is intended to increase measures of Habitat Functionality of areas closer to leks where the majority of breeding and nesting activities occur. Leks also are often an indicator of high quality sagebrush habitat that is important during other seasons of use (Connelly et al. 2011).

Available literature and datasets related to lek-to-nest distances in Montana were used to establish scores for this variable. Generally, most available literature and datasets for Montana indicate that the nesting activities in the state occur within 10.0-km of a lek with two studies finding nests out to 20.0-km. Generally, distances less than 3.2-km of a lek were recognized as important nesting habitat across the state with decreased nest numbers with increased distance from a lek. Montana-specific datasets related to lek-to-nest distances are very similar to those observed elsewhere across the range of the GRSG.

Because of the similarities between Montana-specific data and range-wide datasets, variable scores for the distance to lek variable are based entirely on Montana data out to a distance of 10.0-km from a lek (Appendix A, Figure A. 2). Scores for the variable beyond 10.0-km use the analyses by Coates at al. (2013) and Holloran and Anderson (2005) and their reported observations of declining use beyond 10.0-km out to approximately 20.0-km.

To develop Habitat Scores for the Distance to Lek Population and Habitat Variable, the Montana-specific lek-to-nest distance data were analyzed to evaluate potential breakpoints and score magnitudes. Because the percent of nests within each distance is a cumulative total of all nests between the specified distance and the lek, it is difficult to directly use that measure to establish variable scores. To provide a measure better for analysis and scoring purposes, the percent of nests occurring beyond each distance [y = 1 - percent of nests within distance] was calculated (Appendix A, Figure A. 2). This provides a better measure for establishing scores because habitats closer to the leks receive higher values. See the subsection Population and Habitat Scores of Appendix A for the specific breakdown of the Distance to Lek Habitat Scores and the incorporation into the Montana HQT Basemap.

3.2.2.2. Breeding Density

Leks are widely recognized as a focal point for occupancy and seasonal use, and lek counts provide a reasonable index to relative abundance of GRSG populations (Reese and Bowyer 2007). Higher attendance leks likely influence GRSG populations more than lower attendance leks, and the birds using these leks may use habitats across broader spatial scales (Coates et al. 2013).

Breeding density models were used to identify areas with higher function for GRSG populations. Doherty et al. (2010a) developed a widely used spatial model of breeding density that was used in the HQT. The Doherty et al. (2010a) model provides a spatially explicit, continuous variable that identifies breeding density across the range of the species. The model will be run on an as needed basis as updates from MFWP data allows, to maintain accuracy of this variable. See the subsection Population and Habitat Scores of Appendix A for the specific breakdown of the Breeding Density Habitat Scores and the incorporation into the Montana HQT Basemap.

3.2.2.3. Sagebrush Abundance

This variable describes the proportion of the land cover that is classified as sagebrush (i.e., spatial extent) as opposed to canopy cover of sagebrush plants within sagebrush patches. The latter is measured separately by the Sagebrush Cover variable. Those areas in the Multi-Resolution Land Characteristics Consortium National Land Cover Database (MRLC NLCD) sagebrush cover layer for Montana classified as having 3% or more sagebrush cover were considered sagebrush habitat for purposes of developing scores for this variable (Xian et al. 2015). This variable will be updated as the MRLC NLCD datasets are updated.

Available literature did not use consistent analysis areas for purposes of calculating scores for this variable. A 3.14-km2 (1-km radius circle) window size was selected for the HQT because it better characterized habitat heterogeneity at a scale useful for project siting and mitigation than a larger window (e.g., 6.4-km radius circle) would. Additionally, more areas will receive high scores using a 3.14-km^2 window size versus a 6.4-km buffer from a lek center point, especially in areas that have fragmented or converted to non-sagebrush cover by past land use activities. See the subsection Population and Habitat Scores in Appendix A for the specific breakdown of the Habitat Scores and the incorporation into the Montana HQT Basemap.

3.2.2.4. Sagebrush Canopy Cover

The presence of sagebrush is an essential characteristic of GRSG habitat (Connelly et al. 2000, Hagen et al. 2007, Connelly et al. 2011). However, literature recommendations for sagebrush canopy cover for GRSG habitat varies seasonally and regionally. Scores for this Population and Habitat Variable were calculated by evaluating average seasonal sagebrush requirements for GRSG populations in Montana. Sagebrush canopy cover was characterized for winter, nesting/ breeding, and brood/summer use periods, respectively.

Sagebrush canopy cover is an important attribute of nesting habitat because hens nest almost exclusively under sagebrush plants, with some limited exceptions documented in Montana.

In Montana, sagebrush canopy cover used during nesting and breeding periods are similar to those reported elsewhere across the range of GRSG. However, GRSG in Montana use a wide range of sagebrush canopy cover classes and use is based on availability and spatial variation across the GRSG habitats in Montana. The range of sagebrush canopy cover classes is critically important to provide a variety of cover and forage resources that change seasonally. Sagebrush canopy cover is also an important attribute of brood-rearing habitat. Sagebrush canopy cover is an essential component of winter habitat because GRSG winter diets are almost exclusively sagebrush leaves. See the subsection Population and Habitat Scores of Appendix A for the specific breakdown of the Habitat Scores and the incorporation into the Montana HQT Basemap. Updates to datasets used for sagebrush canopy cover will be made as new data becomes available.

3.2.2.5. Sagebrush Height

Sagebrush canopy height is an important aspect of all GRSG seasonal habitats. However, literature recommendations for sagebrush height for GRSG habitat varies seasonally and regionally. Scores for this Population and Habitat Variable were calculated by evaluating reported average seasonal sagebrush requirements for GRSG populations in Montana. Sagebrush height was characterized for winter, nesting/breeding, and brood/summer use periods, respectively.

Sagebrush height is an important attribute of GRSG nesting habitat. Heights of 40.0-cm to 80.0-cm are rarely reported in literature sources specific to GRSG in Montana. Because of the differences in reported Montana sagebrush height values and values reported elsewhere across the range of the species, Montana-specific data and literature were used to evaluate height requirements during the nesting season. During the brood rearing season, GRSG may use habitats that are not dominated by sagebrush. Important structural components in winter habitat include medium to tall (25.0-cm to 80.0-cm) sagebrush stands (Crawford et al. 2004). Ranges for winter use developed across the range of the GRSG may not be representative of conditions in Montana because of differences in sagebrush communities as well as snowfall depths and winter conditions. See the subsection Population and Habitat Scores of Appendix A for the specific breakdown of the Habitat Scores and the incorporation into the Montana HQT Basemap. Updates to datasets used for sagebrush canopy cover will be made as new data becomes available.

3.2.2.6. Distance to Suitable Upland

The mosaic of upland and mesic habitat is important to support populations of GRSG (Connelly et al. 2000, Schreiber et al. 2015). Donnelly et al. (2016) used an internal buffer of 400.0-m from the edge of mesic habitats to remove areas inside large wet meadow, hay, or other mesic habitat complexes. An internal buffer with multiple distances has been developed as the basis for determining scores for this variable. While vegetation and forage characteristics within mesic areas may not vary with distance to upland habitats, mesic habitats closer to adjacent upland habitats are expected to have a higher level of functionality because they are closer to adjacent escape and roost cover.

Mesic habitats within 50.0-m and 100.0-m of upland habitat receive higher variable scores than those mesic habitats that are between 100.0-m and 400.0-m from the upland-mesic edge (Appendix A, Figure A. 7, Table A. 10). Consistent with Donnelly et al. (2016) areas more than 400.0-m from upland habitats will receive a score of 0.0 for this variable. See the subsection Population and Habitat Scores of Appendix A for the specific breakdown of the Habitat Scores and the incorporation into the Montana HQT Basemap.

3.2.2.7. Unsuitable Lands

The EO defines unsuitable habitat as "land within the historic range of sage grouse that did not, does not, nor will not provide sage grouse habitat due to natural ecological conditions such as badlands or canyons" (EO No. 12-2015). Unsuitable habitat would include rock outcroppings and open water or reservoirs of more than 10-acres in size. Areas designated as Unsuitable Lands will be assigned a score of 0.0. See Appendix L for a complete list of land cover types and their designations (suitable vs. unsuitable); land cover types designated as unsuitable comprise the Unsuitable Lands variable.

The Unsuitable Lands variable does *not* include land cover types that once provided sage grouse habitat but have since been converted. For example, recently burned (< 10 years) shrublands would be considered suitable sage grouse habitat. However, high elevation areas or recently burned forested areas are considered Unsuitable habitat because those land cover types never used to be sage grouse habitat. Therefore, urban areas and currently disturbed areas are considered Suitable if located in areas that once provided sage grouse habitat because they have the potential to be reclaimed. Since cities and towns are exempt from the HQT, they are captured in the Existing Anthropogenic Surface Disturbance layer and those areas receive a 0.0 HQT Score. Other Human Land Use Land Cover Classes are also captured at a higher spatial resolution in the digitized Existing Anthropogenic Surface Disturbance layer than in the MRLC LULC dataset used to define Unsuitable Lands. The Direct footprints of existing disturbances receive a 0.0 HQT Score. The Existing Anthropogenic Surface Disturbance layer is used in the following section to develop the Anthropogenic Variables incorporated in the Montana HQT Basemap.

See the subsection Population and Habitat Scores of Appendix A for the specific breakdown of the Habitat Scores and the incorporation into the Montana HQT Basemap.

3.2.3. Anthropogenic Variables Used to Adjust the Montana HQT Basemap

Anthropogenic factors affect the functionality of GRSG habitat. Each Anthropogenic Variable (e.g., oil and gas wells, transmission lines, agriculture, mining, roads) is thoroughly described along with the spatial data sources in Appendices B – I. Anthropogenic Variables are incorporated into the Montana HQT Basemap and result in the computation of Habitat Function lost for newly proposed development projects.

3.2.3.1. Oil and Gas

Numerous studies have shown that oil and gas well pads consistently have a deleterious effect on habitat selection by GRSG and on lek persistence and attendance, although the size of the effect varied by region, development type, and season. Research indicates that anthropogenic features, including oil and gas well pads, negatively affect GRSG habitat (including lek persistence and winter habitat use) at various spatial scales. Dinkins et al. (2014) notes that sage grouse selected habitat with lower densities of oil and gas structures at all reproductive stages.

See the subsection Anthropogenic Variables of Appendix A for the specific calculation of the Anthropogenic Score for existing oil and gas well pads and the incorporation into the Montana HQT Basemap, as well as Appendix B for the literature review and the specific calculation of the Anthropogenic Score as it pertains to new Oil and Gas projects.

3.2.3.2. Tall Structures

While research is needed to fully assess the effects of tall structures (e.g., communication towers, weather towers, cooling towers), there is a growing body of evidence that tall structures impact GRSG, with recent studies providing additional support for earlier findings that impacts are primarily from increased predation risks and fragmentation of habitat. Here, we consider impacts distinct to tall structures on the landscape that could provide avian perching or nesting subsidies.

Anthropogenic structures such as cooling towers, communication towers, and weather stations provide perching and nesting subsidies for avian predators (Coates et al. 2014a, Dinkins et al. 2014a). Tall structures provide improved avian predator hunting efficiency in an otherwise relatively flat open landscape (Connelly 2004, Dinkins et al. 2014a). GRSG select nest sites and brood rearing habitat farther away from tall structures, partially based on a perceived risk of predation (Braun 1998, Dinkins et al. 2012, Dinkins et al. 2014). Land cover, topography, and cumulative human activity contribute to the level of impacts from tall structures.

See the subsection Anthropogenic Variables of Appendix A for the specific calculation of the Anthropogenic Score for existing tall structures and the incorporation into the Montana HQT Basemap, as well as Appendix C for the literature review and the specific calculation of the Anthropogenic Score as it pertains to new Tall Structure projects.

3.2.3.3. Transmission/Distribution Structures: Lines, Structures/Poles, and/or Substations

Transmission/Distribution Structures are composed of lines and associated structures/poles. The linear characteristics of Transmission/Distribution Structures result in both Direct and Indirect Impacts to GRSG populations through habitat fragmentation and increased predation. The effects of Transmission/Distribution Lines on GRSG have been considered in several recent studies of habitat use and lek attendance (e.g., Walker et al. 2007, Dinkins et al. 2014b, Knick et al. 2013, LeBeau 2012, Johnson et al. 2011, Hanser et al. 2011, Gillan et al. 2013, Shirk et al. 2015, Gibson et al. (in press). Literature sources provide evidence of Transmission Line impacts suggesting that avoidance behavior has the potential to result in a population-level effect. Highly territorial, breeding ravens exploit anthropogenic features common to transmission corridors and are more likely to predate sage grouse nests more often than migrant ravens (Bui et al. 2010). Transmission poles are the primary features of Transmission Structures capable of supporting raven colonization by providing anthropogenic nesting substrates in areas where natural elevated features are limited (Howe et al. 2014, Knight and Kawashima 1993, Steenhof et al. 1993).

Burton and Mueller (2006) documented territorial raven nests were no more than 1-km apart. To allow for nesting behavior of territorial ravens, Transmission/Distribution Structures will be considered as co- located if they are within 1-km of each other.

See the subsection Anthropogenic Variables of Appendix A for the specific calculation of the Anthropogenic Score for existing Transmission/Distribution Structures and the incorporation into the Montana HQT Basemap, as well as Appendix D for the literature review and the specific calculation of the Anthropogenic Score as it pertains to new Transmission Structure projects.

3.2.3.4. Wind Facilities

Disturbances created by wind facilities likely include increased predation to GRSG due to the presence of human development and edge effects. Because scientific research on the effects of wind energy is limited, a conservative approach was used to develop scores for this Anthropogenic Variable.

See the subsection Anthropogenic Variables of Appendix A for the specific calculation of the Anthropogenic Score for existing wind facilities and the incorporation into the Montana HQT Basemap, as well as Appendix E for the literature review and the specific calculation of the Anthropogenic Score as it pertains to new Wind Facility projects.

3.2.3.5. Roads, Railways, and Active Construction Sites

Research on the effects of roads on GRSG indicates that there are variable levels of disturbance based on distance to roads, size of roads, traffic frequency, and associated noise. Seasonal and daily timing of traffic and its associated noise is an important aspect of managing disturbance of GRSG because animal behaviors such as attracting mates, or males competing on leks, often occur in the morning or evening, the same time as rush hour traffic. The frequency of the sound waves produced by traffic on roads can mask these important behavioral communications, which occur at the same or similar frequencies (Blickley and Patricelli 2012). A related source of disturbance is intermittent traffic on smaller roads. This type of activity and noise may be more difficult for species to habituate to due to its unpredictable nature (Blickley et al. 2012).

See the subsection Anthropogenic Variables of Appendix A for the specific calculation of the Anthropogenic Score for existing roads, railways, and active construction sites and the incorporation into the Montana HQT Basemap, as well as Appendix F for the literature review and the specific calculation of the Anthropogenic Score as it pertains to new Road, Railway, and Active Construction Site projects.

3.2.3.6. Pipelines, Fiber Optic Cable, and Other Buried Utilities

Major or minor pipelines, buried fiber optic cable, and other types of buried utilities projects have in common a high level of surface disturbance and human activity during the construction phase, followed immediately by the reclamation phase for the recovery of vegetated habitat. The operations phase is different from most project types in that, although the lifetime of the project would be considered permanent (longer than 25 years), a buried pipeline or cable typically creates a temporary *surface* disturbance. The temporary surface disturbance occurs during the construction phase requiring and results in a relatively brief overall disturbance phase because the operations for a buried feature are sub-surface and do not impact GRSG or their habitat at that point. This would effectively allow buried projects to move directly from the construction phase immediately into the reclamation phase.

It is important for the HQT to accurately quantify the initial disturbance (e.g., construction phase), however, and then estimate the timeframe for the reestablishment of native vegetation (e.g., reclamation phase). Depending on the type of project, surface disturbance could be a corridor of several hundred feet using backhoes and tracked equipment for a major gas pipeline and associated activities, or minimal disturbance for fiber optic cable or other utilities using a single cable plow or micro-trenching machine. After the construction phase, the primary concern for GRSG habitat conservation is controlling for invasive weeds or erosion within the disturbance area as the reclamation phase is initiated.

Relatively few studies have been conducted on the Indirect Impacts of pipelines on GRSG distribution. We are not aware of any studies specifically addressing effects of buried utilities, but the common characteristic is the duration of the construction and reclamation phases. Where the effects of pipelines have been considered, the results are inconclusive because the pipelines are included as one factor among several potential explanatory variables, many of which have confounding effects since they are often co-located with other infrastructure (Knick et al. 2013, Johnson et al. 2011).

See the subsection Anthropogenic Variables of Appendix A for the specific calculation of the Anthropogenic Score for existing pipelines, fiber optic cables, and buried utilities and the incorporation into the Montana HQT Basemap, as well as Appendix G for the literature review and the specific calculation of the Anthropogenic Score as it pertains to new Pipeline, Fiber Optic Cable, and Buried Utility projects.

3.2.3.7. Agriculture, Mines, and Other Large-scale Land Conversion Processes

Conversion of GRSG habitat to agricultural lands is another source of habitat loss and degradation of habitat value at the landscape scale (e.g., Knick et al. 2013, Smith et al. 2016, Aldridge et al. 2008). This same conversion process may also be present for other moderate to large-scale land uses, including mining. The effects of mines on GRSG have not been specifically studied and are likely to vary widely based on the type of mine (e.g., surface or below ground) and infrastructure. Removal of vegetation during surface mining would likely make the area unsuitable for GRSG and may be similar to the conversion of sagebrush to agriculture.

See the subsection Anthropogenic Variables of Appendix A for the specific calculation of the Anthropogenic Score for existing agriculture, mines, and other large-scale land conversion processes and the incorporation into the Montana HQT Basemap, as well as Appendix H for the literature review and the specific calculation of the Anthropogenic Score as it pertains to new Agriculture, Mine, and other Large-scale Land Conversion projects.

3.2.3.8. Compressor Stations and Other Noise Producing Sources

Noise disturbance has been documented in literature to have deleterious effects on GRSG activities. Recent research has demonstrated that noise from natural gas development negatively affects GRSG abundance, stress levels, and behaviors. Other types of anthropogenic noise sources are similar to gas-development noise and, thus, the response by GRSG is likely to be similar. The results of research suggest that effective management of the natural soundscape is critical to the conservation and protection of GRSG (Patricelli et al. 2013). Acoustic communication is very important in the reproductive behaviors of GRSG, and energy exploration and development activities generate substantial noise (Blickley and Patricelli 2012). Such a disruption in GRSG communication may interfere with the ability of females to find and choose mates and ultimately negatively affect mating success (Blickley and Patricelli 2012).

For a prey species, such as GRSG, noise may also increase predation risk by masking the sounds of approaching predators (e.g., coyote, badger), and contribute to behavioral disruptions such as elevated heart rate, interrupted rest, and increased stress levels, all of which may affect health and reproduction or cause avoidance of noisy areas (Patricelli et al. 2013).

The effects of noise production (and, conversely, noise mitigation techniques) have the potential to vary greatly by source, type, and location. The study of noise impacts is an emerging science and this variable may be changed to better represent new findings as required to maintain consistency with the best available science.

See the subsection Anthropogenic Variables of Appendix A for the specific calculation of the Anthropogenic Score for existing compressor stations and other noise producing sources and the incorporation into the Montana HQT Basemap, as well as Appendix I for the literature review and the specific calculation of the Anthropogenic Score as it pertains to new Compressor Station and other noise producing projects.

3.2.4. Creating the Final Montana HQT Basemap

Habitat Scores are averaged (as opposed to multiplied to avoid zeroing out of any given pixel by a single vegetation or population variable having a Habitat Score of 0) to compute the Total Habitat Score. The Anthropogenic Scores are multiplied together to compute the Total Anthropogenic Score. The Total Habitat Score and the Total Anthropogenic Score are multiplied together and divided by 100 to produce the Montana HQT Basemap Total. See Appendix A for more details regarding the specific data sources and technical methodology used for developing the Montana HQT Basemap.

There is one single basemap for the state and it is used as the basis for calculating Functional Acres Gained and Lost for projects. Project specific Raw HQT Scores are computed using the results of the Montana HQT Basemap Total. The technical methodologies for calculating the Raw HQT Score differ for new debit and credit projects, but generally assess the characteristics of the new project and compare the new project with the Montana HQT Basemap Total. See Sections 4.0 for more information related to Credit Providers and Section 5.0 for Debit Producers.

4.0 THE HQT CALCULATION PROCESS FOR CREDIT PROVIDERS

Mitigation credits are created by removing or limiting a threat to GRSG through preservation or by improving habitat quantity and/or quality through restoration or enhancement actions (Appendix J). Permitee-responsible mitigation projects, which the debit developer is solely responsible for ensuring the completion and success of the compensatory mitigation activity(ies), are included as a restoration or enhancement action which credits are calculated for through the HQT in a similar manner. The HQT calculates Functional Acres gained, which are then made equivalent to credits at a ratio of 1:1 in the mitigation marketplace through application of policy described in the *Policy Guidance Document*. A Functional Acre is a single unit that expresses the assessment of quantity (acreage) and quality (function) of habitat or projected habitat through the quantification of a set of local and landscape conditions. The Raw HQT Score is the final output of the Montana HQT after all Functional Acres gained have been summed for the life of the project and Third Level Assessments results are incorporated.

For a project area to be eligible for credits, it must first score 1.0 in the First Level Assessment. This means that the credit project area must be located within designated sage grouse habitats. Credit-eligible habitat must be in context with all essential habitats required annually by GRSG within a fully functioning landscape. For example, an acre of nesting habitat not adjacent and accessible to breeding areas, brood-rearing areas and winter habitat has no value to GRSG and therefore would not qualify as a credit source. Credit sites likely to provide the highest quality habitats and greatest number of Functional Acres will be those that are consistent with the guidance provided in the EO, such as: total disturbance (e.g., DDCT score) is less than 5%, and no overhead transmission lines are found within four miles of active leks. See the *Policy Guidance Document* for more details on qualifying credit projects.

The four mechanisms for credit creation in Montana are:

1. **Preservation:** Credits may be generated on a property through preservation. Montana has large tracts of intact sagebrush habitats that provide year-round habitat for GRSG. These intact areas can be preserved, for example, through conservation easements or lease agreements that avoid future habitat loss or fragmentation by the voluntary, legal removal of identified threats such as subdivision or cultivation.

2. **Restoration:** Credits may be generated on a property through restoration. Restoration can be defined as the process of assisting the recovery of a resource (including its values, services, and/or functions) that has been degraded, damaged, or destroyed to the condition that would have existed if the resource had not been degraded, damaged, or destroyed (BLM 2016). Restored areas can be important links for connectivity, provide important mesic habitat for late summer brood rearing, or can provide other seasonal habitat components, thereby increasing the value of surrounding, intact sagebrush lands.

Examples of restoration include the re-establishment of suitable GRSG habitat on abandoned mining claims, abandoned industrial sites, eradication of invasive plant species, removal of encroaching conifers, removal of abandoned transmission lines and towers or other anthropogenic structures, converting cropland back to rangeland with a sagebrush component, or restoration of wet meadows by restoring proper hydrology and plant communities.

3. **Enhancement: C**redits may be generated on a property through enhancement. Enhancement requires an increase or improvement in quality, value, or extent of sage grouse habitat that has been degraded, or could be managed to increase the value of that habitat over its current value

(BLM 2016). For credit projects, this approach can be used to increase existing credits by improving the habitat quality or function to GRSG, thereby increasing the Raw HQT Score and the amount of credits available to the market. Examples include improving existing suitable GRSG habitat by adding a sagebrush component to existing native grasslands, or increasing native forb abundance or diversity in mesic areas.

4. **Permittee-responsible: C**redits may be generated on a property through permittee-responsible mitigation projects, in which the debit project developer is solely responsible for ensuring that compensatory mitigation activities (which may occur later in time at or away from the site of impact through indirect effects) are completed and successful. Such projects require an increase or improvement in quality, value, or extent of sage grouse habitat that has been degraded, or could be managed to increase the value of that habitat over its current value (BLM 2016). For credit projects, this approach can be used to increase existing credits by improving the habitat quality or function to GRSG, thereby increasing the Raw HQT Score and the amount of credits available to the to the market.

Examples include working directly with a landowner to place a conservation easement or lease on the property, removing obsolete transmission lines and poles or communications towers, permanently plugging and abandoning oil or gas wells that are no longer in production and unlikely to ever be converted back into production.

The following sections describe how the HQT calculates the Functional Acres of a credit project.

4.1. First Level Assessment for Credit Sites in Designated Sage Grouse Habitat

The State completed the First Level Assessment of GRSG habitat in Montana in 2015, mapping currently defined occupied habitat (FWP 2015). The habitat was defined as General Habitat, Core Area, or Connectivity Areas for GRSG (Montana EOs 12-2015 and 21-2015). On federal lands, the U.S. Bureau of Land Management (BLM) and the U.S. Forest Service (USFS) GRSG habitats are delineated in the agency's respective land use plans.

Projects located in the First Level Assessment area receive a score of 1.0 and are evaluated in the Second Level Assessment process. Projects located entirely outside of designated state or federal habitat for GRSG receive a score of 0.0 and are not further evaluated as part of the Montana HQT.

4.2. Second Level Assessment for Credit Sites to Estimate Functional Acres

Credit projects that received a First Level Assessment score of 1.0 complete the Second Level Assessment for an HQT estimate of Functional Acres for the project area (Figure 4. 1 and Figure 4. 2). The Second Level Assessment considers the details of a credit project site such as location, size, type, and duration. Together, these project details define the Project Assessment Area component of the HQT. The Third Level Assessment (site-specific) is required for all credit projects (Section 4.4)

The HQT process converts the physical acres identified in the Project Assessment Area to Functional Acres for analysis. A Functional Acre is a single unit of value that expresses the assessment of quantity (acreage) and quality (function) of habitat or projected habitat through the quantification of a set of local and landscape conditions. The Raw HQT Score (the final output of the HQT) is used for calculating, quantifying, expressing, and exchanging credits and debits.

For credit projects, the Project Assessment Area is the property boundary or the conservation easement agreement boundary. The Project HQT Basemap is extracted from the Montana HQT Basemap based on the Project Assessment Area footprint. The pixel values within the Project HQT Basemap are then averaged and the result is multiplied by the total area (physical acres) of the Project Assessment Area. A pixel is the smallest unit of information in an image or raster map. A pixel is usually square or rectangular and is often used synonymously with cell.

The result is then multiplied by the number of years defined for the project (perpetual conservation easements: 100 years; term leases: number of years of the lease). The final result is the Raw HQT Score (or the Functional Acres gained, including as a result of avoided loss, during the life of the project) which is used to calculate available credits. In some cases, the process can be repeated to calculate subsequent Raw HQT Scores for a project to compare changes in habitat over time after management treatments are applied.

4.2.1. How the HQT is Used to Calculate Functional Acre Scores Depends on the Type of Credit Project

Project milestones can be identified in a credit site management plan to determine how often the HQT should be run to detect changes in the Raw HQT Score because of restoration or enhancement actions (See *Policy Guidance Document*). Habitat uplift can be measured, based on performance standards, by the difference between the Montana HQT Basemap and the milestone HQT score(s) when the HQT is run at intervals. The Third Level Assessment can be used to quantify habitat uplift and inform changes in the habitat values for pixels that are assessed at a site-specific scale. See Appendix J for more details.

- **Preservation** — This type of credit project will not require re-running the HQT (Figure 4. 1). The Raw HQT Score for the Project Assessment Area will be applied in conjunction with policy considerations to calculate the amount of credits available for the preservation project.
- **Restoration** — For this type of project, the Raw HQT Score for the Project Assessment Area will be applied in conjunction with policy considerations to calculate the amount of credits available prior to habitat management actions (Figure 4. 2). This type of credit project will require re-running the HQT at pre-determined milestones to detect changes in habitat variables over time due to habitat management actions. The milestone(s) will set the desired future Raw HQT Score for the Project Assessment Area to calculate uplift after restoration actions are completed. The increase in available Functional Acres is dependent on the species of vegetation being restored, and the expected growth and recovery rates for each species.
- **Enhancement —** For this type of project, the Raw HQT Score for the Project Assessment Area will be applied in conjunction with policy considerations to calculate the amount of credits available prior to habitat management actions (Figure 4. 2). This type of credit project will require re-running the HQT at pre-determined milestones to detect changes in habitat variables over time due to habitat management actions. The milestone(s) will set the desired future Raw HQT Score for the Project Assessment Area to calculate uplift after enhancement actions are completed. The increase in available Functional Acres is dependent on the success of the habitat enhancement actions, and the expected growth and recovery rates for each species.
- **Permittee-responsible** — The Raw HQT Score for this type of credit generating project will be calculated similarly as a restoration or enhancement project (Figure 4. 2).

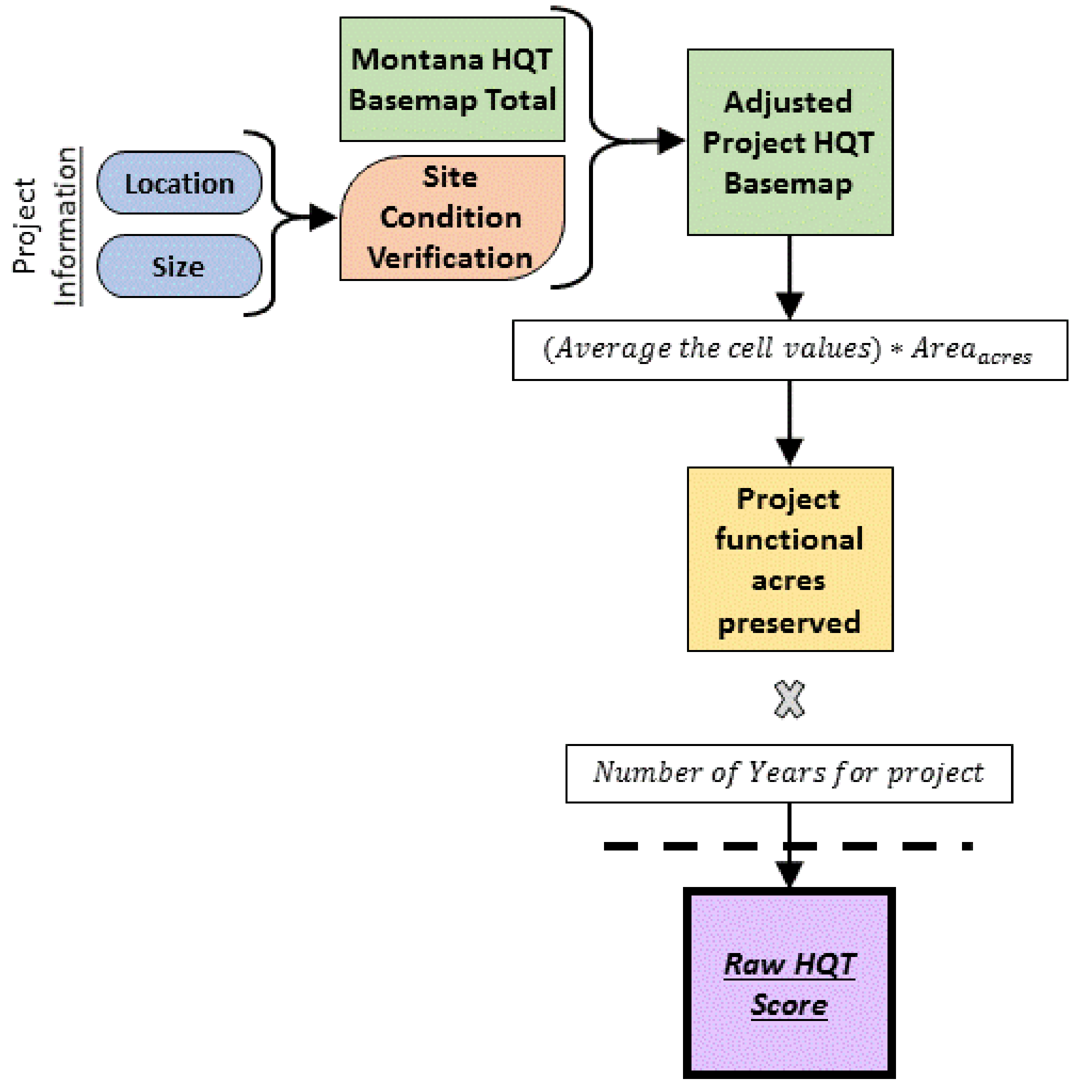

Figure 4. 1. Flowchart for the development of the Raw HQT Score for Preservation Projects.

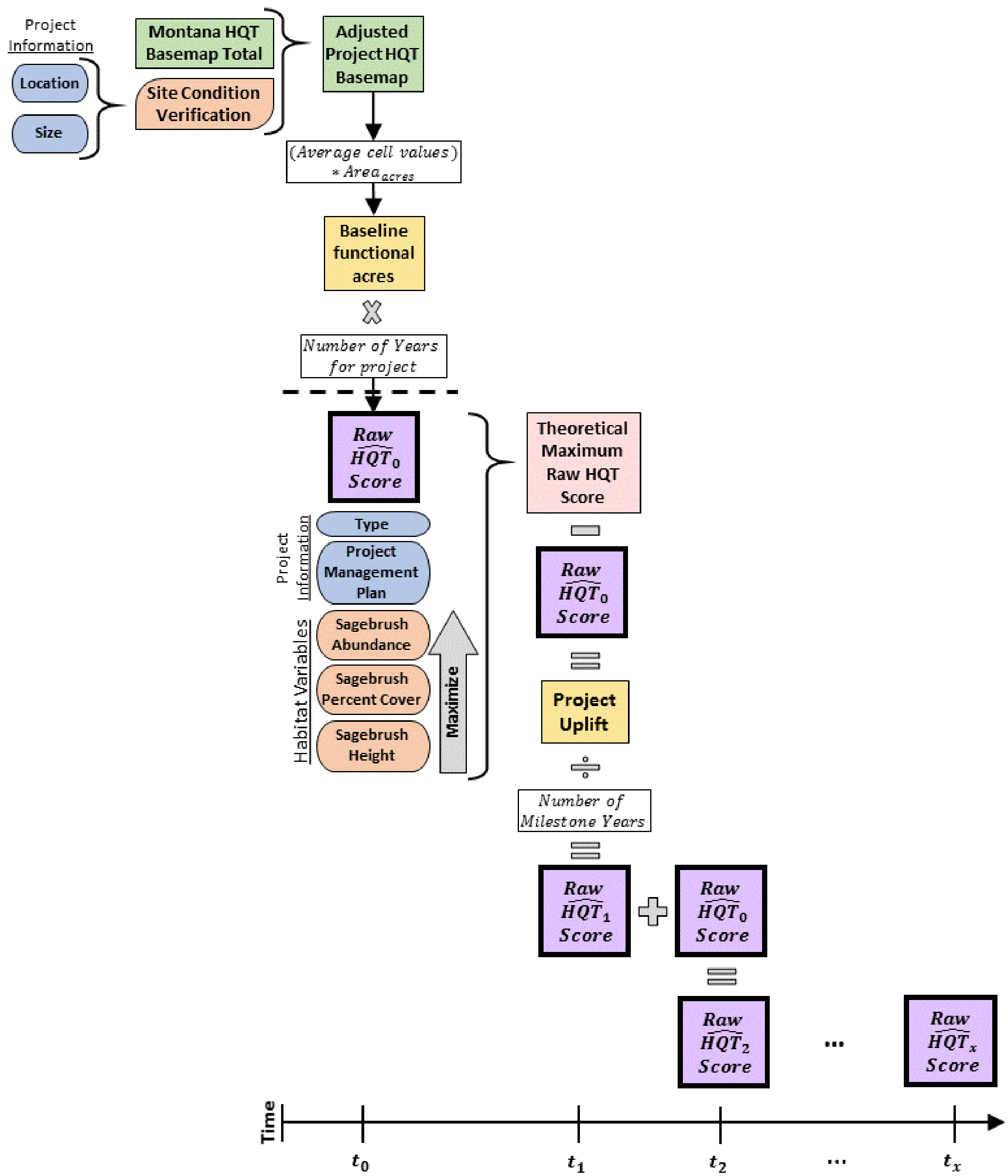

Figure 4. 2. Flowchart for the development of the Raw HQT Scores for Restoration, Enhancement, and Permittee-Responsible Mitigation Projects.

4.3. Third Level Assessment Verification of the Second Level Results at the Local/Site-specific Scale for Credit Providers

The Third Level Assessment will consist of field verification of scores from the Second Level Assessment and consider variables that are not captured in the Second Level geospatial assessment. Field verification of Habitat Function is an important step in the Montana HQT and is similar to other habitat assessment frameworks for GRSG (Boyd et al. 2014, NNHP and SETT 2014, Stiver et al. 2015, EDF 2015a, EDF 2015b).

Credit Producers are encouraged to contemplate local knowledge of a specific site, when proposing a credit site due to the coarse scale of the Second Level Assessment data. A Third Level Assessment is required for credit generation projects to accurately report baseline conditions and opportunity for credit gains not captured in the Second Level Assessment.

The Third Level Assessment (field-based verification) is conducted after the Second Level Assessment has been completed. The assessment process provides a site-scale verification of Habitat Function using detailed vegetation data and allows project proponents to field verify existing conditions and vegetation calculations in the project area. Vegetation variables measured in the Third Level Assessment include: sagebrush canopy cover, sagebrush canopy height, invasive plant species cover, conifer cover, forb cover and unmapped anthropogenic disturbances. The HQT Functional Acres score from the Second Level Assessment may then be adjusted by changing pixel values, based on the results of the Third Level Assessment to accurately characterize on the ground conditions.

Subsequent Third Level Assessments are conducted to verify changes through time and document project success where a credit project Plan outlines specific milestones. Each subsequent Third Level Assessment would be compared to the prior assessment to measure trends. How often Third Level Assessments would be necessary will be identified in the project-specific Plan according to the project type and objectives.

Data collection will be the responsibility of the project proponent/applicant. These data will be submitted to the State for verification purposes. The State may conduct field visits to the site to field verify site conditions. Additional site-specific field-based data collection may be required by federal land management or state agencies following respective agency requirements.

The main goals of Third Level Assessment for credit projects are:

1. to verify the data and output from the Second Level Assessment including sagebrush canopy cover, and sagebrush canopy height habitat variables; and potentially unmapped anthropogenic disturbances or variables on the landscape;

2. to measure important GRSG habitat variables not directly characterized in the Second Level Assessment due to lack of spatial data, including invasive plant species cover, conifer canopy cover, and forb cover; and

3. to verify project trends in meeting specified milestones and performance standards.

4.3.1. Field Protocol

Verification of Second Level Assessment results will be accomplished through low-intensity field sampling. At a minimum, Third Level Assessment data will be collected within the project footprint but should be collected across the entire assessment area (including the footprint for both Direct and Indirect Impacts) if the proponent chooses to do so and has legal access to survey outside of the project footprint.

Data will be collected in general categories (i.e., tree, shrub, grass/forb). These general categories will be surveyed using line-point intercept (LPI; Herrick et al. 2016). Data collection will include sagebrush canopy cover, sagebrush height, grass/forb cover, invasive plant species cover and, conifer canopy cover. Additionally, the presence of anthropogenic or wildfire disturbances not captured by the Second Level Assessment should be noted and delineated.

The Program will provide protocols to be followed for field verification/data collection. The Program protocols will generally follow standardized data collection methods outlined in the Sage-Grouse Habitat Assessment Framework (HAF; Stiver et al. 2015) and BLM Assessment Inventory and Monitoring protocols (AIM; Herrick et al. 2016) to provide consistent data collection across projects. If projects are required to collect other, similar data, using protocols designed for purposes other than use in the HQT (reclamation planning, ecological site or habitat mapping, etc.), proponents should coordinate with the Program to ensure methods and results will provide the information necessary for use in the Third Level Assessment process. All data will be submitted to the State on the required State forms.

Data may be collected by the project proponent or a representative selected by the proponent. State or federal agency cooperators will provide Third Level Assessment field verification training workshops. All individuals completing Third Level Assessment field surveys must attend at least one training workshop. The State and collaborative partners will develop a Third Level Assessment verification field sampling guide, protocols and required data forms. Sample locations within a project footprint (and surrounding assessment area as appropriate) will be randomly selected by the Program and located in a representative area that reflects the general conditions of the larger assessment area.

Figure 4.3 describes the transect pattern for a linear project. A single 50-m transect will be run in a manner which represents all vegetation types present (tree, shrub, forb/grass). The transect should be run perpendicular to but within the project boundary, for every half mile. A minimum number of data transects will be determined on a specific project basis included in the project Plan.

Transects (Figure 4.3) will be run in manner which represents all vegetation types present (tree, shrub, forb/grass). A minimum of one data point per meter will be collected, resulting in 50 data sample points per transect. These transects will be run for linear projects, such as removal and restoration of a road or transmission line.

The spoke design includes a center point with three 50-m transect lines radiating out from the center (Figure 4.4). One data point is collected for each meter along the transect lines. If the site is a monoculture of only one dominant vegetation type (tree or shrub or grass/forb dominated types) each spoke design transect can be randomly selected. If the site is comprised of varied vegetation types, one spoke design transect should be placed within each dominant vegetation type (tree, shrub or forb/grass dominated area) where the dominant vegetation type represents more than 20% of the site.

Each individual transect will include a minimum of one set of photo points. Spoke Design samples will have three separate photo points; one per spoke. Additional photos may be required to document habitat variables. Photo points will correspond with the associated field transect/point locations and be collected using provided forms and protocols.

A minimum number of data transects and photo points will be determined on a project specific basis included in the project Plan.

Table 4. 1. Score Sampling Density for Third Level Site Verification (Minimum Sampling Density).

Size (acres)	No. of Transects (1 point has 3 transects in a spoke design pattern)
≤ 5	1 linear transect
> 5 and ≤ 20	1 Spoke Design point
> 20 and ≤ 100	2 Spoke Design point. 1 Spoke Design point per category*
> 100 and ≤ 400	3 Spoke Design points per 100-acres per category
> 400	1 Spoke Design point per 100-acres per category
Linear features	One linear transect any time the linear feature crosses sage grouse habitat (core, general, connectivity). If the linear feature crosses greater than ½ mile of designated sage-grouse habitat, then the desired sampling frequency is 1 linear transect every half mile randomly placed.

***For sites larger than 20.0-acres, the category (e.g., tree, shrub, or grass/forb) must comprise at least 20% of a site to be sampled separately. Categories comprising less than 20% of a site would be considered small inclusions and would not need to be separated out for sampling purposes.**

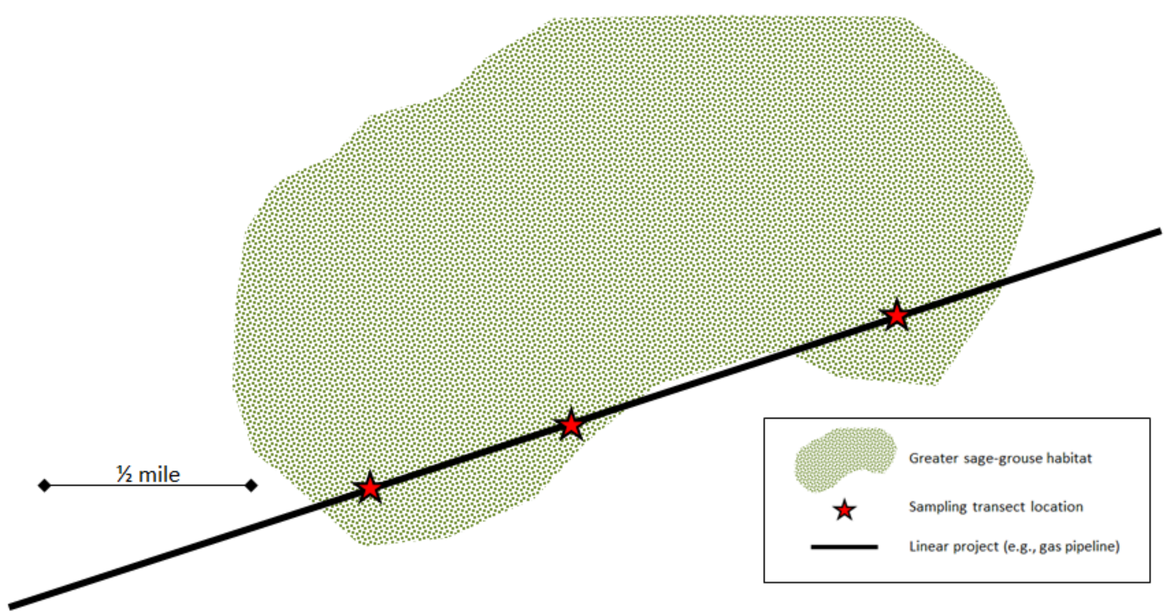

Figure 4. 3. The Linear Design is best for crossing the linear features. Transects are placed perpendicular to the linear feature.

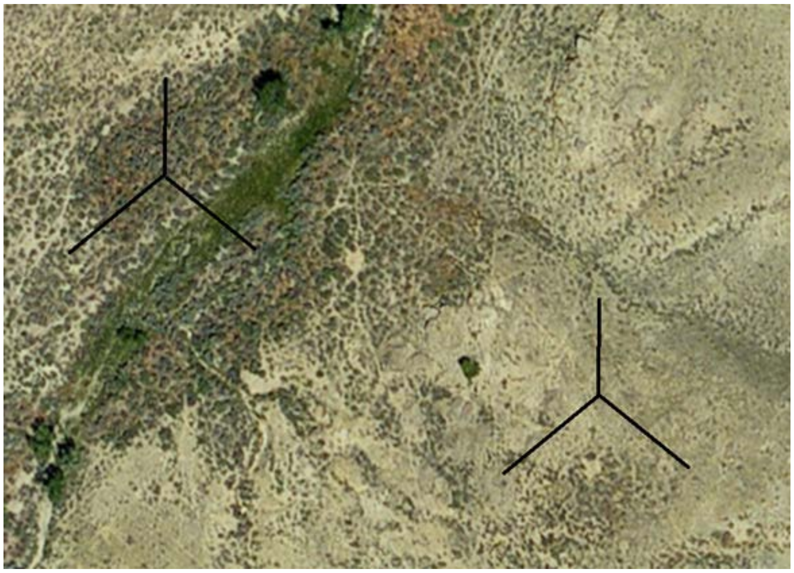

Figure 4. 4. Spoke Design will be used for non-linear projects (Herrick et al. 2016). Example of a project with an area larger than 20.0-acres, requiring two spoke design points with three 50.0-m transects each. Transects are located in a way to capture variation of dominant vegetation.

4.3.2. Updates to Second Level Assessment Results for Credit Projects

The Third Level Assessment is intended to provide a more accurate characterization of the credit project area. Results of Third Level Assessment field data collection efforts will be used to confirm, and where needed, revise Second Level Assessment Habitat or Anthropogenic Variable Scores. The Second Level Assessment provides estimates of sagebrush canopy cover and height (scores range from 0.0-100.0 for each) from publicly available datasets, but these data are reported at a coarse scale and may not always accurately reflect the existing on-the-ground conditions at a given site. Invasive plant species, conifer cover, and forb availability Habitat Variables are not directly assessed in the Second Level Assessment, but are treated as though they provide the maximum suitability for GRSG and are given a Habitat Score of 100, as a default.

The results of the Third Level Assessment field verification will inform Variable Scores and allow for a Final Raw HQT Score, specific to the credit project Assessment Area. Variables used in the Second Level Assessment results would be adjusted, where appropriate, then the HQT model would be run, using the adjusted variables, to generate an updated calculation of Montana HQT Basemap. The revised project-specific Montana HQT Basemap will represent the baseline condition from which the final Raw HQT Score is calculated and projected Functional Acres gained or preserved (avoided loss) are calculated.

The Third Level Assessment is required to provide a more accurate appraisal of the Assessment Area and could produce a score that is lower or higher than the original Second Level results. Third Level Assessment field data used to adjust the Second Level Assessment variables will initially apply only to the site-specific individual project it was collected for. All Third Level Assessment field data will be compiled by the Program and incorporated into the Montana HQT Basemap on a regular basis, determined by the Program.

5.0 THE HQT CALCULATION PROCESS FOR DEVELOPERS

Debits are created by an action that reduces habitat quantity and/or quality. Reclamation is the habitat recovery approach available for project developers to bring development sites back to pre-project conditions (Appendix K). The HQT calculates Functional Acres lost, which are then made equivalent to debits at a ratio of 1:1 in the mitigation marketplace through application of policy described in the Policy Guidance Document. A Functional Acre is a single unit that expresses the assessment of quantity (acreage) and quality (function) of habitat or projected habitat through the quantification of a set of local and landscape conditions. The Raw HQT Score is the final output of the Montana HQT after all Functional Acres lost have been summed for the life of the project and voluntary Third Level Assessments results are incorporated.

Debit projects that received a First Level Assessment score of 1.0 complete the Second Level Assessment for an HQT estimate of Functional Acres for the project area. The Second Level Assessment considers the details of a debit project site such as location, size, type, and duration. Together, these project details define the Project Assessment Area component of the HQT.

The HQT process converts the physical acres identified in the Project Assessment Area to Functional Acres for analysis. A Functional Acre is a single unit of value that expresses the assessment of quantity (acreage) and quality (function) of habitat or projected habitat through the quantification of a set of local and landscape conditions. The Raw HQT Score is the final output of the Montana HQT after all Functional Acres lost (or gained) have been summed for the life of the project and Third Level Assessments results (as needed) are incorporated. The Raw HQT Score is used for quantifying, expressing, and exchanging credits and debits.

For debit projects, the Project Assessment Area is the direct footprint of the project infrastructure (Direct Impacts) and the largest buffer boundary for anthropogenic effects of the project (Indirect Impacts). The Project HQT Basemap is extracted from the Montana HQT Basemap based on the Project Assessment Area footprint. The pixel values within the Project HQT Basemap are then averaged and the result is multiplied by the total area (acres) of the Project Assessment Area. A pixel is the smallest unit of information in an image or raster map. A pixel is usually square or rectangular and is often used synonymously with cell.

The result is then multiplied by the number of years defined for the life of the project, producing the Raw HQT Score (or the Functional Acres lost during the life of the project) which is used to calculate debits.

The distinct phases in the life of a development project are construction, operation, reclamation, and abandonment. From a project planning standpoint, the HQT can be used to evaluate project alternatives and identify least cost development solutions for business decisions.

The following sections describe the implementation of the HQT to quantify Functional Acre losses produced over the life of a project. Functional Acre losses, along with application of policy considerations, will determine the total mitigation obligation. For disturbance specific metrics, see Appendices B – I. For a definition of Reclamation for debit projects, and descriptions of how it can be used to shorten life of project debit calculations, see Appendix K. See the *Policy Guidance Document* for details on credit calculations.

5.1. FIRST LEVEL ASSESSMENT FOR DEVELOPMENT PROJECTS IN DESIGNATED SAGE GROUSE HABITAT

The State completed the First Level Assessment of GRSG habitat in Montana in 2015, mapping currently defined occupied habitat (FWP 2015). The habitat was then defined as General Habitat, Core Area, or Connectivity areas for GRSG (Montana EOs 12-2015 and 21-2015). Projects located in the First Level Assessment area receive a score of 1.0 and are evaluated in the Second Level Assessment process. Projects located entirely outside of designated state or federal habitat for GRSG receive a score of 0.0 and are not further evaluated as part of the Montana HQT and no mitigation is required.

5.2. SECOND LEVEL ASSESSMENT TO ESTIMATE FUNCTIONAL ACRES LOST FROM DEVELOPMENT PROJECTS

All development (debit) projects that received a First Level Assessment score of 1.0 must complete the Second Level Assessment. The Second Level Assessment calculates the number of Functional Acres lost during the construction, operation, reclamation, and abandonment phases in the life of a project. This produces a final Raw HQT Score, which is used to calculate the total number of debits for the project.

The HQT enables project developers to evaluate multiple project sites and configurations to minimize habitat losses. This utility enables HQT users, land managers, and others to make informed choices before making final project decisions and implementing the field-based Third Level Assessment (Section 5.4).

The Second Level Assessment begins when the proponent submits a description for all project activities and geospatial files that detail the physical footprint of the project infrastructure. This information is necessary to identify the type of project being proposed, the duration of the project, and the Project Assessment Area, which is defined by the potential Direct and/or Indirect Impacts that may result from its implementation (Figure 5. 1).

The Project Assessment Area is the combined area of the direct project footprint (where the project removes vegetation from the landscape) and the spatial extent of the Indirect Impacts (the influence of project activities or infrastructure beyond the footprint), if any (Appendices B – I). This is the area from which the number of Functional Acres lost is calculated. The HQT score for each project phase is then multiplied by the number of years for each phase to get the Raw HQT Score for the given project phase (Figure 5. 1).

An important aspect of calculating Raw HQT Scores for a development project is the function of time. The Second Level Assessment considers the details of a debit project such as location, size, type, and duration (i.e., timeframe), and the HQT quantifies functional habitat acres present during each phase (e.g., construction duration, operations duration, reclamation duration). The HQT calculates both the Functional Acres present in a project site, the temporal availability of those Functional Acres, and Functional Acres lost as project activities are implemented and habitat conditions change. After a project and all infrastructure is removed from the landscape, the habitat can begin to recover within the first year. The Raw HQT Score considers the gradual return of suitable GRSG habitat function and vegetation cover because of reclamation activities in disturbed areas.

Changes in the Functional Acres score over the life of a project, in conjunction with policy considerations outlined in the companion *Policy Guidance Document*, determine the final number of debits. Because the HQT is an objective estimate, calculations of Functional Acres lost over time will likely be different from the Reclamation timeframe considered by permitting agencies for regulatory purposes. In addition, the Reclamation time frame may be accelerated by habitat management actions in the project footprint, thereby reducing the Raw HQT Score and resulting debits required for the project. Such actions might include planting containerized stock plants or confirmation of accelerated reclamation through verified monitoring. Calculation of the Reclamation phase is discussed in greater detail in Appendix K.

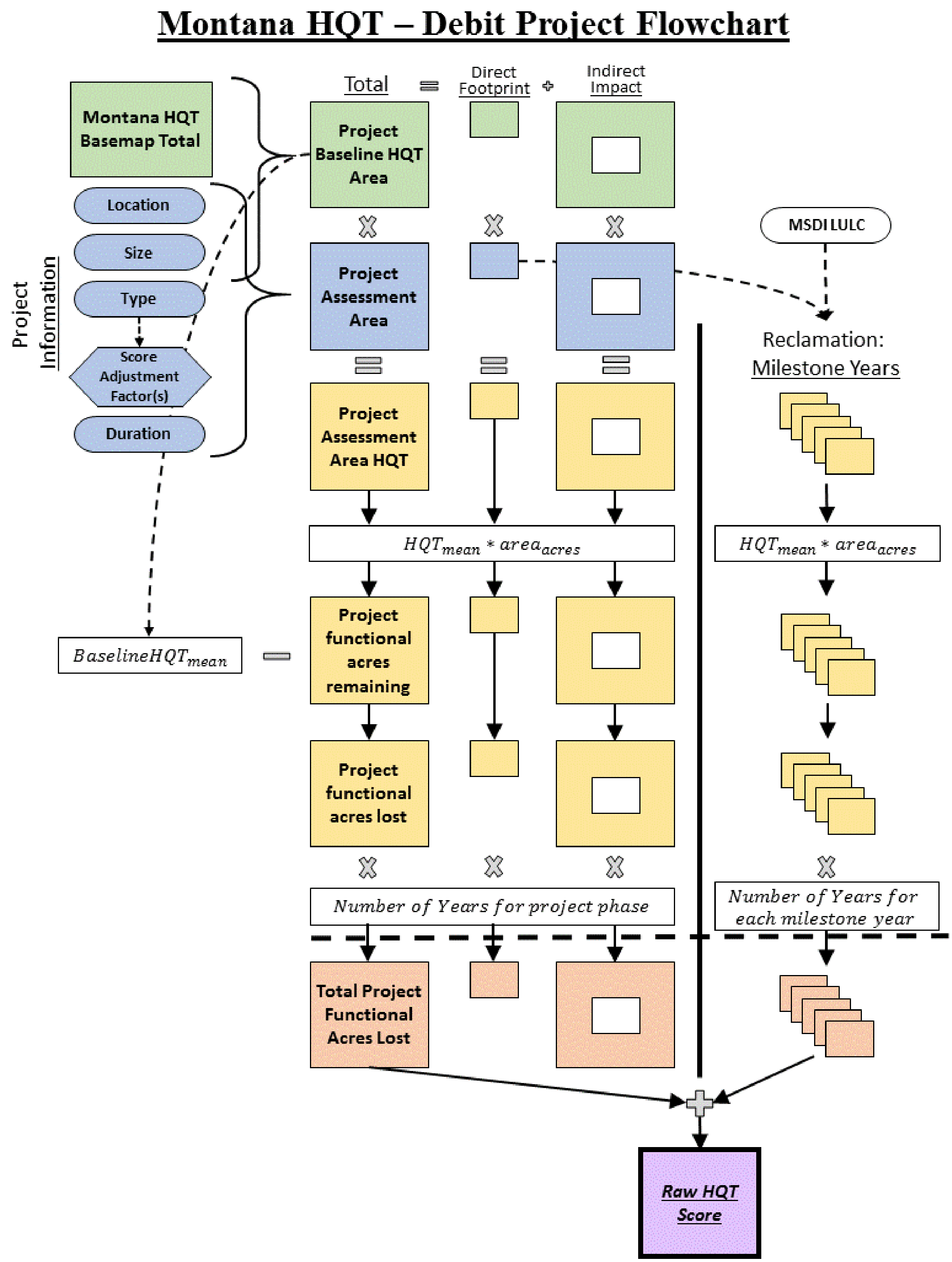

Figure 5. 1. The workflow for computing the total Project Functional Acres lost during the life of the project (Raw HQT Score) for debit projects.

Functional Acre scores are estimated for the following project phases (duration of the project phase). The Functional Acre scores are then used to calculate the Raw HQT Score (Figure 5. 1):

- **Construction** — The construction phase quantifies Functional Acres present in the Project Assessment Area during construction. Construction impacts are dependent on the project type, location, and duration of construction.
- **Operations and Maintenance** — This phase quantifies the Functional Acres present for the Project Assessment Area after the project has been constructed, interim reclamation activities have been initiated (where applicable, such as reduction in well pad size), and operations and maintenance activities are ongoing. During this period, habitat function is gradually returned in areas that have been reclaimed (i.e., construction areas that are outside the operations and maintenance footprint).
- **Reclamation** — This phase quantifies Functional Acres present for the Project Assessment Area after project activities are complete and final reclamation has been initiated. All project infrastructure (e.g., road alignments, transmission lines, well pads) must be removed from the landscape and reseeding activities completed prior to initiation of reclamation. Generally, Indirect Impacts of a project cease in the first year of the reclamation phase and the remaining Functional Acre losses from Direct Impacts are gradually reduced as vegetation regrows. The Functional Acres present during the final year of the Reclamation phase for the Project Assessment Area is equal to the pre-construction HQT Basemap value. The return of Functional Acres is dependent on the vegetation being reclaimed and the expected duration of reclamation (Figure 5. 1). This is likely to require more time than regulatory requirements imposed by permitting agencies, but reclamation in the HQT is predicated on those lands providing ecosystem services and suitable habitat for GRSG.
- **Abandonment** — The abandonment phase quantifies Functional Acres present in the Project Assessment Area after the habitat has been reclaimed to the greatest extent expected. For projects with no permanent impact, the Functional Acres habitat present in the Project Assessment Area at this phase is equal to the pre-construction HQT Basemap value.

Once the Functional Acre estimates are calculated for each project phase, the Raw HQT Score (or the Functional Acres lost during the life of the project) is finalized.

Reclamation is an important phase in the life of a project because it can be a significant portion of the overall Raw HQT Score (Figure 5. 1, Figure 5. 2). As vegetation reclamation takes hold, habitat function increases and the proportion of Functional Acres lost gets smaller (Figure 5. 2).

Accounting for reclamation activities over time must consider the expected reclamation success and timeframe for each vegetation community. For projects with multiple implementation or reclamation stages, a phased assessment may be needed to determine credit needs of different durations. See the *Policy Guidance Document* for policy details on phased release of credits.

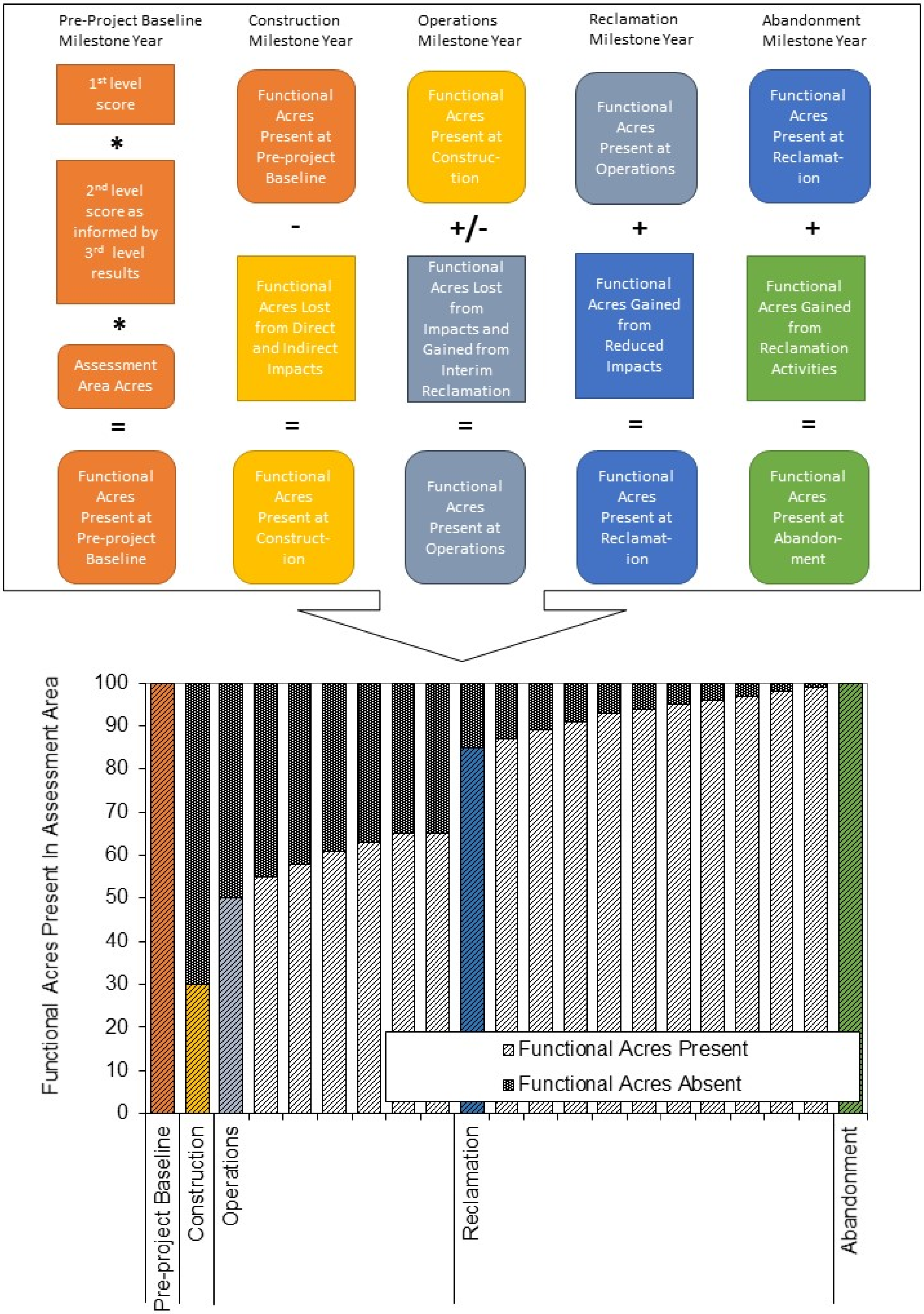

Figure 5. 2. Hypothetical example of Functional Acres present and absent over the life of a debit project as apportioned to each project phase.

Vegetation recovery times incorporated into the HQT must consider that the type of impact to the vegetation, such as bladed and cleared habitat, recovers at a different rate than mowed habitat, and mowed habitat recovers at a different rate than crushed habitat.

To account for these differences, reclamation recovery timeframes have been developed for each of these scenarios (Table 5. 1). As necessary, these recovery timeframes will be updated in the HQT as additional data become available. See Section 6.0 for Adaptive Management and Monitoring information on updating HQT data layers.

Reclamation timeframes for cleared vegetation were estimated as the average time to obtain Class A and Class B seral stages among the specific vegetation types within the aggregate in LANDFIRE Rapid Assessment Modeling and Mapping Zones: Northern and Central Rockies, Great Basin, and Northwest (U.S. Geological Survey). Seral stages used in LANDFIRE are described by the overall structural component and successional progression to a climax plant community (potential vegetation type [PVT]): class A is low cover, low height; and class B is high cover, low height.

The timeframe necessary for full recovery of sagebrush varies widely in the literature. Bunting et al. (2002) stated that recovery times of sagebrush communities vary, and may be as short as 15 years for mountain big sagebrush or as long as 50 to 75 years for Wyoming big sagebrush.

Cooper et al. (2007) looked at post-fire recovery of sagebrush shrub-steppe communities in central and southeastern Montana and found that full recovery of Wyoming big sagebrush took over 100 years and that recovery of mountain big sagebrush cover took slightly more than 30 years. They found that the mean recovery rate for Wyoming big sagebrush canopy cover was 0.16% per year in the study area, and the fastest recovery rate was 0.72% per year (Cooper et al. 2007).

Wambolt et al. (2001) reported 72% recovery of Wyoming big sagebrush after 32 years at one site in southwestern Montana, and 96% recovery after only 9 years at another site. Baker (2006) found that recovery times for mountain big sagebrush ranged from 35 to 100 years, and that recovery times for Wyoming big sagebrush ranged from 50 to 120 years.

Table 5. 1 was formulated based on published literature available for reclamation of GRSG habitat vegetation types.

Table 5. 1. Percent of habitat restored/reclaimed in each year of reclamation by habitat and disturbance type.

Years After Implementation of Reclamation (Reclamation Milestone)	Cleared Habitat	Mowed Habitat	Drive and Crush Habitat
0 (Year of Implementation)	• 0% of all vegetation communities	• 0% of agriculture, developed, badland/break, grassland, and riparian/wetland • 0% of remaining classes	• 0% of ag, developed, badland/break, grassland, and riparian/wetland • 0% of remaining classes
1 year	• 100% of agricultural and wetland • 20% of grassland and riparian • 5% shrub • 1% of low and big sagebrush	• 100% of agricultural, wetland, grassland, and riparian • 10% shrub and low sagebrush • 2% of big sagebrush	• 100% of agricultural, wetland, grassland, and riparian • 20% shrub and low sagebrush • 7% of big sagebrush
5 years	• 100% of agricultural, wetland, grassland, and riparian • 25% shrub • 5% of low and big sagebrush	• 100% of agricultural, wetland, grassland, and riparian • 50% shrub and low sagebrush • 10% of big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush • 33% of big sagebrush
10 years	• 100% of agricultural, wetland, grassland, riparian, and shrub • 10% of low and big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush • 20% of big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush • 67% of big sagebrush
15 years	• 100% of agricultural, wetland, grassland, riparian, and shrub • 15% of low and big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush • 30% of big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush, big sagebrush
25 years	• 100% of agricultural, wetland, grassland, riparian, and shrub • 20% of low and big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush • 40% of big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush, big sagebrush
50 years	• 100% of agricultural, wetland, grassland, riparian, and shrub • 50% of low and big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush, big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush, big sagebrush
75 years after Reclamation	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush, big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush, big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush, big sagebrush

5.3. Third Level Assessment to Validate the Second Level Results at the Local/Site-specific Scale for Development Projects

The Third Level Assessment will consist of field validation of scores from the Second Level Assessment and consider variables that are not captured in the geospatial analysis conducted in the Second Level Assessment. Field validation of habitat function is an important step in the Montana HQT and is similar to multiple other habitat assessment frameworks for GRSG (Boyd et al. 2014, NNHP and SETT 2014, Stiver et al. 2015, EDF 2015a, EDF 2015b).

The Third Level Assessment (field-based validation) is conducted after the Second Level Assessment has been completed. The voluntary Third Level Assessment process provides a site- scale evaluation of Habitat Function using detailed vegetation data and allows project proponents to field verify existing conditions in their project Assessment Area. Vegetation variables measured in the Third Level Assessment include: sagebrush canopy cover, sagebrush canopy height, invasive plant species cover, conifer cover, forb cover and unmapped anthropogenic disturbances. The Raw HQT Score may then be adjusted by changing individual pixel values, based on the results of the Third Level Assessment, to accurately characterize on-the-ground conditions. However, the degree to which a given Raw HQT Score may change as a result of the Third Level Assessment is dependent on the sampling effort undertaken relative to the size of the project Assessment Area. The field methodologies defined below are designed to be low-intensity and to provide a qualitative assessment to detect if major differences exist between the Raw HQT Score computed in the Second Level Assessment and what is observed in the field during the Third Level Assessment. The low-intensity sampling effort is not likely to dramatically change the Raw HQT Score. Project Developers may increase sampling effort and coordinate with the Program to develop sampling designs and field methods that would more likely have a higher impact on the Raw HQT Score.

Third Level Assessment field surveys are generally recommended for all project types. However, the third level field surveys are voluntary for development projects if the Project Developer chooses to accept the Raw HQT Score computed in the Second Level Assessment. Project Developers should contemplate actual on-the-ground conditions of their project specific Assessment Area. Due to the coarse scale of some vegetation data used in the Montana HQT Basemap, site-specific variables may not be accurately represented. Invasive plant species, conifer cover and forb cover are not directly assessed in the HQT. These Habitat Variables are treated as though they provide the maximum suitability for GRSG and are given a Habitat Score of 100 as a default in the Second Level Assessment. This could inflate the value of given pixels in the project Assessment Area resulting in overvaluing (in the case of forb cover) or undervaluing (in the case of conifer cover) the HQT score. If the geospatial data used to develop the Second Level Assessment score results appear erroneous, then certain vegetative variables included in Third Level Assessment field protocols can be measured to ground-truth these Second Level Assessment variables (e.g., sagebrush canopy cover) and thereby used to modify the Raw HQT Score (see Section 5.4.3).

Data collection will be the responsibility of the project proponent/applicant; these data will be submitted to the State for validation purposes. The State may conduct field visits to the site to field verify site conditions. Additional site-specific field-based data collection may be required by federal land management or state agencies following respective agency requirements.
The main goals of the Third Level Assessment are:

The main goals of the Third Level Assessment are:

1. to validate the data and output from the Second Level Assessment including sagebrush canopy cover, and sagebrush canopy height habitat variables; and potentially unmapped disturbances or modifiers on the landscape; and

2. to measure important sage grouse habitat score modifiers not directly characterized in the Second Level Assessment due to lack of spatial data, including invasive plant species cover, conifer canopy cover, and forb cover.

5.3.1. Field Protocol

Validation of Second Level Assessment results will be accomplished through low-intensity field sampling. At a minimum, Third Level Assessment data will be collected within the project footprint (i.e., Direct Impact area) but should be collected across the entire Assessment Area (which includes the Direct and Indirect Impact areas) if the proponent chooses to do so and has legal access to survey the Indirect Impact area of the project Assessment Area.

Data will be collected in general categories by vegetation type (i.e., tree, shrub, grass/forb). These general categories will be surveyed using line-point intercept (LPI; Herrick et al. 2016). Data collection will include sagebrush canopy cover, sagebrush height, forb cover, invasive plant species cover, and conifer canopy cover. Additionally, the presence of anthropogenic or wildfire disturbances not captured by the Second Level Assessment should be noted and delineated. For accurate representation in the HQT, Project Developers are encouraged to provide spatial data that delineates the boundaries of such disturbances.

The Program will provide protocols to be followed for field validation/data collection. The Program protocols will generally follow standardized data collection methods outlined in the Sage- Grouse Habitat Assessment Framework (HAF; Stiver et al. 2015) and BLM Assessment Inventory and Monitoring protocols (AIM; Herrick et al. 2016) to provide consistent data collection across projects. If projects are required to collect other, similar datasets, using protocols designed for purposes other than use in the HQT (reclamation planning, ecological site or habitat mapping, etc.), proponents should coordinate with the Program to ensure methods and results will provide the information necessary for use in the Third Level Assessment process. All data will be submitted to the State on the required State forms.

Data may be collected by the project proponent or a representative selected by the proponent. State or federal agency cooperators will provide Third Level Assessment field validation training workshops. All individuals completing Third Level Assessment field surveys must attend at least one training workshop. The State and collaborative partners will develop a Third Level Assessment validation field sampling guide, protocol and required data forms.

Sample locations within the Direct Impact area of a project (and the surrounding Indirect Impact area) will be randomly selected by the Program and located in a representative area that reflects the general conditions of the project Assessment Area.

Figure 5. 3 describes the transect pattern for a linear project. A single 50-m transect will be run in a manner which represents all vegetation types present (tree, shrub, forb/grass). The transect should be run perpendicular to but within the project boundary, for every half mile of line (i.e., pipeline, cable, transmission line). A minimum of one data point per meter will be collected, resulting in 50 sample points per half mile.

For a project with a contiguous area of five acres, one 50-m linear transect (Figure 5. 3) will be run in a manner which represents all vegetation types present (tree, shrub, forb/grass). A minimum of one data point per meter will be collected, resulting in 50 data sample points. Table 5. 2 describes the Score Sampling Density for Third Level Site validation.

One spoke design point transect will be run for every five acres, for projects having more than five and up to 20-acres of contiguous area (Figure 5. 4). The spoke design includes a center point with three 50-m transect lines radiating out from the center. One data point is collected for each meter along the transect lines. If the site is a monoculture of only one dominant vegetation type (tree or shrub or grass/forb dominated types) each spoke design transect can be randomly selected. If the site is comprised of varied vegetation types, one spoke design transect should be placed within each dominant vegetation type (tree, shrub or forb/grass dominated area) where the dominant vegetation type represents more than 20% of the site.

Each transect will include a minimum of one set of photo points (Spoke Design samples will have three separate photo points; one per spoke). Additional photos may be required to document habitat variables. Photo points will correspond with the associated field transect/point locations and be collected using provided forms and protocols.

Table 5. 2. Score Sampling Density for Third Level Site Verification (Minimum Sampling Density).

Size (acres)	**No. of Transects (1 point has 3 transects in a spoke design pattern)**
≤ 5	1 linear transect
> 5 and ≤ 20	1 Spoke Design point
> 20 and ≤ 100	2 Spoke Design points. 1 Spoke Design point per category*
> 100 and ≤ 400	3 Spoke Design points per 100-acres per category
> 400	1 Spoke Design point per 100-acres per category
Linear features	One linear transect any time the linear feature crosses sage grouse habitat (core, general, connectivity). If the linear feature crosses greater than ½ mile of designated sage-grouse habitat, then the desired sampling frequency is 1 linear transect every half mile randomly placed.

*For sites larger than 20.0-acres, the category (e.g., tree, shrub, or grass/forb) must comprise at least 20% of a site to be sampled separately. Categories comprising less than 20% of a site would be considered small inclusions and would not need to be separated out for sampling purposes.

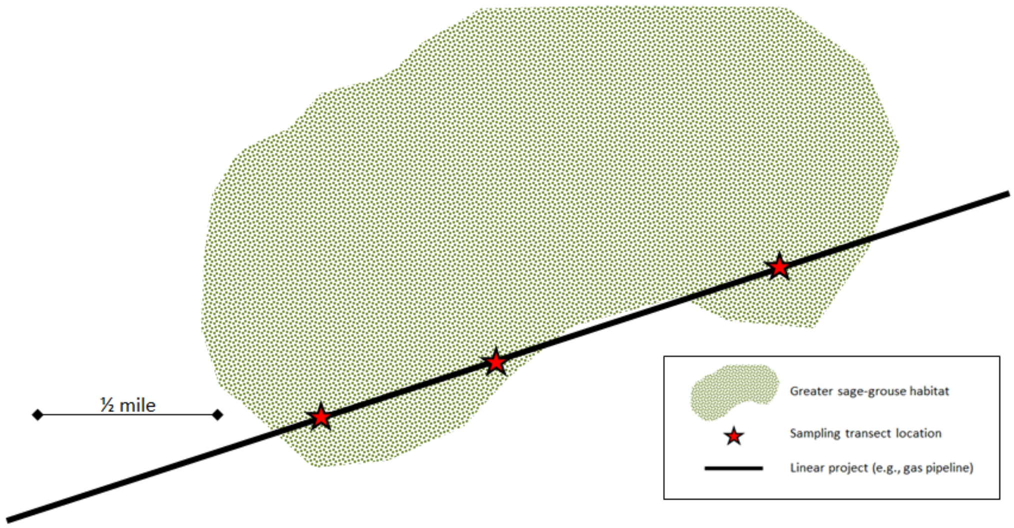

Figure 5. 3. The Linear Design is best for crossing linear features such as proposed transmission lines, pipelines. Transects are placed perpendicular to the linear feature.

Figure 5. 4. Spoke Design will be used for non-linear projects (Herrick et al. 2016). Example of a project with an area larger than 20-acres, requiring two spoke design points with three 50-m transects each. Transects are located in a way to capture variation of dominant vegetation.

5.3.3. Updates to Second Level Assessment Results for Debits Projects

Results of Third Level Assessment is intended to provide a more accurate characterization of the development project Assessment Area. Results of Third Level Assessment field data collection efforts will be used to confirm, and where needed, revise Second Level Assessment Habitat or Anthropogenic Variable Scores. The Second Level Assessment provides estimates of sagebrush canopy cover and height (scores range from 0.0-100.0 for each) from publicly available datasets, but these data are reported at a coarse scale and may not always accurately reflect the existing on-the-ground conditions at a given site.

The results of the Third Level Assessment field verification will inform Variable Scores and allow for a Final Raw HQT Score, specific to the development project Assessment Area. Variables used in the Second Level Assessment results would be adjusted, where appropriate, and then the HQT model would be run, using the adjusted variables, to generate an updated calculation of Montana HQT Basemap. The revised project-specific Montana HQT Basemap will represent the baseline condition from which the final Raw HQT Score is calculated and projected Functional Acres gained are calculated.

The Third Level Assessment is intended to provide a more accurate appraisal of the Assessment Area and could produce a score that is lower or higher than the original Second Level results. Third Level Assessment field data used to adjust the Second Level Assessment variables will initially apply only to the site-specific individual project it was collected for. Third Level Assessment field data may be compiled by the Program and may be incorporated into the Montana HQT Basemap on a regular basis, as determined by the Program.

6.0 ADAPTIVE MANAGEMENT

Adaptive management is a fundamental principle of the Montana Mitigation System. When it comes to conserving GRSG populations, much is known about the species' habitat preferences and population responses to the loss and fragmentation of sagebrush habitats. However, less is known about how GRSG populations respond to some specific anthropogenic disturbance types and more generally to mitigation measures which are intended to offset anthropogenic disturbance. Furthermore, Montana's Mitigation System includes assumptions in both the Policy Guidance Document and the HQT Technical Manual in the absence of perfect knowledge or experience in implementation. For these reasons and others, the Montana Mitigation System implements an adaptive management approach to periodically evaluate whether mitigation effectively offsets impacts in space and through time, sage grouse populations are sustained, and to assure Montana achieves the standard of no net loss of habitat (Figure 6. 1).

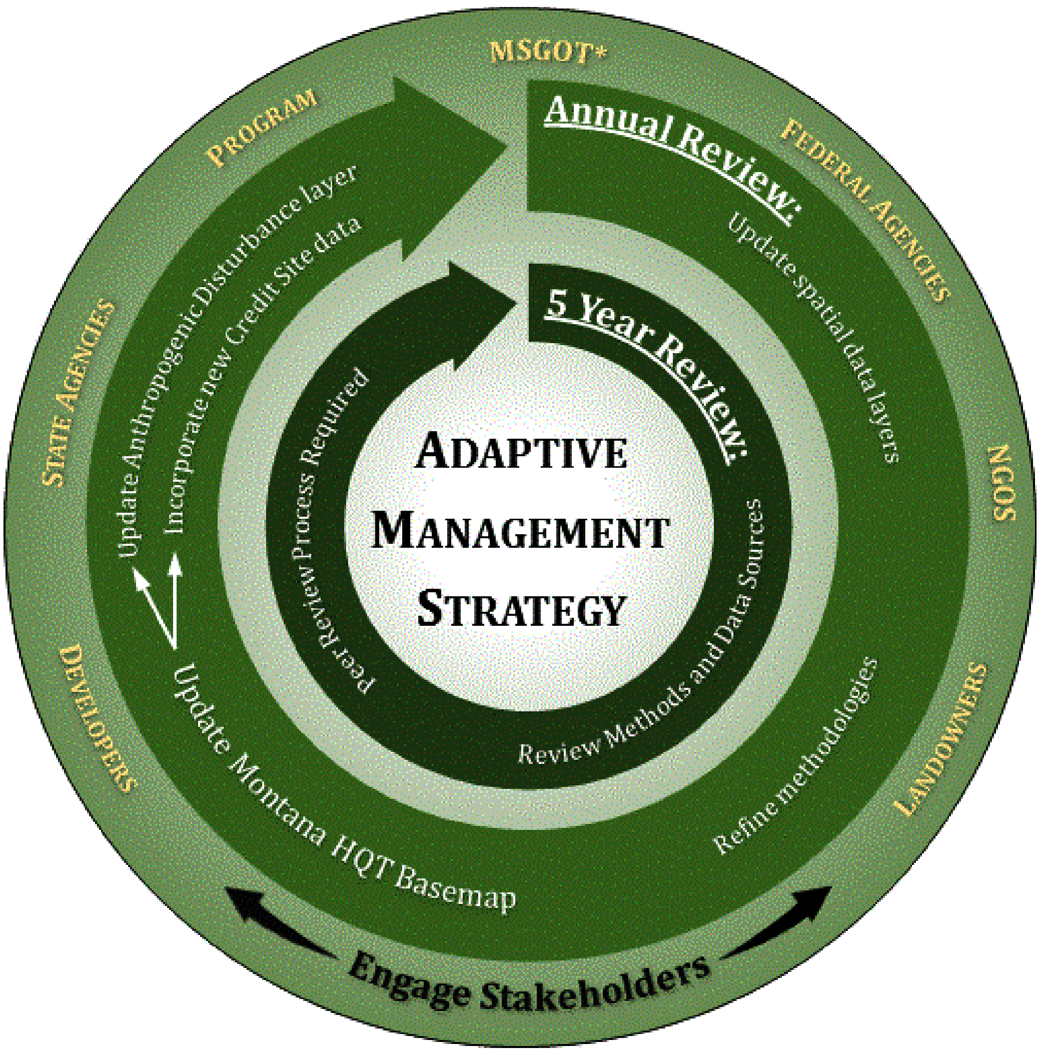

Figure 6. 1. Conceptual model of the Adaptive Management Strategy implemented by the Program to engage stakeholders in a continuous process to improve the HQT based on the best available science. *MSGOT may notice and comment at any time and may initiate rulemaking at any time but will at least do so every 5 years.

This Section describes a process for transparent, science-based, and inclusive adaptive management of the Policy Guidance Document, HQT Technical Manual, and associated products. Adaptive management is fundamental to making sure that the Montana Mitigation System is effective and successful, as is the broader conservation strategy.

Adaptive management is a systematic, but dynamic approach for improving natural resource management, with an emphasis on learning from management outcomes and incorporating what is learned into ongoing management. Uncertainty in management outcomes is addressed through the incorporation of procedures that seek to periodically review, revise, and update tools, strategies, and approaches in response to changing conditions or new information.

Adaptive management strategies allow for changes to the overall conservation strategy to occur in response to changing conditions or new information, including those identified through monitoring. The power of adaptive management lies in its ability to provide a viable path forward for management when information is lacking. By recognizing that management or implementation questions initially remain unanswered, information may be gained through this cyclical process of continuous evaluation and improvements with the goal to resolve outstanding questions and uncertainties through time through transparent processes based on the best available science. By definition, adaptive management requires a commitment to change approaches when appropriate and necessary in response to the previous cycle's acquisition of new information.

The HQT specifically warrants an adaptive management approach. This is because it relies heavily on data that are subject to change through time. For example, as new debit and credit projects are added to the landscape, the HQT Basemap will change through time. Wildfire can lead to sudden, and potentially significant losses of habitat in a single year. New research can and likely will shed new light on how sage grouse respond to anthropogenic changes on the landscape.

To ensure Montana meets the goals outlined in Section 1.1 of the Policy Guidance Document and specific measurable objectives that arise from those goals, an adaptive management review will occur annually. Adaptive management will require consideration of both habitat outcomes and population status and trends over time, in concert and at multiple spatial scales. The Program will focus on habitat outcomes, while sage grouse population monitoring, population estimation and reporting, and harvest management will remain the purview of MFWP. The Program will collaborate with MFWP and others as described more fully below.

Specific habitat-based objectives can be stated as follows:

- Meet the mitigation standard of no net loss, net gain preferred.
    - The number of functional acres created should be equal to or greater than the number of functional acres lost (i.e., HQT results prior to application of modifiers).
    - The number credits created should be greater than or equal to the number of debits.
- Maintain sufficient credits in the Reserve Account to replace lost or impaired credits.
    - The Reserve Account should have a sufficient number of reserve credits to replace lost or impaired credits listed and already used to offset debits.
- Produce and maintain an adequate supply of credits, regardless of the entity who creates them.

Specific metrics that will be summarized include: (1) the number of functional acres gained compared to the number of functional acres lost; (2) the number of credits created compared to number of debits created; (3) the number of credits available in the Reserve Account to replace impaired or lost credits; and (4) the supply of credits already developed and available in the registry, as well as those that could potentially be developed. Sources of data for habitat metrics can include: the registry, development projects reviewed by the Program, data contributed by other participants in the Mitigation System, other state and federal agencies, universities, non-governmental organizations, and conservation projects funded using funds from the Stewardship Account.

Consideration of population trends at multiple scales and through time with respect to conservation habitat efforts, development, and mitigation will enhance Montana's understanding about how populations at multiple scales are doing and may be influenced by changes in habitat quality and quantity (both development and conservation).

Specific population-based objectives are listed below. It is recognized that populations will vary naturally over time and across regions.

- a report of performance and operational findings, including a synthesis of monitoring and tracking of pre-project and post-project conditions for both crediting and debiting projects based on the Program's own experience and those of others engaged in the Mitigation System;
- identification of any overarching lessons learned;
- a quantification of the total debit impacts and credit project benefits provided by mitigation projects in terms of functional habitat acres;
- a summary of sage grouse monitoring information and populations at multiple spatial scales;
- a list of recommended changes to the Policy Guidance Document and HQT Technical Manual and associated documents, processes, and tools needed to meet (or continue to meet) program goals and objectives;
- a list of monitoring and research findings and needs to better guide mitigation efforts, developed in collaboration with MSGOT, scientific experts, and stakeholders; and
- a prioritized list of recommendations.

On an annual basis, the MSGOT will review the adaptive management report at a publicly noticed meeting to share the results of the adaptive management review and report, describe suggested changes, processes, or tools, and receive stakeholder feedback. There will be an assessment of whether major or minor changes to the approach are needed, and the recommendations will be prioritized. Progress towards meeting goals and objectives will be considered.

6.1. Potential Changes Specific to the HQT

Adaptive management of the HQT entails changes that update data sources and GIS processes and calculations, consistent with best available science and monitoring information provided by entities engaged with the Montana Mitigation System. Updates to the HQT will also be informed more broadly by the status of sage grouse populations and any changes to the Policy Guidance Document. Specific to the HQT, the annual review will focus on questions such as whether new data are available and whether any new science is available that warrants revision of mathematical formulas used to calculate Functional Acre gains or losses, respectively (Figure 6. 1).

On an annual basis, the HQT will be updated to perform website or data maintenance functions such as updating publicly available data layers or refining methodologies (Table 6. 1). Additionally, on an annual basis, the Program will update the HQT Basemap layer that is used to calculate functional acres gained or lost by credit or debit projects, respectively. This entails updating the anthropogenic disturbance layer, incorporating any new credit site data where it can be demonstrated that functional acres have been increased, and replacing any of the other data layers included in the HQT Basemap.

MSGOT and the Program may implement changes identified during the annual review if MSGOT and the Program believe the HQT's methods and data sources require revision so as to be consistent with the best available science, improve methodologies, or incorporate new data (Figure 6. 1, Table 6. 1). MSGOT may only adjust the HQT's methodologies or underlying data sources after a publicly announced MSGOT meeting and after accepting written and oral comment. Soliciting independent peer reviews may be warranted, but not required.

Once every five years, MSGOT and the Program will undertake a more thorough review (Figure 6. 1). HQT methods and data sources will be thoroughly scrutinized. Because these changes are likely to be more substantive and material, MSGOT will be required to undertake rulemaking to formally designate the new HQT. Independent peer review is required. MSGOT may only designate the new HQT after a publicly announced MSGOT meeting and after accepting written and oral comment.

Table 6. 1. The frequency which the Program expects to conduct updates specific to the variables used to develop the HQT Basemap.

Model Parameter	Update Frequency	Rationale
Population & Habitat Variables		
Distance to Lek	Annually	Monitoring efforts are conducted by MTFWP[1] on an annual basis to best capture lek activity.
Breeding Density	Annually	Based on the MTFWP annual lek activity data.
Distance to Suitable Upland (*from Mesic areas*)	Every 3 years	Delineation of Upland areas derived from MSDI LULC[2], which is compiled by MTNHP[3] every 3 years.
Mesic Mask layer	As available	Currently derived from 3 data sources (see Table A. 10). Other source(s)[4] will likely be available soon and decrease data processing and resulting compounding errors.
Sagebrush Abundance	As available	Derived from the Shrubland Products produced by MRLC[5] at irregular intervals.
Sagebrush Percent Cover		
Sagebrush Height Classes		
Unsuitable Land Cover Types	Every 3 years	Land Cover types which EO suitable/unsuitable definitions are applied to, are derived from MSDI LULC, which is compiled by MTNHP every 3 years.

Anthropogenic Variables		
Existing Anthropogenic Surface Disturbance	Annually	Based on heads-up digitized Existing Anthropogenic Surface Disturbance compiled by DNRC. New Debit projects submit spatial data to the Program periodically. Program will conduct data Quality Assurance and Quality Control (QA/QC) measures annually prior to incorporation of spatial data into HQT Basemap for delineation and update to Existing Anthropogenic Surface Disturbance. * The traffic count used to delineate Major Roads will be updated annually as provided by Montana Department of Transportation.
Oil & Gas Well Density		
Distance to Tall Structure		
Distance to Transmission Lines & Associated Towers		
Distance to Moderate Road & Railways		
Distance to Pipelines, Fiber Optic Cables, & Other Buried Utilities		
Agriculture, Mines, & Other Large-Scale Land Conversion (%)		
Compressor Stations & Other Noise Producing Sources		
Distance to Major Roads & Railroads		
Other layers		
Credit Site data	Annually	Obtained when Credit Producers submit spatial data to the Program. Program will conduct QA/QC annually prior to incorporation of spatial data into HQT Basemap.
Conifer Cover	As available	Currently captured through Third Level Assessment. Potential data source(s)[6] may be available to allow for incorporation of this variable into the Second Level Assessment.
Invasive Species Cover, Composition, & Abundance	As available	Currently captured through Third Level Assessment. Potential data source(s)[7] may be available soon to allow for incorporation of this variable into the Second Level Assessment.

[1] MTFWP = Montana Fish, Wildlife, and Parks

[2] MSDI LULC = Montana Spatial Data Infrastructure Land Use/Land Cover

[3] MTNHP = Montana Natural Heritage Program

[4] Other sources include the Sage Grouse Initiative (SGI) Mesic Resources data (*not currently available for download*; data link: https://map.sagegrouseinitiative.com/ecosystem/mesic-resources?ll=43.4799,-110.7624&overlay=mesic_average&opacity=0.80&z=6&basemap=roadmap; data citation: Donnelly et al. 2016. Public lands and private waters: scarce mesic resources structure land tenure and sage-grouse distributions. Ecosphere 7(1):1-15. http://onlinelibrary.wiley.com/doi/10.1002/ecs2.1208/full)

[5] MRLC = Multi-Resolution Land Characteristics Consortium; Data Link: https://www.mrlc.gov/nlcdshrub_avail.php.

[6] Potential data source for Conifer Cover includes the SGI Tree Canopy Cover data (data link: https://map.sagegrouseinitiative.com/ecosystem/tree-cover?ll=43.4799,-110.7624&overlay=tree_cover&opacity=0.80&z=6&basemap=roadmap; data citation: Falkowski et al. 2017. Mapping tree canopy cover in support of proactive prairie grouse conservation in western North America. Rangeland Ecology & Management 70:15-24. http://dx.doi.org/10.1016/j.rama.2016.08.002)

[7] Potential data source for Invasive Species includes the U.S. Geological Survey's Early Estimates of Herbaceous Annual Cover in the Sagebrush Ecosystem (May 1, 2018) (*not currently available for all of Montana*; data link: https://www.sciencebase.gov/catalog/item/5b0305f1e4b0da30c1c1d63a; data citation: Boyte, S.P., and Wylie, B.K., 2018, Early estimates of herbaceous annual cover in the sagebrush ecosystem (May 1, 2018): U.S. Geological Survey data release, https://doi.org/10.5066/P9KSR9Z4).

7.0 LIMITATIONS OF THE MONTANA HQT

The HQT is the scientific underpinning of the Montana Mitigation System and is policy-neutral. The credibility of the Montana Mitigation 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 kept in mind and addressed through time as issues are revealed with use.

7.1. LINKING TO POPULATION OUTCOMES

The ultimate objective of the Montana Mitigation System is to contribute to conservation of the GRSG, which ultimately leads to larger and more secure GRSG populations. Therefore, the Montana Mitigation System must have a means of measuring aggregate cumulative habitat impacts and benefits, and relating the results 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 birds “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, the Montana Mitigation System will have contributed to avoided loss of habitat that can help to sustain resilient populations over time. The State of Montana and its partners will continue to monitor GRSG populations across the state.

7.2. 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 GRSG vital rates varies by ecosystem, geography, climate, and land use. For GRSG, 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 regeneration time of sagebrush; where soils and vegetation are highly disturbed, sagebrush restoration can be challenging if not impossible (Pyke et al. 2011, Monsen 2005).

7.3. ANTHROPOGENIC IMPACTS LITERATURE

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

7.4. VEGETATION SAMPLING PROTOCOL

The HQT currently relies on a standardized, site-specific vegetation sampling protocol to establish vegetation conditions for the Montana HQT Basemap. 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 the Montana HQT Basemap

8.0 GLOSSARY

Active Lek: Designation by Montana Fish Wildlife and Parks. Data supports existence of lek. Defined as having two or more males lekking on site followed by evidence of lekking (birds or sign, vegetation trampling, feathers, or droppings) in subsequent years within 10 years of initial observation.

Anthropogenic Score: Adjustments made in the Second Level Assessment to account for anthropogenic impacts from the project in the Raw HQT Score. For a credit project, this score is incorporated into the HQT Basemap as existing disturbance. In a development project, this is accounted for with the Indirect Impacts buffers.

Anthropogenic Variable: Where human activity has substantially modified an area's primary ecological functions and **species** composition. For sage grouse, examples include wind farms, transmission lines, or gravel pits.

Assessment Area: The geographic area associated with a development project's impact or credit project's benefit. This defines the boundaries of the calculation of Functional Acres in the habitat quantification tool using the Montana HQT Basemap.

Baseline: The pre-existing condition of a resource, at all relevant scales, as quantified by application of the HQT.[1]

Connectivity Area, State of Montana: Areas that provide important linkages among populations of sage-grouse, particularly between Core Areas or priority populations in adjacent states and across international borders.[2]

Construction Phase: Initial phase of development or start of project activity, when surface disturbance or disrupting activities are initiated for the first time, through to the beginning of the Operation Phase.

Core Area, State of Montana: An area that has the highest conservation value for sage grouse and has the greatest number of displaying male sage grouse and associated sage grouse habitat, as presently delineated by Executive Order 21-2015.[3]

Credit: A defined unit of trade representing the accrual or attainment of resource functions or value at a proposed project site.[4]

Credit Provider: An entity generating credits as mitigation for impacts to sage grouse habitat.

Debit Project: A development action proposed in sage grouse habitat that requires state or federal agency review, approval, or authorization and is required to avoid, minimize, reclaim, and/or compensate for impacts to sage grouse habitat.

Direct Impacts: Effects that are caused by a development activity. Direct effects are the footprint of a project and usually occur from construction or operation activities, or project infrastructure.

Distribution Line: (From APLIC Guidelines) A circuit of low-voltage wires, energized at voltages from 2.4 kV to 35 kV, and used to distribute electricity to residential, industrial and commercial customers.

Enhancement: An increase or improvement in quality, value, or extent (of a resource) that has been degraded or could be managed to increase the value of that habitat over its current value.[5]

First Level Assessment: The First Level Assessment area consists of the distribution of GRSG in Montana. For the State, GRSG range is defined as General Habitat, Core Area, and Connectivity. On BLM and USFS federal lands, GRSG range is defined as Priority or General Habitat Management Areas.

[1] Bureau of Land Management. 2016. Manual Section 1794: Mitigation.
[2] MCA § 76-22-103(1) (2017).
[3] MCA § 76-22-103(3) (2017).
[4] MCA § 76-22-103(4) (2017).
[5] Bureau of Land Management. 2016. Manual Section 1794: Mitigation.

Functional Acre: A single unit that expresses the assessment of quantity (acreage) and quality (function) of habitat or projected habitat through the quantification of a set of local and landscape conditions. A Functional Acre is the metric for outputs from the habitat quantification tool and for quantifying, expressing, and exchanging credits and debits.

Functional Habitat: The expression of the assessment of quality (function) of habitat or projected habitat through the quantification of a set of local and landscape conditions.

General Habitat, State of Montana: An area providing habitat for sage grouse but not identified as a core area or connectivity area.[6]

General Habitat, BLM and US Forest Service (GHMA): BLM or USFS-administered sage grouse habitat that is occupied seasonally or year-round and is outside of PHMAs, where some special management would apply to sustain sage grouse populations. The boundaries and management strategies for GHMAs are derived from and generally follow the preliminary general habitat (PGH) boundaries.

GIS terms: pixel, pixel resolution, GIS, continuous data layer: Pixel: The smallest unit of information in an image or raster map, usually square or rectangular. Pixel is often used synonymously with cell. Pixel resolution: The dimensions represented by each cell or pixel in a raster, also referred to as spatial resolution or cell size; note that smaller cell sizes equate to increased spatial resolution. GIS: Geographic Information System. A computer mapping system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. Continuous data layer: Values that are assigned to the cells of a surface can be represented as either discrete or continuous data. Continuous data, or a continuous surface, represents phenomena where each location on the surface is a measure of the concentration level or its relationship from a fixed point in space or from an emitting source. Continuous data is also referred to as field, non-discrete, or surface data.

Habitat Function: The degree of effectiveness of a sage grouse habitat component to provide services for sage grouse use and survival. The HQT measure increase or decrease in habitat function to quantify management or debit project impacts to habitat.

Habitat Metric Score: A unit of measure the HQT uses to quantify suitable annual habitat values for GRSG. These include an upland metric & mesic metric.

Habitat Quantification Tool (HQT): The scientific method used to evaluate vegetation and environmental conditions related to the quality and quantity of sage grouse habitat and to quantify and calculate the value of credits and debits.[7]

Habitat Variables: vegetation community proportion of sagebrush, sagebrush canopy cover, sagebrush canopy height, distance to shrub habitat, average upland habitat score used in the Montana HQT Basemap.

Habitat Score: Combined score of all Habitat and Population Variables within a Montana HQT Basemap.

Indirect Impacts: Effects that are caused by or will ultimately result from a development activity. Indirect effects usually occur later in time or are removed in distance compared to Direct Impacts, but are still reasonably foreseeable. Indirect Impacts may include growth-inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems.[8]

LANDFIRE: Landscape Fire and Resource Management Planning Tools. A GIS layer used in the HQT. Used to describe vegetation, wildlife fuel, and fire regimes across the U.S. to support cross-boundary planning, management, and operations between agency wildland fire management programs.

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[6] MCA § 76-22-103(7) (2017).
[7] MCA § 76-22-103(9) (2017).
[8] 40 CFR § 1508.8

Lek: Traditional areas where male sage grouse gather during early spring to conduct a courtship display, attract females, and breed.[9]

Mesic Habitat: Habitat containing a moderate amount of moisture with unique plant and insect species not found in upland habitats.

Milestone Recovery Year (MRY): Designated increments of scoring for Functional Acre habitat scores in the assessment area over the life of the project. Typically, these are designated as year 1 through 15, then 25, 50, and 75.

Minimum Sampling Density: Minimum number of transects (sample size) necessary for valid Third Level site validation.

Mitigation Credit Project: Conservation actions, including enhancement, restoration, creation, or preservation, taken by an entity on a mitigation credit project site.

Montana HQT Basemap: The pre-existing Functional Acre condition of GRSG habitat, as quantified by the HQT Model using anthropogenic, population and habitat variable scores.

Montana Mitigation System: The framework of the Montana Mitigation System Policy Guidance for Greater Sage-grouse and Montana Mitigation System Habitat Quantification Technical Manual for Greater Sage-grouse processes.

Montana Mitigation System Policy Guidance Document for Greater Sage-grouse, *Policy Guidance Document*: A companion document to the Montana Mitigation System Habitat Quantification Technical Manual for Greater Sage-grouse. The *Policy Guidance Document* outlines how HQT results are applied in a decision process.

MSGOT or Oversight Team: Montana Sage Grouse Oversight Team[10]

Multi-Resolution Land Characteristics Consortium National Land Cover Database (MRLC NLCD): The MRLC is a group of federal agencies, including the Bureau of Land Management, Environmental Protection Agency, National Aeronautics and Space Administration, National Agricultural Statistics Services, National Oceanic and Atmospheric Administration, National Park Service, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, U.S. Forest Service, and U.S. Geological Survey. The MRLC developed and maintains the NLCD with the objective of providing land cover data that is nationally complete, current, consistent, and publicly available. The NLCD is the comprehensive land cover product derived from decadal Landsat satellite imagery and other ancillary datasets (Xian et al. 2015).

Nest Facilitating: Anthropogenic structure that supports avian nesting.

Non-Nest Facilitating: Anthropogenic structure that does not support avian nesting.

Operation Phase: Period of time after the completion of the construction phase and prior to initiation of the reclamation phase, corresponding to the length of time in which a development project is present and operational on the landscape and causes surface disturbance or disrupting activities.

Pole: (From APLIC Guidelines) A vertical structure used to support electrical conductors and equipment for the purpose of distributing electrical energy. It can be made of wood, fiberglass, concrete, or steel, and manufactured in various heights.

Population Variable: Includes sage grouse population variables (distance to lek, breeding density) used in the Montana HQT Basemap.

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[9] Montana's Greater Sage-grouse Habitat Conservation Advisory Council. Greater Sage-Grouse Habitat Conservation Strategy (2014) (hereafter "2014 Recommendations"), available at http://governor.mt.gov/Portals/16/docs/GRSG%20strategy%2029Jan_final.pdf.

[10] MCA § 76-22-103(10) (2017).

Predicted Uplift: The Final Raw Score for a restoration or enhancement project calculated after making Third Level Assessment adjustments.

Preservation: The removal of a threat to, or preventing the decline of, resources. Preservation may include the application of new protective designations on previously unprotected land or the relinquishment or restraint of a lawful use that adversely impacts resources.[11]

Priority Habitat Management Area, BLM and US Forest Service (PHMA): BLM or USFS-administered lands identified as having highest habitat value for maintaining sustainable sage grouse populations. The boundaries and management strategies for PHMAs are derived from and generally follow the preliminary priority habitat (PPH) boundaries. PHMAs largely coincide with areas identified as priority areas for conservation (PACs) in the Conservation Objectives Team (COT) Report.

Project Assessment Area: Project specific Assessment Area that defines the spatial extent of a project, based on the largest Indirect Impact buffer for Debit Projects and based on the Direct Impact for Credit Projects.

Project Developer: An entity proposing an action that will result in a debit.[12]

Program: The Montana Habitat Conservation Program.

Raw HQT Score: Final project score produced from Montana HQT Basemap Score after adding all project related Anthropogenic Variables for existing anthropogenic features on the landscape in GRSG habitat. The score reflects the total Functional Acres lost for the project or gained for a credit project.

Reclamation: Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.[13]

Reclamation Phase: Period of time after completion of the Operation Phase, corresponding to the beginning of site recovery to and attainment of pre-project baseline condition and habitat function after the removal of all surface disturbance, infrastructure and/or cessation of disrupting activities

Restoration: The process of assisting the recovery of a resource (including its values, services, and/or functions) that has been degraded, damaged, or destroyed to the condition that would have existed if the resource had not been degraded, damaged, or destroyed.[14]

Restoration Habitat Management Area, BLM (RHMA): BLM-administered lands where maintaining populations is a priority, a balance between ongoing and future resource use so that enough quality habitat is maintained to allow some residual population in impacted areas to persist and that emphasizes the restoration of habitat to reestablish or restore sustainable populations.

Second Level Assessment: Level at which the HQT quantifies Functional Habitat to provide a benchmark of GRSG Habitat Functionality for a specific credit or development project. Computed using a geospatial platform (e.g., ArcGIS) using scores developed for selected Population and Habitat Variables associated with GRSG habitat selection and use.

Stakeholder Group: Included private, local, state, industry, and non-profit partners, as well as the Bureau of Land Management, the U.S. Forest Service, and the U.S. Fish and Wildlife Service.

Structure: (From APLIC Guidelines) A pole or lattice assembly that supports electrical equipment for the transmission or distribution of electricity.

Substation: (From APLIC Guidelines) A transitional point (where voltage is increased or decreased) in the transmission and distribution system.

The State: State of Montana.

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[11] Bureau of Land Management. 2016. Manual Section 1794: Mitigation.
[12] MCA § 76-22-103(11) (2017).
[13] See 40 CFR § 1508.20 definition of mitigation hierarchy (avoid, minimize, rectify, reduce, compensate).
[14] Bureau of Land Management. 2016. Manual Section 1794: Mitigation.

Third Level Assessment: Site level validation of site condition. This assessment is used to verify credit site conditions as calculated by the HQT, and to validate development site conditions as calculated by the HQT. Results may be used to adjust the Raw HQT Score.

Total Anthropogenic Score: Calculated by multiplying all the Anthropogenic Scores specific to the Anthropogenic Variables.

Total Habitat Score: Calculated by averaging all the Habitat Scores specific to the Population and Habitat Variables.

Transmission line: Power lines designed and constructed to support voltages >69 kV. Voltages of 46kV to 69kV are considered sub-transmission lines and lines > 69kV but < 345kV are referred to as transmission lines. A high voltage power line is considered 345 kV or above.

Upland Habitat: Upland is defined as high or hilly habitat and is considered drier than a mesic area. These areas have unique plant species not generally found in mesic habitats.

Verification: An independent, expert check on the credit estimate, processes, services, or documents provided by a project developer or credit provider. The purpose of verification is to provide confidence to all program participants that credit calculations and project documentation are a faithful, true, and fair account – free of material misstatement and conforming to credit generation and accounting standards, state and federal laws, and policies.

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Appendix A. MONTANA HQT BASEMAP – GIS METHODS

This appendix provides details about the geospatial methods used to process and manipulate the data layers for inclusion in the final calculation of the Montana HQT Basemap (Table A. 1).

Table A. 1. List of model parameters and associated data sources.

Model Parameters	**Data Source**
Population & Habitat Variables	
Distance to Lek	DNRC[1]/MTFWP[2] Lek Points
Breeding Density	Doherty et al. (2010)[3] Lek Density[4]
Distance to Suitable Upland (*from Mesic areas**)	MSDI LULC[5]
*Mesic Mask layer	MSDI LULC, MTNHP[6] Wetland/Riparian[7], USFWS NWI[8] for MT[9]
Sagebrush Abundance	MRLC[10] Shrubland Products[11] – Percent Sagebrush & Percent Big Sagebrush
Sagebrush Percent Cover	
Sagebrush Height Classes	MRLC Shrubland Products – Sagebrush Height
Unsuitable Land Cover Types	MSDI LULC
Anthropogenic Variables	
Oil & Gas Well Density	DNRC Existing Disturbance[12]
Distance to Tall Structure	DNRC Existing Disturbance
Distance to Transmission Structure (Lines, Structures/Poles, Substations)	DNRC Existing Disturbance
Distance to Moderate Road & Railways	DNRC Existing Disturbance
Distance to Pipelines, Fiber Optic Cables, & Other Buried Utilities	DNRC Existing Disturbance
Agriculture, Mine, & Other Large-scale Land Conversion (%)	DNRC Existing Disturbance
Distance to Major Roads & Railroads	DNRC Existing Disturbance, MDT[13] Yearly Traffic Count data[14]
Compressor Stations & Other Noise Producing Sources	DNRC Existing Disturbance

[1] DNRC = Department of Natural Resources and Conservation
[2] MTFWP = Montana Fish, Wildlife, and Parks
[3] Citation: Doherty, K., J.D. Tack, J.S. Evans, and D.E. Naugle. 2010a. Mapping breeding densities of greater sage-grouse: a tool for range-wide conservation planning. Prepared for the Bureau of Land Management. BLM Completion Report: Interagency Agreement #L10PG00911.
[4] Data Link: https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/Pages/sagegrouse.aspx
[5] MSDI LULC = Montana Spatial Data Infrastructure Land Use/Land Cover; Data Link: http://geoinfo.msl.mt.gov/Home/msdi/land_use_land_cover
[6] MTNHP = Montana Natural Heritage Program
[7] Data Link: https://mslservices.mt.gov/Geographic_Information/Data/DataList/datalist_Details.aspx?did=%7bf57e92f5-a3fa-45b2-9de8-0ba46bbb2d46%7d
[8] USFWS NWI = U.S. Fish and Wildlife Service National Wetland Inventory
[9] Data Link: https://www.fws.gov/wetlands/data/State-Downloads.html
[10] MRLC = Multi-Resolution Land Characteristics Consortium
[11] Data Link: https://www.mrlc.gov/nlcdshrub_avail.php
[12] DNRC Existing Disturbance is analogous to the heads-up digitized Existing Anthropogenic Surface Disturbance.
[13] MDT = Montana Department of Transportation
[14] Data Link: http://gis-mdt.opendata.arcgis.com/datasets/montana-traffic-counts?geometry=-130.884%2C44.135%2C-96.958%2C49.397

Montana HQT Basemap Flowchart

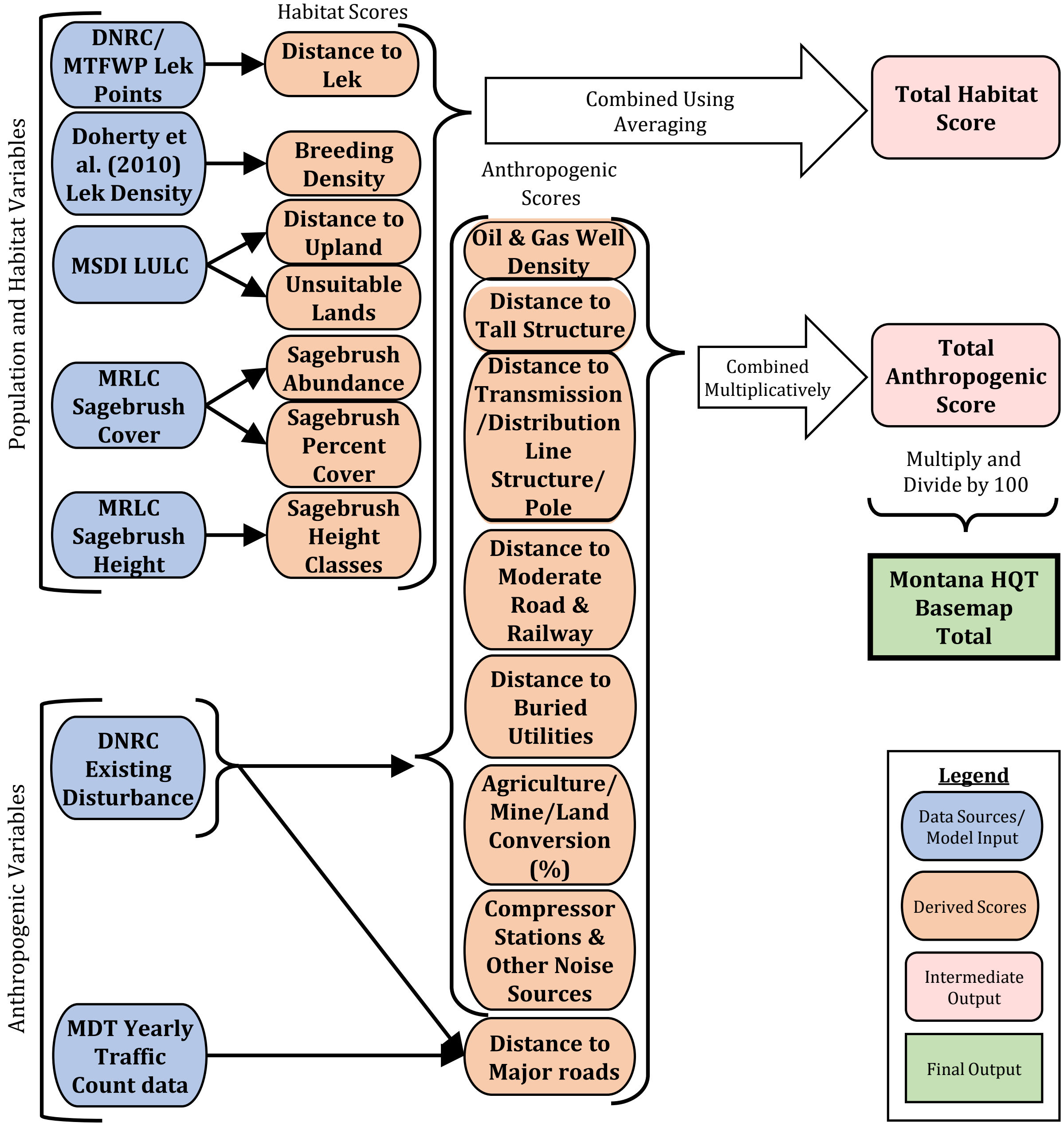

Figure A. 1. Flowchart showing the steps of data manipulations to develop the Final Montana HQT Basemap.

POPULATION AND HABITAT VARIABLES

1. Distance to Lek

Data Layers used in Habitat Score Creation: Montana Sage-grouse Lek Location Point Data.

Sage-grouse leks in the Montana statewide data layer are classified by their activity status as defined in Table A. 2. Only active leks, those classified as Confirmed Active (CA), Confirmed

Inactive (CI) or Unconfirmed (UC), are used in this metric. Leks classified as Confirmed Extirpated (CE) or Never Confirmed Active (NCA) are not included in the analysis because they are either permanently abandoned or there is not enough evidence to officially classify them as leks.

Table A. 2. Definitions for Lek Activity Status used in the Montana HQT Basemap data layers.

Lek Activity Status	Definition
Confirmed Active	Data supports existence of lek. Supporting data defined as 1 year with 2 or more males lekking on site followed by evidence of lekking (Birds - male, female or unclassified; -OR- Sign - vegetation trampling, feathers, or droppings) within 10 years of that observation.
Confirmed Inactive	Confirmed Active lek with no evidence of lekking (Birds - male, female or unclassified; -OR- Sign - vegetation trampling, feathers, or droppings) for the last 10 years. Requires a minimum of 3 survey years with no evidence of lekking during a 10-year period. Reinstating Confirmed Active status requires meeting the supporting data requirements.
Unconfirmed	Unconfirmed lek. Grouse activity documented. Data insufficient to classify as Confirmed Active status.
Confirmed Extirpated	Habitat changes have caused birds to permanently abandon a lek (e.g., plowing, urban development, overhead power line) as determined by the biologists monitoring the lek.
Never Confirmed Active	Unconfirmed lek that was never confirmed active. Requires 3 or more survey years with no evidence of lekking (Birds - male, female or unclassified; -OR- Sign - vegetation trampling, feathers, or droppings) over any period of time.

Available literature and datasets related to lek-to-nest distances in Montana were used to establish scores for this variable. Generally, most available literature and datasets for Montana indicate that the nesting activities in the state occur within 10.0-km of a lek. In southeastern Montana, Foster et al. (2014) found that an 8.0-km buffer around all leks was adequate to protect 100% of nests used by radio tagged hens in southeast Montana, respectively (Figure A. 2). Foster et al. (2014) found that this relationship remained relatively consistent when active and inactive leks or only active leks were included in the analysis. Similarly, in southeastern Montana and northeastern Wyoming, Doherty (2008) found that 95% of all nesting activity occurred within 10.0-km of a lek. *The Final Management Plan and Conservation Strategies for Sage-Grouse in Montana* (FWP 2005) describes similar lek-to-nest distance relationships. Based on these Montana-specific findings, detailed scoring for the distance to lek variable was completed for distances less than 10-km from leks in Montana (Figure A. 2). Scoring for distances farther than 10-km was based on findings not specific to Montana, as discussed in subsequent paragraphs.

Montana-specific datasets and publications were used to establish scores for the distance to lek variable were developed within 10.0-km of a lek (Figure A. 2). Generally, distances less than 3.2-km of a lek were recognized as important nesting habitat across the state with decreased nest numbers with increased distance from a lek. Foster et al. (2014) found that a 3.2-km buffer was adequate to protect 84% of nests used by radio tagged hens in southeast Montana, respectively (Figure A. 2). The Foster et al. (2014) findings are consistent with Martin (1970, from FWP 2005) who found that greater than 80% of nests were located less than 3.2-km from leks in southwestern Montana. Data presented in Woodward (2006) indicate that populations in Golden Valley and Musselshell counties also follow this pattern with 66% and 80% of nests occurring within 3.0-km of a lek, respectively.

Musselshell counties also follow this pattern with 66% and 80% of nests occurring within 3.0-km of a lek, respectively. The Musselshell County population used nesting habitats closer to leks than any other population documented in Montana with 98% and 100% of nests located within 4.0-km and 5.0-km of a lek, respectively. Similarly, Wallestad and Pyrah (1974, from FWP 2005) reported that 68% of all nests were located within 2.4-km of a lek in central Montana. In southern Phillips County, results presented by Moynahan (2004 unpublished presentation materials) differ slightly from results from other parts of Montana with less than 40% of nests occurring within 3.0-km of a lek and 60% of nests occurring within 5.0-km. While the Moynahan results differ slightly from the remainder of the state, they should be considered when developing scores for this variable, especially at distances greater than 3.0-km as they indicate that in some areas of the state, habitats farther from leks may still be important for nesting and breeding activities.

Montana-specific datasets related to lek-to-nest distances are very similar to those observed elsewhere across the range of the GRSG. While not specific to Montana, MTFWP (2005) reported that unpublished data from Idaho (Autenrieth 1976) found that 59%, 85%, and 96% of nests occurred within 3.2-km, 6.4-km, and 8.0-km of leks, respectively. Holloran and Anderson (2005) studied nesting GRSG at 30 leks in central and western Wyoming and determined that 45% and 64% of female GRSG nested within 3.2-km and 5.0-km, respectively, of the lek where the hen was radio-collared. Although it occurs infrequently, female GRSG do nest at greater distances from a lek. Holloran and Anderson (2005) reported approximately 10% of all nests occurring between 9.0-km and 15.0-km from a lek and approximately 3% of all nests occurring beyond 15.0-km. The farthest distance reported in Holloran and Anderson (2005) was 27.4-km. Coates et al. (2013) observed declining surface use beyond 9.6-km, and that the majority of utilization for breeding populations, including migratory populations, was contained within 15.0-km.

Based on available literature and the professional judgment of the stakeholder group, all habitats within 3.2-km of a lek were assigned a score of 100 for this variable (Figure A. 2). Scores for remaining distances out to 10.0-km were developed in 1.6-km (1 mile) distance bins. Scores for each distance bin were determined by standardizing the percent of nests beyond each distance value by 0.32 (the minimum value of percent of nests beyond the specific distance for the 0.0-km to 3.2-km distance bin). All remaining scores were developed by averaging the standardized values within each distance bin and rounding to the nearest tenth. The score for the 6.4-km to 8.0-km distance bin was increased to 20 to provide a more conservative score than would have been calculated by rounding to the nearest tenth. The score for the 10.0-km to 20.0-km bin were 50% of the score for the 8.0-km to 10.0-km bin (Table A. 3).

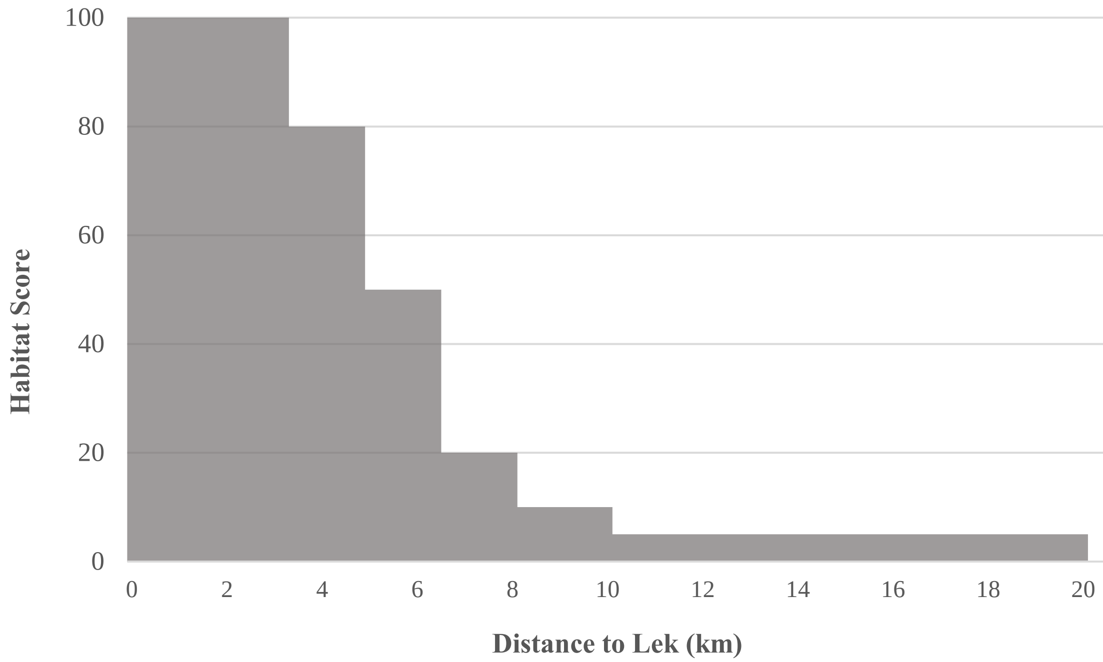

Figure A. 2. The Habitat Score for the Distance to Lek Population and Habitat Variable.

<u>GIS Steps for Habitat Score Creation:</u>

1. Select active leks (CA, CI, UC) from Montana statewide lek dataset.
2. Create a Euclidean distance raster with a maximum distance of 20,000-m.
3. Reclassify raster with values corresponding to the Habitat Score (Table A. 3) based on an individual raster cells' distance from an active lek.

Table A. 3. Habitat Scores for each distance bin for the Distance to Lek Population and Habitat Variable.

Distance from Lek (km)	Habitat Score
0.0 – 3.2	100
>3.2 – 4.8	80
>4.8 – 6.4	50
>6.4 – 8.0	20
>8.0 – 10.0	10
>10.0 – 20.0	5
>20.0	0

2. Breeding Density

Data Layers used in Habitat Score Creation: *Range-wide breeding densities*, Doherty, et al. (2010; hereafter, Doherty model; incorporates the Montana Sage-grouse Lek Location Point Data from 2000 - 2009 provided by MTFWP).

Leks are widely recognized as a focal point for occupancy and seasonal use, and lek counts provide a reasonable index to relative abundance of GRSG populations (Reese and Bowyer 2007). Studies show that during breeding seasons (lekking and nesting), GRSG select habitat near and surrounding leks (Holloran and Anderson 2005, Cagney et al. 2009, Doherty et al. 2011, Fedy et al. 2012). Higher attendance leks likely influence GRSG populations more than lower attendance leks, and the birds using these leks may use habitats across broader spatial scales (Coates et al. 2013).

Breeding density models were used to identify areas with higher function for GRSG populations. Doherty et al. (2010a) developed a widely used spatial model of breeding density that can be used in the HQT. The Doherty et al. (2010a) model provides a spatially explicit, continuous variable that identifies breeding density across the range of the species. In their study, breeding density areas were modeled by assigning an abundance-weighted density (based on number of displaying males) to each lek, and then summed the number of displaying males, starting with the highest density until a given percent population threshold was met. This resulted in a defined percent of the population being identified in areas of the highest density of breeding sites across the range of the species. Doherty et al. (2010a) used known distributions of nesting hens around leks to delineate the outer boundaries of breeding areas. The model output is a grouping of nesting areas that represent the smallest areas necessary to contain 25, 50, 75, and 100 percent of the nesting GRSG populations. Area estimates are inclusive, in that the 25% population threshold is included within the boundary of the 50% population threshold. While this metric may correlate closely with the distance to lek variable, it was decided to retain both variables in the Montana HQT because the Stakeholder Group determined that for mitigation purposes, habitats closer to leks (greater numbers of nests) in areas with higher breeding densities (higher populations) should generate more credits if they are conserved.

The range-wide breeding density model (Doherty et al. 2010a) is classified into 25%, 50%, 75%, and 100% cumulative breeding thresholds quartiles with the highest relative breeding density in the 25% threshold quartile and the lowest breeding density in the 100% quartile (Figure A. 3). These thresholds were used to assign variable scores with the scores of 100 being assigned to the areas with the highest breeding density (25% quartile) with scores decreasing linearly to 25 for the 100% threshold quartile (Table A. 4). Areas outside of the breeding density model (modeled breeding density of 0) receive a score of 0. The Habitat Scores for this variable will be updated as new breeding density data and research become available. The breeding density model itself will be updated on an as needed basis as the lek activity dataset is annually updated by MFWP, to maintain accuracy of this variable.

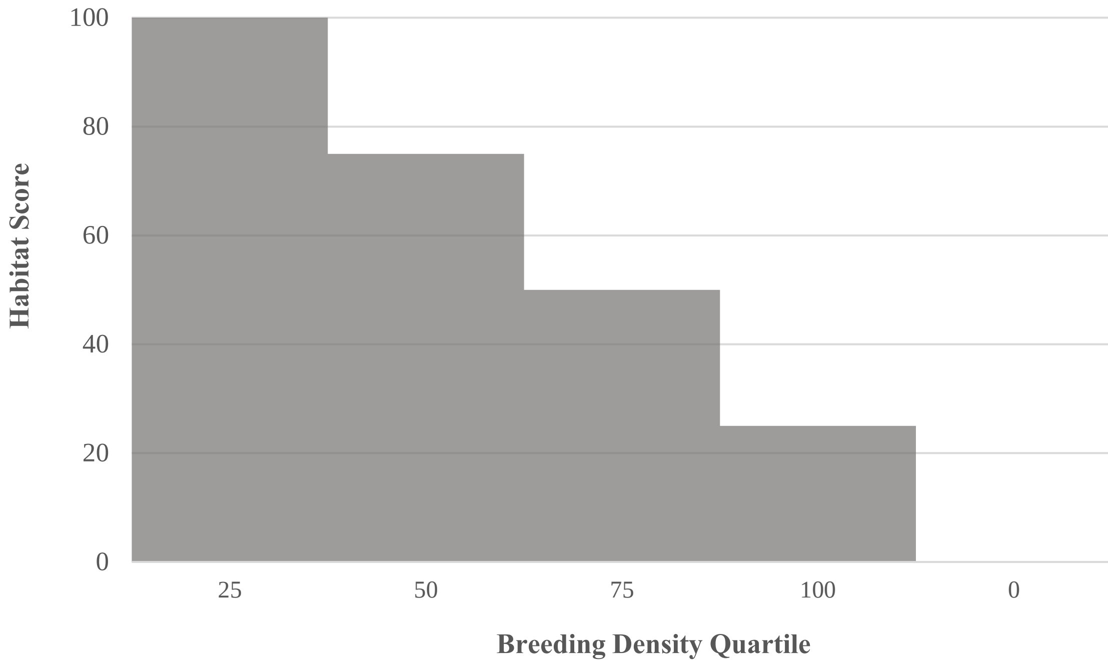

Figure A. 3. The Habitat Score for the Breeding Density Population and Habitat Variable.

GIS Steps for Habitat Score Creation:

1. Create raster that combines all vector outputs of Doherty model.
2. Reclassify Doherty model (Table A. 4) based on Table A. 3 above.

Table A. 4. Habitat Scores for each breeding density quartile bin for the Breeding Density Population and Habitat Variable.

Breeding Density (%)	**Habitat Score**
25	100
50	75
75	50
100	25
0 (outside model)	0

3. Unsuitable Land Cover Types

The EO defines unsuitable habitat as "land within the historic range of sage grouse that did not, does not, or will not provide sage grouse habitat due to natural ecological conditions such as badlands or canyons" (EO No. 12-2015). Unsuitable habitat would include rock outcroppings, and open water or reservoirs of more than 10 acres in size. For the purposes of the HQT, excluded unsuitable lands would also include land cover classes that do not provide basic life requisites for GRSG, and may include urban areas, existing disturbance footprints, recent burns (<10 years) or areas of high elevation or forested habitats not suitable for sage grouse.

Data Layers used in Habitat Score Creation: MSDI 2016 Landcover

This metric "zeros" out all non-habitat land use types.

GIS Steps for Habitat Score Creation:

1. Reclassify the NHP land cover dataset so that all unsuitable/excluded land cover types are given a value of 0 while all other suitable land cover types are given a value of 100.
2. Use the table described in Appendix L for appropriate land cover values to remap.

4. Sagebrush Abundance

Data Layers used in Habitat Score Creation: MRLC Sagebrush Cover

This metric measures the proportion of sagebrush habitat available within a 1.0-km radius (3.14-km^2) moving window.

Walker et al. (2007) found that the proportion of habitat that was classified as sagebrush within 6.4-km of a given lek's center location was a strong predictor of lek persistence in the Powder River Basin of Wyoming and Montana. Leks had a lower probability of persisting when areas within 6.4 km of the lek center had less than 30% sagebrush cover. Aldridge and Boyce (2007) used a moving window (1-km^2) to measure sagebrush cover and availability on the landscape. Their resource selection function found that GRSG selected nesting habitat that contained large patches (1-km^2) of sagebrush with moderate canopy cover and moderate sagebrush availability (i.e., heterogeneous distribution of sagebrush). Aldridge and Boyce (2007) found increasing probability of population persistence with increased availability of sagebrush on the landscape. Carpenter et al. (2010) found similar results. Their top resource selection functions included a quadratic function for sagebrush availability on the landscape, which indicates that areas of moderate sagebrush were selected more frequently than areas of low or homogenous sagebrush abundance. Doherty (2008) found that probability of GRSG use increased with increasing availability of sagebrush within 100.0m of a location. Wisdom et al. (2011) found that landscapes with less than 27% sagebrush availability were not different from landscapes from which GRSG have been extirpated. Similar to Aldridge and Boyce (2007), Wisdom et al. (2011) found that 50% sagebrush across a landscape was a good indicator of GRSG persistence.

Breakpoints for sagebrush cover in the model were determined from the above literature. The average probability of use of sagebrush by GRSG (odds or population persistence were also used, depending on study design) was calculated for projects occurring in Montana or in nearby states or Canadian provinces. Average values from Doherty (2008), Walker et al. (2007) and Aldridge and Boyce (2007), were calculated and standardized to a range of values between 0 and 100.

Using this approach, lands classified as sagebrush comprising 80% to 100% of a 3.14-km^2 window were characterized as having high habitat function and were assigned a score of 100 for this variable (Table A. 5; Figure A. 4). Lands classified as sagebrush comprising 40% to 80% of the window were determined to still have high habitat function and were assigned a score of between 75 and 90. Moderate functional scores (50 – 60) were assigned for areas having between 20% and 40% of lands classified as sagebrush in the assessment area. Areas with little sagebrush occurring in the assessment area received lower scores although areas having as little as 2% of the landscape classified as sagebrush still received a score of 15 due to use of silver sagebrush by GRSG.

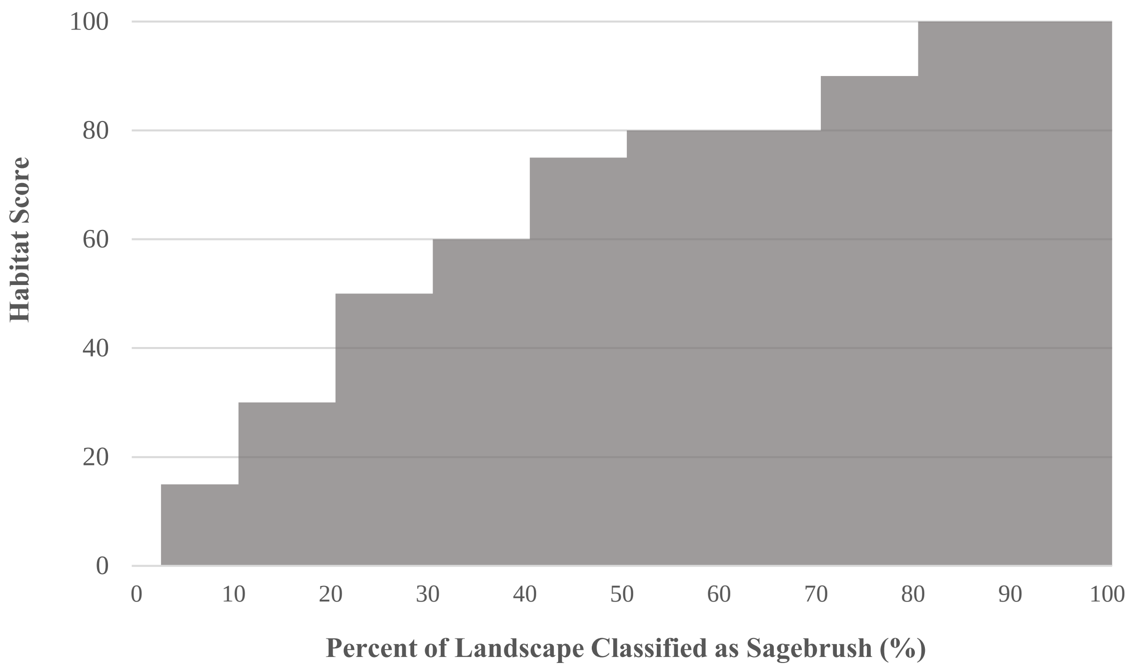

Figure A. 4. The Habitat Score for the Sagebrush Abundance Population and Habitat Variable represented by the percent of land cover classified as sagebrush in a 3.14-km² moving assessment window.

GIS Steps for Habitat Score Creation (for areas covered by NLCD data):

1. Extract by mask and project the MRLC NLCD sagebrush cover dataset to sage grouse habitat.
2. Reclassify the MRLC NLCD sagebrush cover dataset so that all areas with > 2% sagebrush cover are given a value of 1 and all areas with ≤ 2% sagebrush cover are assigned a value of 0.
3. Use the "Focal Statistics" tool (1,000-m radius circle neighborhood, SUM statistics) to create a raster that represents the number of cells surrounding a particular cell that have been converted.
4. Convert the new raster to a float.
5. Divide the resulting raster by the maximum possible number of cells within a 1,000-m radius circle. This maximum value will be dependent on cell size used, so script in a variable equal to float (arcpy.GetRasterProperties_management(sagefloat, "MAXIMUM").getOutput(0)) to plug into the Division step.
6. Reclassify the resulting raster (Table A. 5).

Table A. 5. Range of values and Habitat Scores for the Sagebrush Abundance Population and Habitat Variable represented by the percent of land cover classified as sagebrush in a 3.14-km² moving assessment window.

Sagebrush Abundance (%)	Habitat Score
0 – 2	0
>2 – 10	15
>10 – 20	30
>20 – 30	50
>30 – 40	60
>40 – 50	75
>50 – 70	80
>70 – 80	90
>80 – 100	100

5. Sagebrush Canopy Cover (%)

Data Layers used in Metric Creation: MRLC Sagebrush cover, MT sage grouse AOI

This metric measures the average sagebrush cover over the landscape. For most of the state, we can use the MRLC NLCD sagebrush cover dataset but it does not cover the western part of the state. For the areas not covered by the NLCD dataset, we calculate the sagebrush cover by extrapolating attributes from various vegetation transects in the area.

Sagebrush cover is an important attribute of nesting habitat because hens nest almost exclusively under sagebrush plants, with some limited exceptions documented in Montana. Connelly et al. (2000) cite 13 references to suitable sagebrush cover that range from 15% to 38% mean canopy cover surrounding the nest. Citations contained within Crawford et al. (2004) reported 12% to 20% cover, including 41% cover in nesting habitat though this percentage is likely rare in Montana. In their species assessment, Connelly et al. (2000) conclude that 15% to 25% canopy cover is the recommended range for productive GRSG nesting habitat. This is also the range identified in the *Sage-grouse Habitat Assessment Framework* (Stiver et al. 2015) as providing the highest function for GRSG based on a review of the available literature. Wallestad and Pyrah (1974) reported that successful nests were in stands where sagebrush cover approximated 27%. This cover range is used as a goal in some GRSG management guidelines (Bohne et al. 2007, BLM et al. 2000). Cagney et al. (2009) guidelines for grazing in GRSG habitat state that hens tend to select an average 23% live sagebrush canopy cover when selecting nesting sites. However, outside the optimal range, other studies (e.g., Perkins 2010) have found canopy cover >25% may still provide moderate suitability for nesting. For example, sagebrush canopy cover was higher on average around successful nests (33%) than unsuccessful nests (22%) in Wildcat Knoll, Utah (Perkins 2010).

In Montana, sagebrush cover used during nesting and breeding use periods are similar to those reported elsewhere across the range of GRSG. Doherty (2008) reported 20-30% cover surrounding nest locations in the Powder River Basin. Foster et al. (2014) found that habitat use by radio-collared GRSG during the breeding and nesting season was highest between 15-25% canopy cover. Tack (2009), Lane (2005), Woodward (2006), and Woodward et al. (2011) reported similar results with an average of approximately 15% canopy cover around nest locations. Overall, GRSG in Montana use a wide range of sagebrush canopy cover classes and use is based on availability and spatial variation across the GRSG habitats in Montana. The range of sagebrush canopy cover classes is critically important to provide a variety of cover and forage resources that change seasonally.

Sagebrush cover is also an important attribute of brood-rearing habitat. Connelly et al. (2000) found that productive brood-rearing habitat should include 10% to 25% cover of sagebrush. This is the range used as a goal in GRSG management guidelines in Oregon (Bohne et al. 2007, BLM et al. 2000). While sagebrush is a vital component of GRSG habitat, very thick shrub cover (e.g., >60%) may inhibit understory vegetation growth and reduce the birds' ability to detect predators (Wiebe and Martin 1998). In Montana, the range of canopy cover conditions reported for GRSG is largely consistent with reported values elsewhere in the range of the species. Klebenow (1969) reported that brood-rearing and summer use activities occurred in habitats having 15-35% cover. Martin (1970) reported brood and summer use activities in habitats having 10-35% cover. Foster et al. (2014) found that radio-collared GRSG in southeastern Montana used habitats having 10-35% cover with the majority of use occurring in areas having 15-25% cover. Woodward et al. (2011) and Lane (2005) reported brood/summer use in habitats having 10-15% cover.

Sagebrush is an essential component of winter habitat because GRSG winter diets are almost exclusively sagebrush leaves. Connelly et al. (2000) cite 10 references to sagebrush coverage in winter-use areas that range from 15% to 43% mean canopy cover [Crawford et al. (2004) also cites 2 of these references in their assessment]; however, they considered a canopy of 10-30% cover (above the snow) as a characteristic of sagebrush needed for productive GRSG winter habitat. This is the cover range used as a goal in GRSG management guidelines in Oregon (Bohne et al. 2007, BLM et al. 2000). However, conditions in Montana may not be consistent with these studies because of differences in winter conditions and snow depth. Eng and Schladweiler (1972), Foster et al. (2014), Wallestad and Pyrah (1974), and Woodward et al. (2011) provide Montana-specific values of sagebrush canopy cover in winter use areas. Eng and Schladweiler (1972) found that GRSG winter use in eastern Montana generally occurred in areas with greater than 20% sagebrush canopy cover. Foster et al. (2014) found that 78% of all use by radio-collared GRSG in southeastern Montana occurred in sagebrush habitats having 11-25% cover with an average of 11-13% cover in critical and important habitats. Only 7% of all GRSG use occurred in habitats greater than 25% cover with no use in habitat having greater than 31% cover.

Seasonal canopy cover values were standardized to a range of values between 0 and 100 for habitat variable scoring purposes. The maximum standardized seasonal use value across all three seasons was used as the basis for variable scoring (Table A. 6). Recognizing that optimal canopy cover conditions may vary slightly across seasons, the maximum standardized seasonal value was used rather than the average standardized value. This approach ensures that the HQT score for this habitat variable receives the maximum score possible for each sagebrush cover bin that was identified.

Across all seasons, the highest reported GRSG use in Montana occurred in habitats having 15-25% cover with the lowest use occurring in areas with sparse or extremely high sagebrush canopy cover. Sagebrush percent canopy cover of 15% to 30% was assumed to provide the highest function and was assigned a score of 100 (Table A. 7; Figure A. 5). Consistency in use of this range of sagebrush cover across all seasons supports this score. Areas with moderately more (30-40%) or less (10-15%) cover than the optimal range were determined to be highly functional and received scores of 70 and 90, respectively, using the maximum standardized seasonal values. Areas with substantially more (>45%) or less (<10%) cover than the optimal range were given lower scores. Areas with less than 3% canopy cover were given a score of 0.

Table A. 6. Standardized seasonal canopy cover values used to develop the Habitat Scores for the Sagebrush Canopy Cover Population and Habitat Variable.

Canopy Cover (%)	Nesting/ Breeding	Brood/ Summer	Winter	Maximum Seasonal Value
0	10	0	0	10
5	40	40	0	40
10	60	90	50	90
15	100	100	100	100
20	100	100	100	100
25	100	100	100	100
30	70	70	50	70
35	60	70	50	70
40	50		50	50
45	40			40
50	40			40

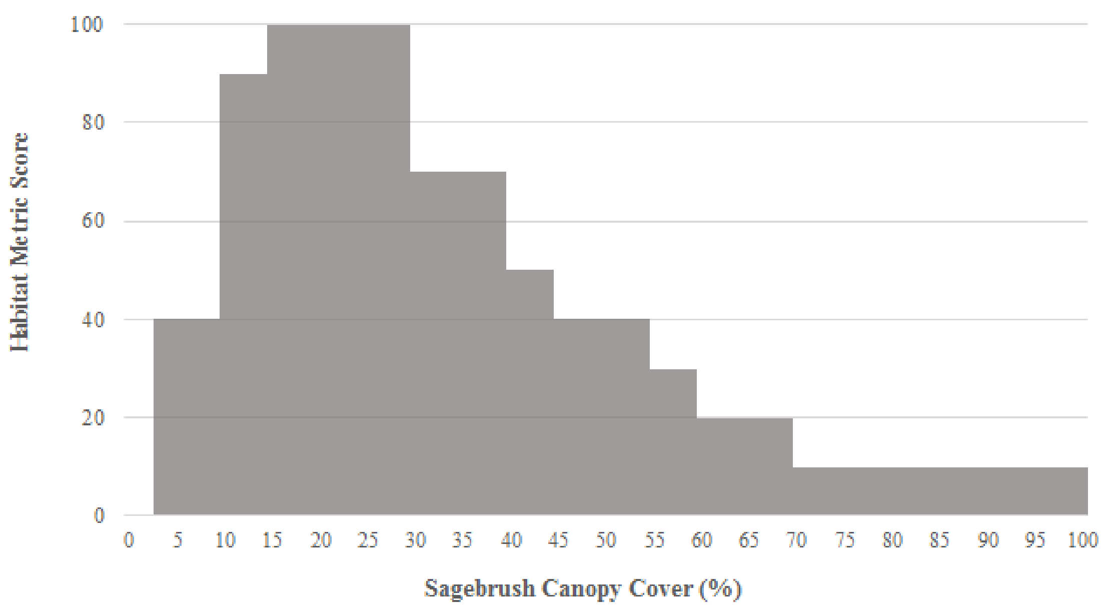

Figure A. 5. The Habitat Score for the Sagebrush Canopy Cover Population and Habitat Variable.

<u>GIS Steps for Habitat Score Creation:</u>

1. Reclassify the MRLC NLCD sagebrush cover raster according to the table below.
2. Extract by mask the MRLC NLCD sagebrush cover using the MT sage grouse AOI.
3. Reclassify sagebrush cover percentage (Table A. 7):

Table A. 7. Range of values and Habitat Scores for the Sagebrush Canopy Cover Population and Habitat Variable.

Sagebrush Cover (%)	Habitat Score
0 – <3	0
3 – <10	40
10 – <15	90
15 – <30	100
30 – <40	70
40 – <45	50
45 – <55	40
55 – <60	30
60 – <70	20
≥70	10

6. Sagebrush Height

Data Layers used in Habitat Score Creation: MRLC Sagebrush Height

Sagebrush canopy height is an important aspect of all GRSG seasonal habitats. However, literature recommendations for sagebrush height for GRSG habitat vary seasonally and regionally. Scores for this habitat variable were calculated by evaluating reported average seasonal sagebrush requirements for GRSG populations in Montana. Sagebrush height was characterized for winter, nesting/breeding, and brood/summer use periods, respectively.

Sagebrush height is an important attribute of GRSG nesting habitat. Connelly et al. (2000) reports that sagebrush heights ranging from 29.0-cm to 79.0-cm mean height are most commonly used during nesting. In their assessment, Connelly et al. (2000) conclude that sagebrush with a height of 30.0-cm to 80.0-cm is needed for productive GRSG nesting habitat in arid sites and 40.0-cm to 80.0-cm in mesic sites. These ranges are used by Stiver et al. (2015), who recommend a range of 30.0-cm to 80.0-cm at arid sites, and BLM et al. (2000), which state that optimum GRSG nesting habitat consists of sagebrush stands containing plants 40.0-cm to 80.0-cm tall. Heights of 40.0-cm to 80.0-cm are rarely reported in literatures specific to GRSG in Montana.

Because of the differences in reported Montana sagebrush height values and values reported elsewhere across the range of the species, Montana-specific data and literature were used to evaluate height requirements during the nesting season. In Montana, GRSG nesting was most commonly reported in habitats having sagebrush heights between 15.0-cm and 50.0-cm (Eng and Schladweiler 1972, Lane 2005, Wisinski 2007, Woodward et al. 2011, Foster et al. 2014). Lane (2005) reported the most variable range of conditions with nesting occurring in sagebrush with heights between 25.0-cm and 50.0-cm. In southeastern Montana, Foster et al. (2014) reported that radio-collared GRSG most commonly nested in habitats having heights between approximately 30.0-cm and 40.0-cm. Wisinski (2007) reported similar ranges of conditions in nesting habitats with highest use reported for sagebrush heights between 25.0-cm and 45.0-cm.

During the brood rearing season, GRSG may use habitats that are not dominated by sagebrush (Connelly et al. 2000). Schreiber et al. (2015) found that while sagebrush was necessary to support brood-rearing in most cases, visual obstruction provided by all vegetation types between 0.0-cm and 45.7-cm was the most influential variable in models predicting brood survival. Hansen et al. (2016) found a similar influence of visual obstruction for nesting sites although sagebrush cover and height greater than 20.0-cm were also influential in models of nest site selection. In Montana, sagebrush heights were reported for a number of studies and were used to evaluate Montana-specific requirements of sagebrush height during the brood-rearing and summer use periods. Sagebrush heights of 20.0-cm to 65.0-cm have been reported for brood and summer use habitats in Montana (Martin 1970, Lane 2005, Wisinski 2007, Woodward et al. 2011, Foster et al. 2014). The most commonly reported range of sagebrush heights used in Montana falls between 20.0-cm and 45.0-cm (Lane 2005, Wisinski 2007, Foster et al. 2014).

Important structural components in winter habitat include medium to tall (25.0-cm to 80.0-cm) sagebrush stands (Crawford et al. 2004). Connelly et al. (2000) cite 10 references to sagebrush height in winter habitat that range from 20.0-cm to 46.0-cm above the snow. Two studies cited by Connelly et al. (2000) measured the entire plant height and provided a range from 41.0-cm to 56.0-cm. In their assessment, Connelly et al. (2000) conclude that characteristics of productive winter habitat include sagebrush that is 25.0-cm to 35.0-cm in height above the snow. This is the height range used as a goal in GRSG management guidelines in Oregon (Bohne et al. 2007, BLM et al. 2000).

Ranges for winter use developed across the range of the GRSG may not be representative of conditions in Montana because of differences in sagebrush communities as well as snowfall depths and winter conditions. For Montana GRSG, Eng and Schladweiler (1972) and Woodward et al. (2011) found that sagebrush height of 25.0-cm to 35.0-cm were most commonly used in winter months. In southeastern Montana, Foster et al. (2014) found that use by radio-collared GRSG occurred in habitats having sagebrush height between approximately 8.0-cm and 80.0-cm with mean sagebrush heights of 20.0-cm to 28.0-cm in important winter habitat areas.

Seasonal sagebrush height averages were standardized to a range of values between 0 and 100.0 for final scoring purposes. The maximum standardized seasonal value across all three seasons was used as the basis for the habitat variable scoring (Table A. 8). Recognizing that optimal sagebrush height conditions may vary slightly across seasons, the maximum standardized seasonal value was used rather than the average standardized value. This approach ensures that the HQT score for this variable receives the maximum score possible for each sagebrush height bin that was identified.

Across all seasons, the highest reported GRSG use in Montana occurred in habitats having sagebrush heights of 25.0-cm to 40.0-cm (Table A. 8; Figure A. 6). This range of values was assigned a score of 100.0 (Table A. 8) for the sagebrush height habitat variable as that range has the potential to provide high quality habitat conditions across all seasons (Table A. 8). Based on the maximum standardized seasonal height values, sagebrush having heights between 15.0-cm and 25.0-cm and those with heights between 45.0-cm and 70.0-cm were assigned moderate to high scores (60-90). As sagebrush canopy height decreases, the value of a sagebrush plant to provide cover for nesting females and their nests/broods or provide winter habitat is diminished. Sagebrush heights of less than 10.0-cm were assigned a score of 0.0 due to the lack of reported use in habitats with extremely low growing sagebrush.

Table A. 8. Standardized seasonal sagebrush height values used to develop the Habitat Scores for the Sagebrush Height Population and Habitat Variable.

Sagebrush Height (cm)	Nesting/ Breeding	Brood/ Summer	Winter	Maximum Seasonal Value
0	--	--	--	--
5	--	--	--	--
10	10	10	10	10
15	60	30	20	60
20	70	80	50	80
25	90	90	100	100
30	100	100	100	100
35	100	100	80	100
40	100	100	20	100
45	80	90	10	90
50	70	70	10	70
55	40	80	10	80
60	20	60	10	60
65	10	60	10	60

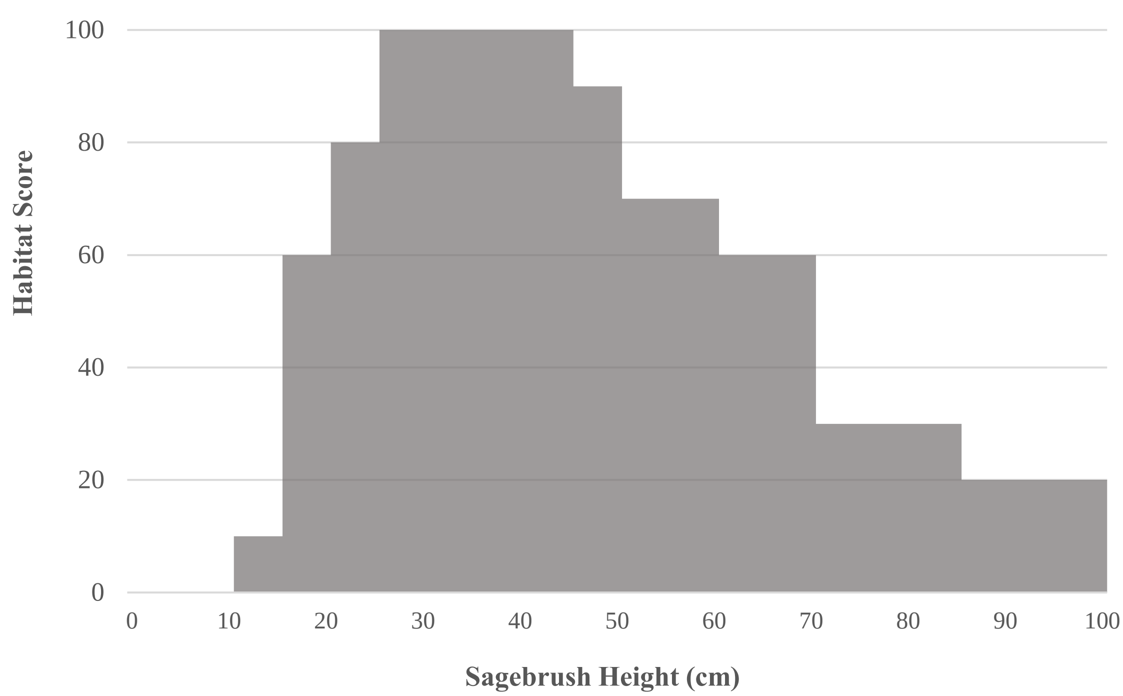

Figure A. 6. The Habitat Score for the Sagebrush Height Population and Habitat Variable.

GIS Steps for Habitat Score Creation (for areas covered by the NLCD data):

1. Reclassify the MRLC NLCD sagebrush height raster (Table A. 9).
2. Extract by mask the MRLC NLCD sagebrush height to sage grouse habitat

Table A. 9. Range of values and Habitat Scores for the Sagebrush Height Population and Habitat Variable.

Sagebrush Canopy Height (cm)	Habitat Score
0 – 10	0
>10 – 15	10
>15 – 20	60
>20 – 25	80
>25 – 45	100
>45 – 50	90
>50 – 60	70
>60 – 70	60
>70 – 85	30
>85	20

7. Distance to Suitable Upland Habitat

Data Layers used in Metric Creation: MSDI 2016 Landcover

This metric measures the distance to suitable upland/nesting habitat from all mesic/lowland habitats developed from 3 spatial datasets (Montana Natural Heritage Program [MTNHP] Landcover raster, MTNHP Wetland/Riparian shapefile, USFWS National Wetlands Inventory [NWI] for Montana shapefile) by extracting attribute types based on their importance to GRSG during the late-brood rearing season (Figure A. 10).

Table A. 10. Datasets and the associated selected attributes used to delineate Mesic habitat in the development of the Mesic Mask layer.

Dataset	Field Name	Selected Attributes
MTNHP Landcover[1]	SNAME	Alpine-Montane Wet Meadow
		Great Plains Closed Depressional Wetland
		Great Plains Open Freshwater Depression Wetland
		Great Plains Prairie Pothole
		Great Plains Riparian
		Great Plains Saline Depression Wetland
		Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland
		Pasture/Hay
		Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland
		Rocky Mountain Subalpine-Montane Mesic Meadow
		Rocky Mountain Subalpine-Montane Riparian Shrubland
MTNHP Wetland/Riparian[2]	WETLAND_TYPE	Freshwater Emergent Wetland
		Riparian Emergent
		Riparian Scrub-Shrub
		Freshwater Pond
USFWS NWI – MT[3]	WETLAND_TYPE	Freshwater Emergent Wetland
		Freshwater Pond
		Riverine

[1] MTNHP (Montana Natural Heritage Program) Landcover data source: ftp://ftp.geoinfo.msl.mt.gov/Data/Spatial/MSDI/LandUse_LandCover
[2] MTNHP Wetland/Riparian data source: https://mslservices.mt.gov/Geographic_Information/Data/DataList/datalist_Details.aspx?did={f57e92f5-a3fa-45b2-9de8-0ba46bbb2d46}
[3] USFWS NWI – MT (U.S. Fish and Wildlife Service National Wetlands Inventory for Montana) data source: https://www.fws.gov/wetlands/data/State-Downloads.html ; layer name "CONUS_wet_poly"

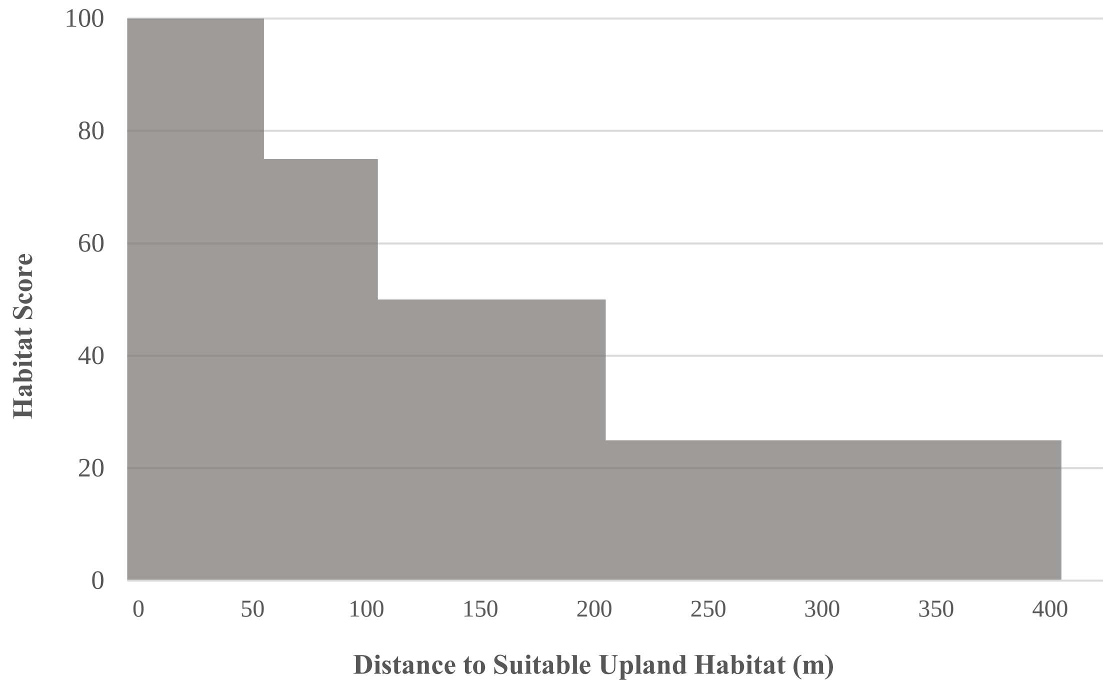

Figure A. 7. The Habitat Score for the Distance to Suitable Upland Population and Habitat Variable.

GIS Steps for Habitat Score Creation:

1. Reclassify the NHP land cover dataset so that all suitable upland land cover types (shrub habitats) are given a value of 1 while all other land cover types are given a value of 0.
2. Extract by attribute only the suitable upland land cover types.
3. Run the Euclidean Distance tool to create a raster that represents the distance to the closest suitable upland habitat.
4. Reclassify the distance raster (Table A. 11).
5. Create the Mesic Mask layer by selecting the attribute types listed in Table A. 10.
   a. Clip to GRSG habitat
   b. Convert to raster and reclassify, specifying a value of 1 for all the selected attributes to represent Mesic areas.
6. Combine the reclassified distance raster with the Mesic Mask layer using 'Mosaic to New Raster' making sure to use 'MINIMUM' as the mosaic operator.

Table A. 11. Range of values and Habitat Scores for the Distance to Suitable Upland Population and Habitat Variable.

Distance to Suitable Upland Habitat (m)	Habitat Score
0 – 50	100
>50 – 100	75
>100 – 200	50
>200 – 400	25
>400	0

8. Habitat Score Raster

The Habitat Score Raster is computed by averaging all the Habitat Score rasters specific to the Population and Habitat Variables defined above. Given that habitats outside the sage grouse occupied range and non-habitats (i.e., unsuitable lands; see Appendix L for a complete list of land cover types designated as suitable or unsuitable lands in the model) are masked from scoring, an averaging approach (as compared to a multiplicative approach) provides a method where potential habitat cannot be zeroed out by a single vegetation or population variable. This is important for considering the mosaic of habitat conditions important for sage grouse through their annual life cycle.

Create a raster output that is the average of the seven Habitat Score raster outputs described above:

Habitat Score **=**

([*Distance to Lek* + *Breeding Density* + *Excluded Lands* + *Sagebrush Abundance* + *Sagebrush Cover* + *Sagebrush Height* + *Distance to Upland*]/7)

ANTHROPOGENIC VARIABLES

<u>GIS Steps for Preprocessing the input data sources:</u>

1. Dissolve DNRC Existing Disturbance by 'Disturbance Type' attribute field.
2. Create 'Dummy Mosaic' with value = 100 that covers all of GRSG habitat.
3. Resulting data layer: DNRC Total Disturbance

1. Oil & Gas Well Density

<u>Data Layers used in Anthropogenic Score Creation</u>: DNRC Total Disturbance

This metric measures the density of oil and gas wells in an area to quantify their impact on nearby habitats. See Appendix B for complete literature review for support of the following values.

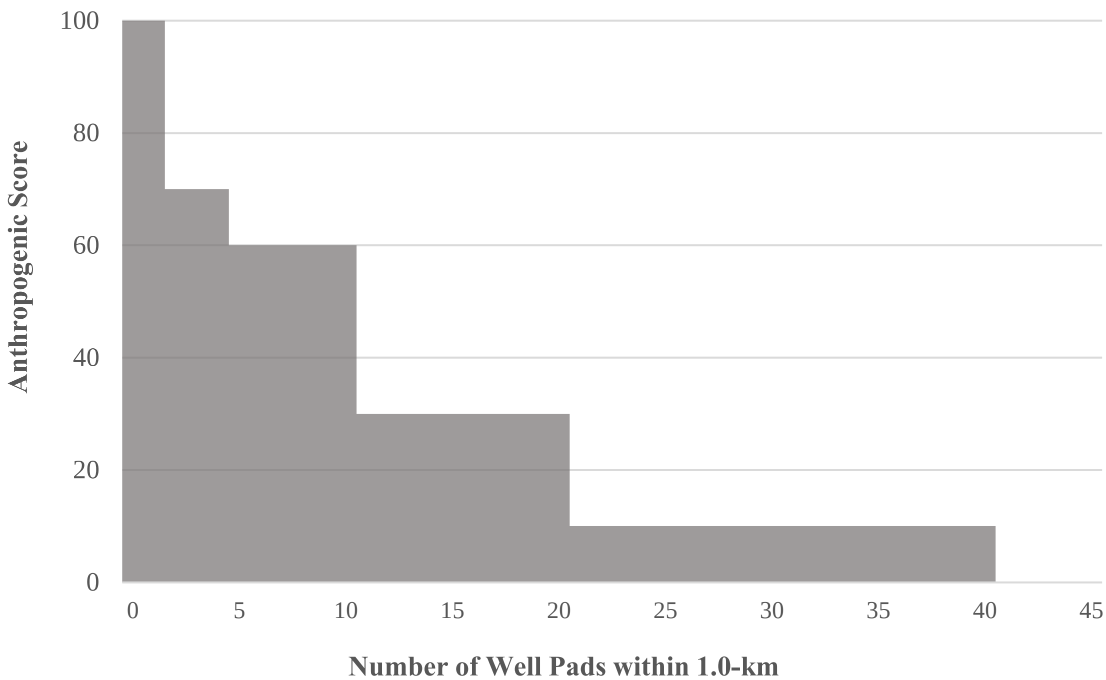

Figure A. 8. The Anthropogenic Score for the Oil and Gas Well Density Anthropogenic Variable.

GIS Steps for Anthropogenic Score Creation:

1. Query "well pads" out of DNRC Total Disturbance to create Well Pads layer.
2. Convert features in the Well Pads layer to points using centroid and point location.
3. Add a new field to the Well Pads layer called "count" and calculate the field = 1. This field will be used in the next step to run the point statistics tool.
4. Run the Point Statistics tool (1,000-m radius circle neighborhood, SUM statistics) on the "count" field in the Well Pads layer. The resulting raster layer represents the number of wells within 1.0-km of each cell.
5. Reclassify the point statistics raster (Table A. 12).
6. Combine the reclassified well density raster with the dummy raster that covers all sage grouse habitat using 'Mosaic to New Raster' making sure to use "MINIMUM" as the mosaic operator to create the Final Well Density raster.

Table A. 12. Range of values for the number of well within a 1.0-km radius and the associated Anthropogenic Scores for the Oil & Gas Well Density Anthropogenic Variable.

Number of Wells within 1.0-km	Anthropogenic Score
0 – 1	100
2 – 4	70
5 – 10	60
11 – 20	30
21 – 40	10
≥41	0

2. Distance to Tall Structure

Data Layers used in Anthropogenic Score Creation: DNRC Total Disturbance

Disturbances included in this metric are tall features such as Communication Towers and Weather Towers. This metric measures the distance to the nearest Tall Structure for each cell to quantify the impacts of Tall Structures on nearby habitats (Figure A.9). Because the DNRC Total Disturbance layer cannot distinguish between nest facilitating and non-nest facilitating, all Tall Structures will be assumed to be nest facilitating for the purposes of the HQT Basemap. See Appendix C for complete literature review for support of the following values and the application of the nest vs. non-nest facilitating concept.

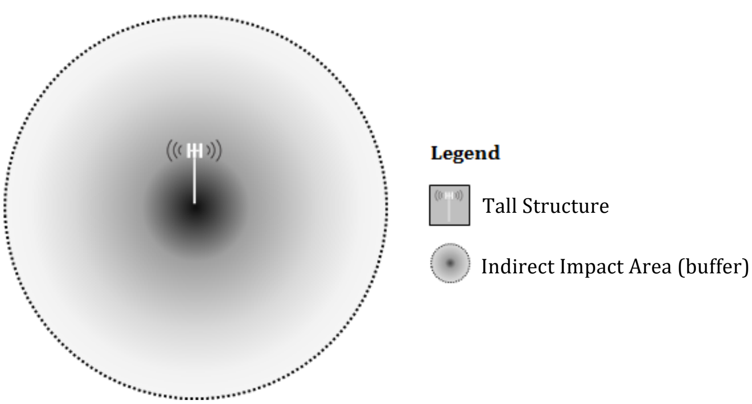

Figure A. 9. Conceptual diagram of the 6.0 or 3.0-km radius buffer applied to Tall Structures to establish the Indirect Impact area.

GIS Steps for Anthropogenic Score Creation:

1. Query Tall Structures out of DNRC Total Disturbance to create Tall Structures layer.
2. Query Tall Structures within 4-miles of an active sage grouse lek to create Tall Structures Near Lek layer and the remainder Tall Structures will create the Tall Structures Far Lek layer.
3. Buffer the Tall Structures Near Lek layer by 6,000-m to create an Output Extent Near Lek layer and buffer the Tall Structures Far Lek layer by 3,000-m to create an Output Extent Far Lek layer.
4. Run Euclidean distance on Tall Structures Near Lek layer and on Tall Structures Far Lek layer with a maximum distance of 6,000-m and 3,000-m, respectively, specifying the previous associated buffer as the extent in environments settings.
5. Reclassify the resulting Tall Structures Near Lek raster (Figure A. 10, Table A. 13) and the Tall Structures Far Lek raster (Figure A. 11, Table A. 14).
6. Combine the two reclassified rasters with the dummy raster that covers all sage grouse habitat using 'Mosaic to New Raster' making sure to use "MINIMUM" as the mosaic operator to create the Final Tall Structures raster.

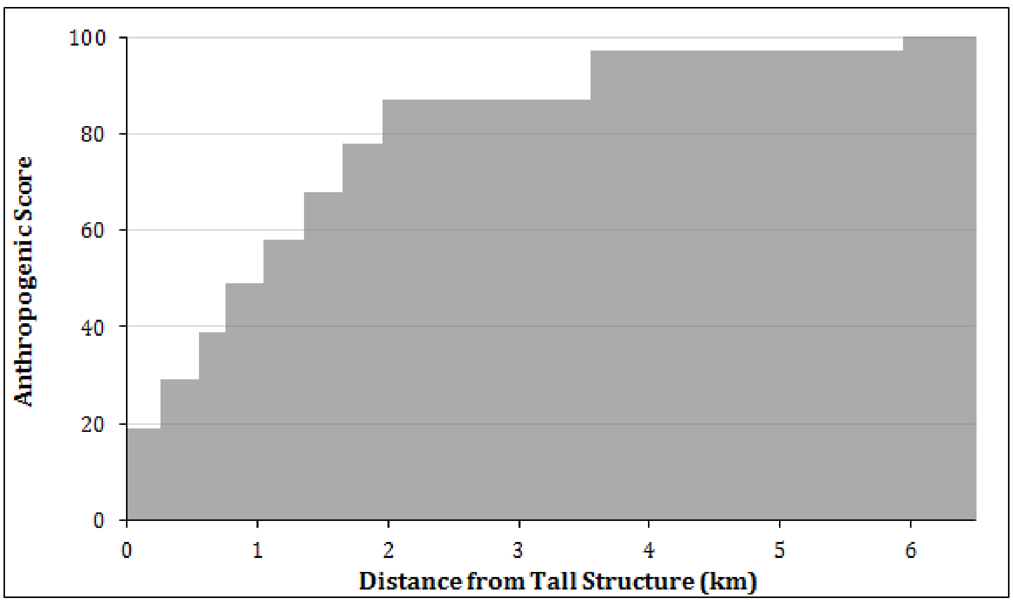

Figure A. 10. The Anthropogenic Score for the Distance to Tall Structures Near Lek component of the Final Tall Structures Anthropogenic Variable.

Table A. 13. Range of values and Anthropogenic Scores for the Distance to Tall Structures Near Lek component of the Final Tall Structures Anthropogenic Variable.

Distance to Tall Structure (km)	Anthropogenic Score
0 – <0.3	19
0.3 – <0.6	29
0.6 – <0.8	39
0.8 – <1.1	49
1.1 – <1.4	58
1.4 – <1.7	68
1.7 – <2.0	78
2.0 – <2.3	87
2.3 – <3.6	87
3.6 – <6.0	97
≥ 6.0	100

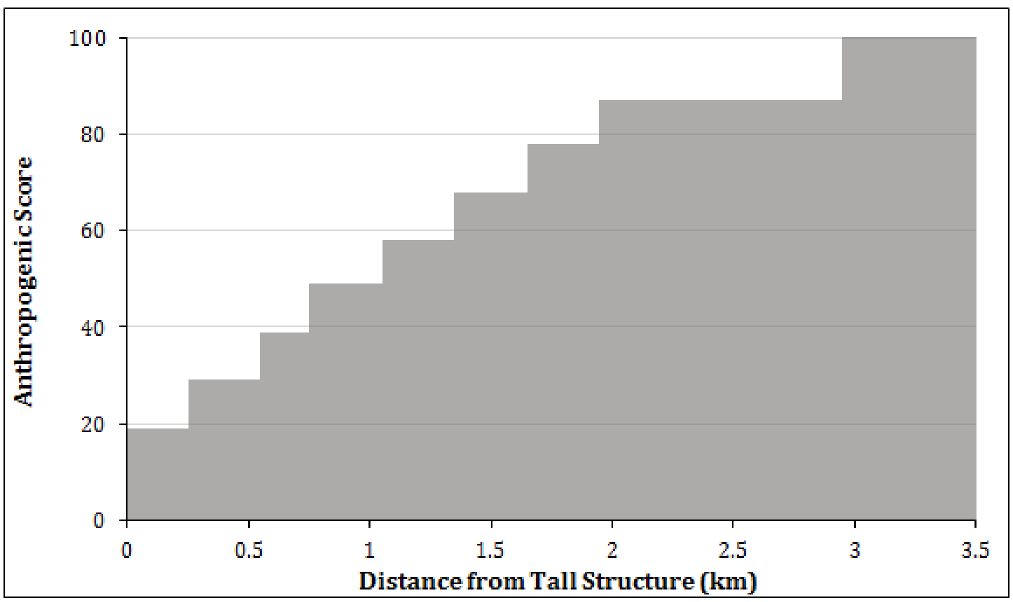

Figure A. 11. The Anthropogenic Score for the Distance to Tall Structures Far Lek component of the Final Tall Structures Anthropogenic Variable.

Table A. 14. Range of values and Anthropogenic Scores for the Distance to Tall Structures Far Lek component of the Final Tall Structures Anthropogenic Variable.

Distance to Tall Structure (km)	Anthropogenic Score
0 – <0.3	19
0.3 – <0.6	29
0.6 – <0.8	39
0.8 – <1.1	49
1.1 – <1.4	58
1.4 – <1.7	68
1.7 – <2.0	78
2.0 – <2.3	87
2.3 – <3.0	87
≥ 3.0	100

3. Distance to Transmission/Distribution Structures (Lines, Structures/Poles, and/or Substations)

Data Layers used in Metric Creation: DNRC Total Disturbance

Disturbances included in this metric are above-ground linear features such as Transmission/ Distribution Lines and the associated Towers/Poles and/or Substations. This metric measures the distance to the nearest Transmission Line, Pole, and/or Substation for each cell to quantify the impacts on nearby habitats. As a default all Transmission/Distribution Lines the are digitized in the DNRC Total Disturbance layer will be considered to be >115-kV in size and receive the 6.0-km buffer to establish the indirect impact area. Additionally, because the DNRC Total Disturbance layer cannot distinguish between nest facilitating and non-nest facilitating, all Transmission/Distribution Structures will be assumed to be nest facilitating for the purposes of the HQT Basemap. See Appendix D for complete literature review for support of the following values and the application of the smaller 3.0-km buffer and the nest vs. non-nest facilitating concept.

GIS Steps for Anthropogenic Score Creation:

1. Query Transmission/Distribution Structures from the DNRC Total Disturbance to create the Transmission/Distribution Structures layer.
2. Buffer the Transmission/Distribution Structures layer by 6.0-km to create the output extent layer.
3. Run Euclidean Distance on the Transmission/Distribution Structures layer with a maximum distance of 6.0-km, specifying the previous buffer as the extent in environments settings.
4. Reclassify the resulting Transmission/Distribution Structures raster (Figure A. 12, Table A. 15).
5. Combine the reclassified Transmission/Distribution Structures raster with the dummy raster that covers all GRSG habitat using 'Mosaic to New Raster' making sure to use "MINIMUM" as the mosaic operator to create the Final Transmission/Distribution Structure raster.

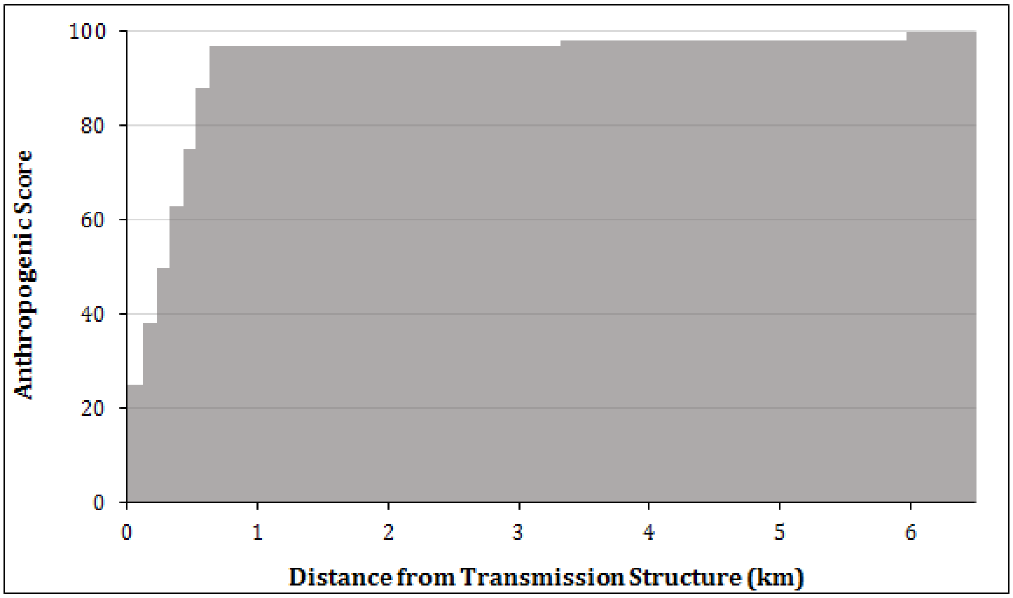

Figure A. 12. The Anthropogenic Score for the Distance to Transmission/Distribution Structure Anthropogenic Variable.

Table A. 15. Range of values and Anthropogenic Scores for the Distance to Transmission/ Distribution Structure Anthropogenic Variable.

Distance to Tall Structure (km)	Anthropogenic Score
0 – <0.3	19
0.3 – <0.6	29
0.6 – <0.8	39
0.8 – <1.1	49
1.1 – <1.4	58
1.4 – <1.7	68
1.7 – <2.0	78
2.0 – <2.3	87
2.3 – <3.0	87
≥ 3.0	100

4. Wind Facilities (Percent Disturbance)

Data Layers used in Metric Creation: DNRC Total Disturbance

This metric measures the percent disturbance in an area due to Wind Energy Infrastructure. See Appendix E for complete literature review for support of the following values.

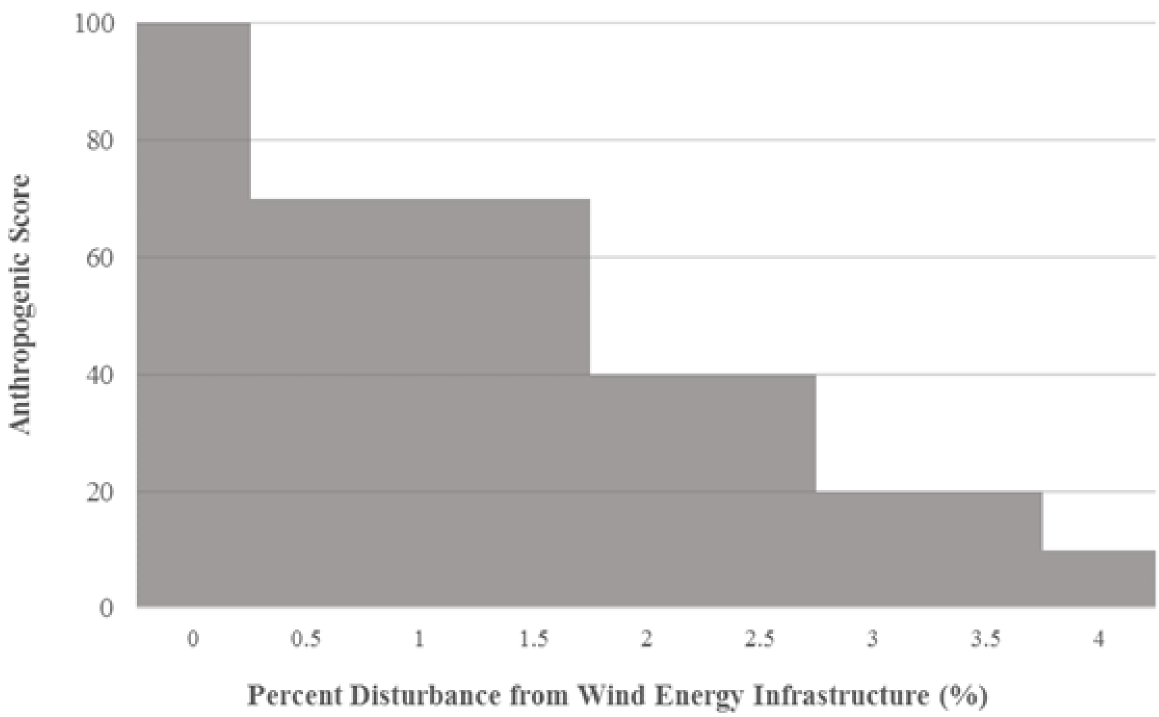

Figure A. 13. The Anthropogenic Score for the Wind Facilities Anthropogenic Variable.

GIS Steps for Anthropogenic Score Creation:

1. Query Wind Facilities out of DNRC Total Disturbance to create Wind Facilities layer.
2. Use the Focal Statistics tool (1.5-km radius circle neighborhood, SUM statistics) to create a raster that represents the number of cells surrounding a particular cell that are categorized as Wind Facility Infrastructure (pixel value = 1).
3. Convert the new raster to data type: float.
4. Divide the resulting raster by the maximum possible number of cells within a 1.5-km radius circle to create the "Wind Facility Percent Disturbance" raster. This maximum value will be dependent on cell size used, so script in a variable equal to: "float(arcpy.GetRasterProperties_management(windfacilityfloat, "MAXIMUM").getOutput(0))" to plug into the Division step.
5. Reclassify the resulting raster (Figure A. 13, Table A. 16).
6. Combine the reclassified Wind Energy Percent Disturbance raster with the dummy raster that covers all sage grouse habitat using 'Mosaic to New Raster' making sure to use "MINIMUM" as the mosaic operator to create the Final Wind Energy raster.

Table A. 16. Anthropogenic Scores for area covered by wind energy facilities.

Percent Disturbance from Wind Energy Infrastructure within 1.5-km moving window (%)	Anthropogenic Score
0 – <0.5	100
0.5– <2	70
2 – <3	40
3 – <4	20
≥4	10

5. Distance to Moderate Roads & Railways

Data Layers used in Anthropogenic Score Creation: DNRC Total Disturbance

This metric measures the distance to the nearest moderate road or railway (e.g., spur rail) for each cell to quantify the impacts on nearby habitats. See Appendix F for complete literature review for support of the following values.

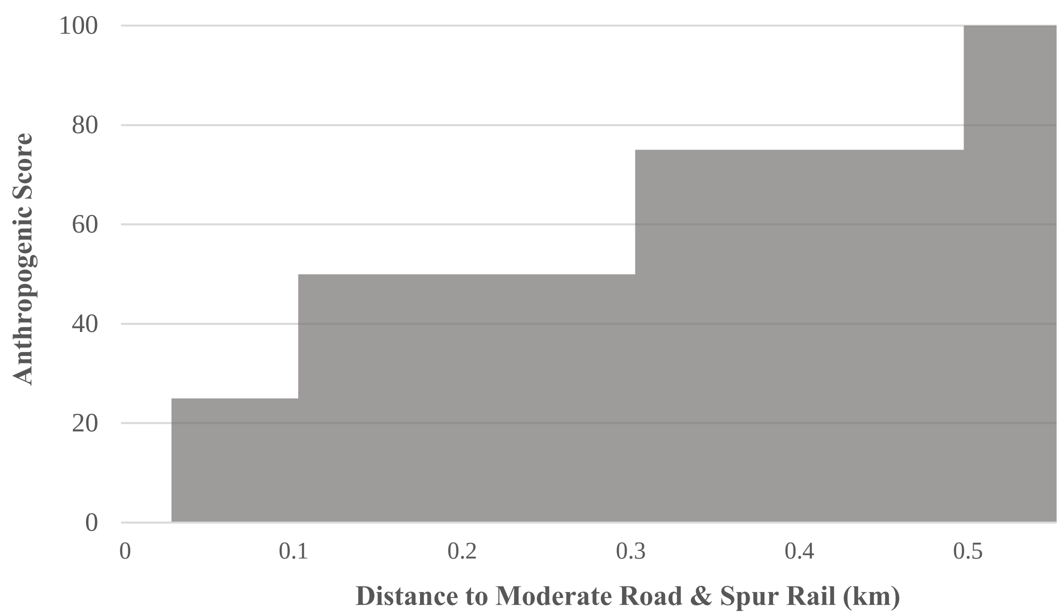

Figure A. 14. The Anthropogenic Score for the Distance to Moderate Road and Spur Rail Anthropogenic Variable.

GIS Steps for Anthropogenic Score Creation:

1. Query DNRC Total Disturbance to extract moderate roads or spur rails.
2. Buffer the resulting Moderate Roads & Railways layer by 500-m, creating an extent buffer.
3. Run Euclidean Distance on the layer with 500-m as the maximum distance. Assign the 500-m extent buffer layer as the extent in environment settings.
4. Reclassify the resulting raster (Figure A. 14, Table A. 17).
5. Combine reclassified Moderate Roads & Railways raster with dummy raster (represents all sage grouse habitat) using 'Mosaic to New Raster', setting "MINIMUM" as the mosaic operator to create the Final Moderate Roads & Railways raster.

Table A. 17. Range of values and Anthropogenic Scores for the Distance to Moderate Roads and Spur Rails Anthropogenic Variable.

Distance to Moderate Road & Spur Rail (km)	Anthropogenic Score
>0.5	100
>0.3 – 0.5	75
>0.1 – 0.3	50
>0.025 – 0.1	25
0.0 – 0.025	0

6. Distance to Pipelines, Fiber Optic Cables, & Other Buried Utilities

Data Layers used in Anthropogenic Score Creation: DNRC Total Disturbance

This metric measures the distance to the nearest pipeline, fiber optic cable, or other buried utility for each cell to quantify the impacts on nearby habitats. See Appendix G for complete literature review for support of the following values.

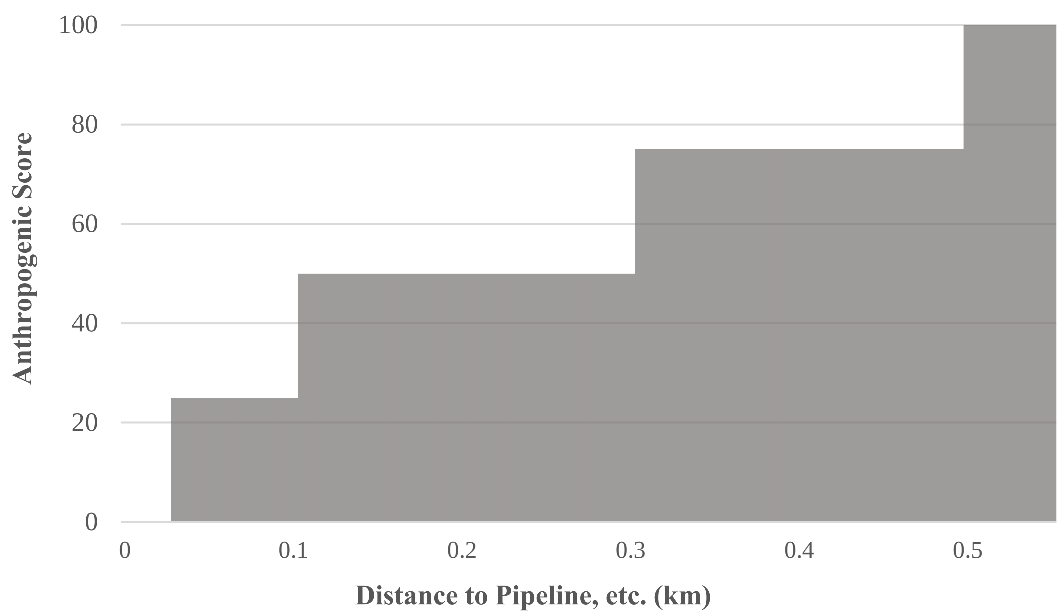

Figure A. 15. The Anthropogenic Score for the Distance to Pipelines, Fiber Optic Cables, and Other Buried Utilities Anthropogenic Variable.

GIS Steps for Anthropogenic Score Creation:

1. Query DNRC Total Disturbance to extract pipelines, fiber optics & other buried utilities.
2. Buffer the resulting Buried Utilities layer by 500-m, creating an extent buffer.
3. Run Euclidean Distance on the layer with 500-m as the maximum distance. Assign the 500-m extent buffer layer as the extent in environment settings.
4. Reclassify the resulting raster (Figure A. 15, Table A. 17).
5. Combine reclassified Buried Utilities raster with dummy raster (all sage grouse habitat) using 'Mosaic to New Raster', setting "MINIMUM" as the mosaic operator to create the Final Buried Utilities raster.

7. Agriculture, Mine, and Other Large-scale Land Conversion Activities (%)

Data Layers used in Anthropogenic Score Creation: MSDI LULC and DNRC Total Disturbance

This metric measures the density of land conversion (due to agriculture, mining, etc.) in an area. See Appendix H for complete literature review for support of the following values.

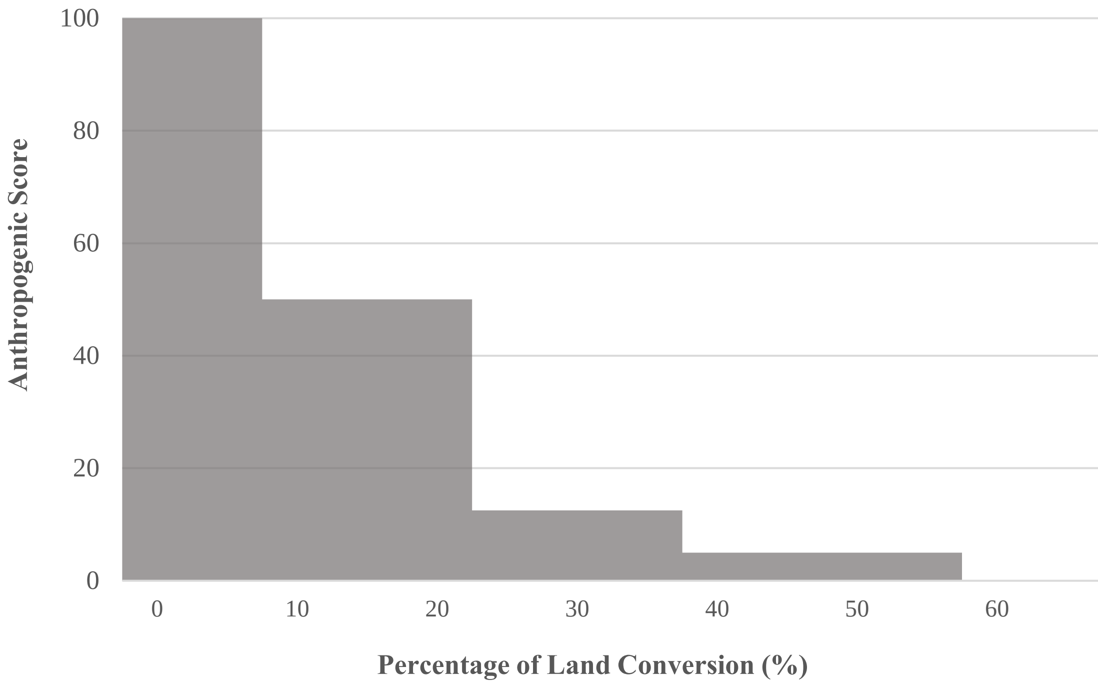

Figure A. 16. The Anthropogenic Score for the Agriculture, Mines, and Other Large-scale Land Conversion Activities Anthropogenic Variable.

GIS Steps for Anthropogenic Score Creation:

1. Reclassify the MSDI LULC data layer so all land conversion land cover types (agriculture, mining, etc.) are given a value of 1 while all other land cover types are given a value of 0 to create an MSDI Land Conversion layer.
2. Create a feature layer of land conversion disturbances (agriculture, cropland, mining) from the DNRC Total Disturbance layer and convert to raster. Reclassify this raster so that all areas of land conversion are given a value of 1 to create a DNRC Land Conversion layer.
3. Merge the MSDI Land Conversion layer and DNRC Land Conversion layer using the "Mosaic to New Raster" tool (MAXIMUM Mosaic operator) to create a Land Conversion layer.
4. Use the Focal Statistics tool (3,200-m radius circle neighborhood, SUM statistics) to create a raster that shows the number of cells surrounding a given cell that have been converted.
5. Convert the new raster to data type: float.
6. Divide the resulting raster by the maximum possible number of cells within a 3,200-m radius circle. This maximum value will be dependent on cell size used, so script in a variable equal to: "float(arcpy.GetRasterProperties_management(Agminefloat, "MAXIMUM").getOutput(0))" to plug into the Division step.
7. Reclassify the resulting raster (Figure A. 16, Table A. 18).
8. Combine the reclassified Land Conversion Density raster with dummy raster (all sage grouse habitat) using 'Mosaic to New Raster', setting "MINIMUM" as mosaic operator to create the Final Land Conversion raster.

Table A. 18. Range of values for the percent of land converted and the associated Anthropogenic Scores for the Agriculture, Mines, and Other Large-scale Land Conversion Activities Anthropogenic Variable.

Percentage of Land Conversion (%)	Anthropogenic Score
0 – <10	100
10 – <25	50
25 – <40	12.5
40 – <60	5
≥60	0

8. Distance to Major Roads

Data Layers used in Anthropogenic Score Creation: DNRC Existing Disturbance, MDT Yearly Traffic Count data

This metric measures the distance to the nearest major road for each cell to quantify the impacts on nearby habitats. See Appendix F for complete literature review for support of the following values.

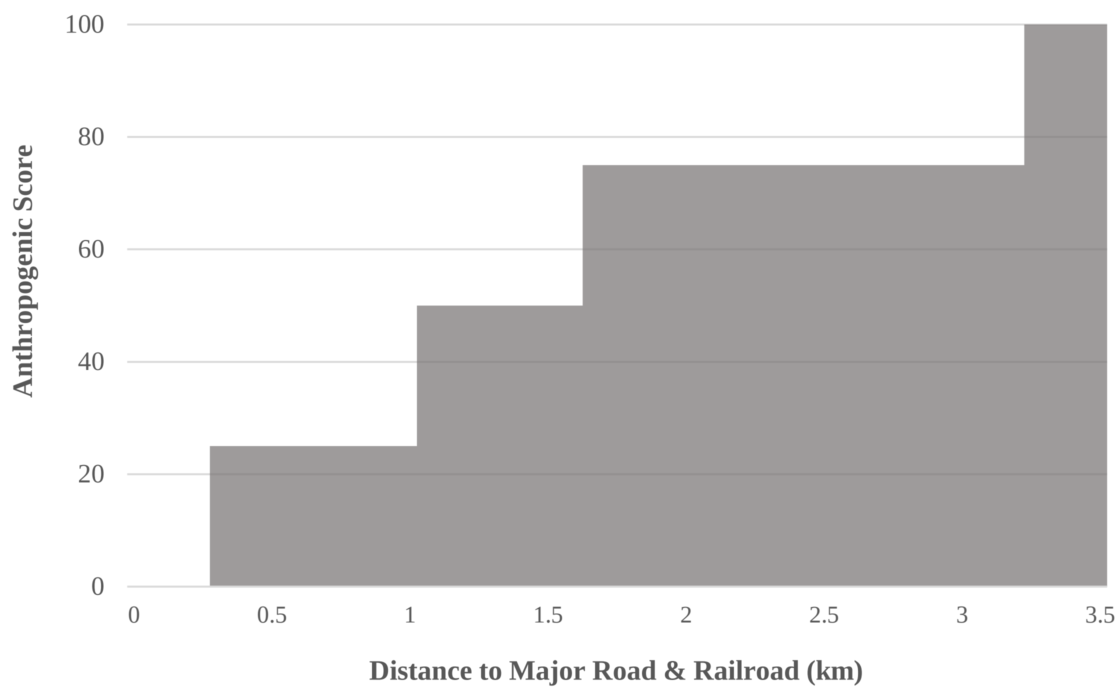

Figure A. 17. The Anthropogenic Score for the Distance to Major Roads and Railroads Anthropogenic Variable.

GIS Steps for Anthropogenic Score Creation:

1. Query high traffic roads from MDT Yearly Traffic Count data that intersect roads from DNRC Existing Disturbance and merge with queried railroads from DNRC Existing Disturbance to create Major Roads & Railroads layer.
2. Buffer the Major Roads & Railroads layer by 3,200-m to create an output extent layer.
3. Run Euclidean distance on Major Roads & Railroads layer with a maximum distance of 3,200-m, specifying the previous buffer as the extent in environments settings.
4. Reclassify this raster (Figure A. 17, Table A. 19).
5. Combine the reclassified Major Roads & Railroads raster with the dummy raster that covers all sage grouse habitat using 'Mosaic to New Raster' making sure to use "MINIMUM" as the mosaic operator to create the Final Major Roads & Railroads raster.

Table A. 19. Range of values and Anthropogenic Scores for the Distance to Major Road and Railroad Anthropogenic Variable.

Distance to Major Road & Railroad (km)	Anthropogenic Score
>3.2	100
>1.6 – 3.2	75
>1.0 – 1.6	50
>0.25 – 1.0	25
0.0 – 0.25	0

9. Compressor Stations & Other Noise Sources

Data Layers used in Anthropogenic Score Creation: DNRC Total Disturbance and other sources to be determined.

This metric measures the distance to the nearest noise producing disturbance for each cell to quantify the impacts on nearby habitats. See Appendix I for complete literature review for support of the following values.

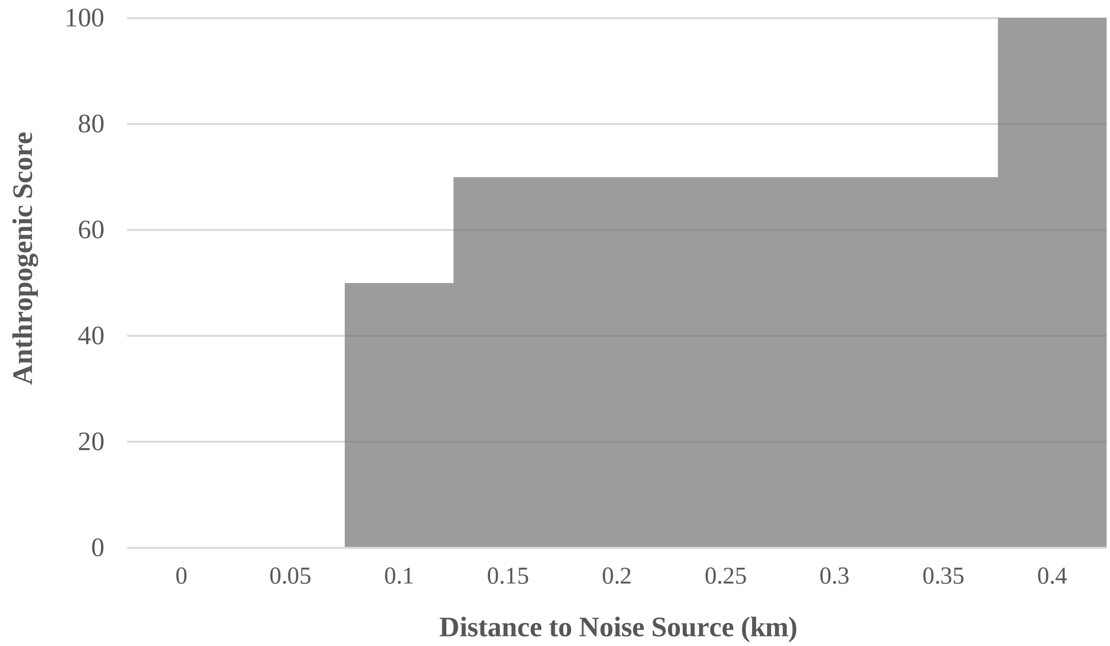

Figure A. 18. The Anthropogenic Score for the Distance to Noise Source (e.g., compressor station, road traffic, etc.) Anthropogenic Variable.

<u>GIS Steps for Anthropogenic Score Creation:</u>

1. Query DNRC Total Disturbance to extract noise producing sources.
2. Buffer the resulting Noise layer by 500-m, creating an extent buffer.
3. Run Euclidean Distance on the layer with 500-m as the maximum distance. Assign the 500-m extent buffer layer as the extent in environment settings.
4. Reclassify the resulting raster (Figure A. 18, Table A. 20).
5. Combine reclassified Noise raster with dummy raster (all sage grouse habitat) using 'Mosaic to New Raster', setting "MINIMUM" as the mosaic operator to create the Final Noise raster.

Table A. 20. Anthropogenic Scores for the Distance to Noise Source Anthropogenic Variable.

Distance (km)	Anthropogenic Score
0 – 0.05	0
>0.05 – 0.10	50
>0.10 – 0.40	70
>0.40	100

10. All Other Disturbances

Data Layers used in Anthropogenic Score Creation: DNRC Total Disturbance

The All Other Disturbances metric includes disturbances not explicitly mentioned above. For All Other Disturbances, the direct footprint of the disturbance will be converted to a pixel value of 0, but the disturbance will not be buffered to create an Indirect Impacts modifier for these types of disturbances.

11. Total Anthropogenic Score

Rasters used in Anthropogenic Score Creation: Final Well Density, Final Tall Structures, Final Transmission/Distribution Structure, Final Wind Energy, Final Moderate Roads & Railways, Final Buried Utilities, Final Land Conversion, Final Major Roads & Railroads, Final Noise, and All Other Disturbances.

This metric combines all Anthropogenic Scores into one overall Total Anthropogenic Score.

GIS Steps for Anthropogenic Score Creation:

1. Divide each raster in Data Layer list by 100 to convert to decimal values between 0 – 1.
2. Multiply rasters together to get the Total Anthropogenic Score raster.

MONTANA HQT BASEMAP TOTAL: FINAL RASTER CREATION

Rasters used in Final Raster Creation: Total Habitat Score, Total Anthropogenic Score

This metric combines the Total Habitat Score and Total Anthropogenic Score to create the Final Montana HQT Basemap raster.

GIS Steps for Metric Creation:

1. Multiply Total Habitat Score by Total Anthropogenic Score and divide by 100.

$$\boldsymbol{Montana\ HQT\ Basemap\ Total} =$$

$$\left(\frac{[Total\ Habitat\ \ Score * Total\ Anthropogenic\ Score]}{100}\right)$$

Appendix B. ANTHROPOGENIC VARIABLE: OIL & GAS

When a new Oil and Gas project is proposed, all infrastructure for the proposal is overlain on the Montana HQT Basemap. Other infrastructure for the proposed project may include roads, transmission/distribution lines, etc. Specific Anthropogenic Scores are calculated to generate the Total Anthropogenic Score for the new Oil and Gas project (Figure B. 1). This project-specific score is multiplied by the Montana HQT Basemap Total to produce a project-specific Raw HQT Score
(Section 3.2.3).

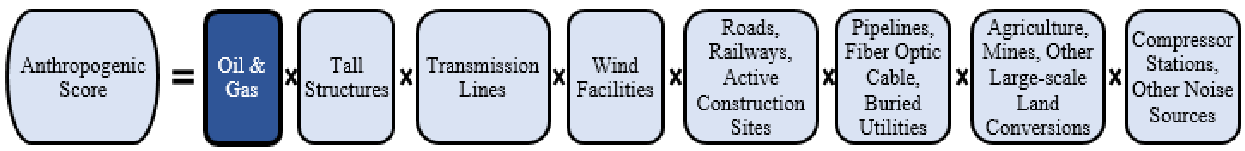

Figure B. 1. Equation for calculating the Anthropogenic Score for Oil & Gas projects and any additional infrastructure.

SUPPORTING LITERATURE

Numerous studies have shown that oil and gas well pads consistently have a deleterious effect on habitat selection by GRSG and on lek persistence and attendance, although the size of the effect varied by region, development type, and season. Research indicates that anthropogenic features, including oil and gas well pads, negatively affect GRSG habitat (including lek persistence and winter habitat use) at various spatial scales. Dinkins et al. (2014) notes that sage grouse selected habitat with lower densities of oil and gas structures at all reproductive stages.

After controlling for habitat, Walker et al. (2007) found support for negative effects of coal bed natural gas (CBNG) development within 0.8-km and 3.2-km of the lek and for a time lag between CBNG development and lek disappearance, as indexed by male lek attendance and lek persistence. From 2001 to 2005, lek-count indices in CBNG fields declined by 82%, at a rate of 35% per year, whereas indices outside CBNG declined by 12%, at a rate of 3% per year. Among leks active in 1997 or later, fewer leks remained active by 2004–2005 in CBNG fields (38%) than outside CBNG fields (84%). Of 12 leks in CBNG fields monitored intensively enough to determine the year when they disappeared, 12 became inactive after or in the same year that development occurred. The average time between CBNG development and lek disappearance for these leks was 4.1 +/- 0.9 years. Walker's findings refute the idea that prohibiting surface infrastructure within 0.4 km of the lek is sufficient to protect breeding populations and indicate that increasing the size of no-development zones around leks would increase the probability of lek persistence. The buffer size required would depend on the amount of suitable habitat around the lek and the level of population impact deemed acceptable. Timing restrictions on construction and drilling during the breeding season do not prevent impacts of infrastructure (e.g., avoidance, collisions, raptor predation) at other times of the year, during the production phase (which may last a decade or more), or in other seasonal habitats that may be crucial for population persistence (e.g., winter).

Findings from Dinkins et al. (2014a) suggests that anthropogenic features influence GRSG habitat selection at a large spatial extent, and that a 3.0-km radius from a point count location represents the best spatial extent for density variables (including oil and gas structures, power lines, and major roads). In general, GRSG responded to most anthropogenic features by avoiding them, regardless of the bird's reproductive stage. Further, Dinkins notes that sage-grouse exhibit high individual (among seasons) and generational site fidelity (Fisher et al. 1993, Holloran and Anderson 2005, Thompson 2012), which likely limits their ability to move in response to changing distributions of avian predators. Site fidelity has been suggested to delay nonuse patterns of sage-grouse in response to developing oil and gas fields, with older birds displaying strong fidelity despite low productivity and yearling birds (first nesting season) avoiding new anthropogenic structures (Holloran et al. 2010, Naugle et al. 2011).

Johnson et al. (2011) found that, across the range of the species, trends on leks within 5.0-km of a producing oil or natural gas well were depressed. Trends were also lower on leks with more than 10 producing wells within 5.0-km or more than 160 wells within 18.0-km. Their results conservatively suggest that a density of more than one producing well/6.4 km^2 within 18 km of leks negatively influences lek count trends.

Research conducted by Holloran et al. (2015) investigated GRSG use of wintering habitats relative to distances to infrastructure, densities of infrastructure, and activity levels associated with infrastructure of a natural gas field over 5 years in southwestern Wyoming. This study investigated the total number of sage-grouse logged (Logs) and the total number of independent log events (Events) by data logger stations relative to distance to and density of natural gas field infrastructure on the Pinedale Mesa in Sublette County, Wyoming, 2005–2006 through 2009–2010 winters. Comparisons between density and distance models indicated that well pad density was a better predictor of both the total number of GRSG and the total number of log events occurring at data logger stations than distance to well pads. As the number of well pads within 2.8 km of a data logger station increased, the number of sage-grouse and the number of events decreased. For each additional conventional well pad within 2.8-km, the number of GRSG logged decreased by 1 and the number of events decreased by 2. For each additional Liquid Gathering System (LGS) well pad within 2.8-km, the number of GRSG logged decreased by four, and the number of events decreased by six. Holloran et al. (2015) concluded that GRSG avoided areas with high well pad densities during the winter regardless of differences in activity levels associated with well pads. They also note that GRSG visiting a given area spent in general less time near infrastructure with higher levels of activity (i.e., conventional well pads, drilling rigs, plowed main haul roads), and more time in areas with taller sagebrush. This suggests that decreased human activity levels around important GRSG winter areas may reduce on-site effects of energy development. Holloran suggests that minimizing the densities of well pads, as well as reducing anthropogenic activity levels associated with energy development may reduce on-site impacts of energy development on wintering sage-grouse, and may reduce the temporal scale of indirect habitat loss.

Doherty et al. (2008) modeled winter habitat use by female greater GRSG in the Powder River Basin of Wyoming and Montana. They found that the number of CBNG wells within a 4.0-km^2 area was the best model to represent energy development. GRSG were 1.3 times more likely to occupy sagebrush habitats that lacked CBNG wells within a 4-km^2 area, compared to those that had the maximum density of 12.3-wells/4.0-km^2 allowed on federal lands, and that GRSG avoid CBNG development in otherwise suitable winter habitat. Doherty et al. (2008) also noted that timing stipulations that restrict CBNG development within 3.2-km of a lek during the breeding season (15 Mar–15 Jun) are insufficient because they do not prevent infrastructure from displacing GRSG in winter.

Doherty et al. (2008) used lek count data to test for differences in rates of lek inactivity and changes in bird abundance at various intensities of energy development within 32.2-km^2 (3.22-km or 2-mile radius) of a lek to identify thresholds of development compatible with conservation of GRSG in

Wyoming from 1997 – 2007. Doherty's study used a 3.2 km radius because it is a conservative estimate of the distance at which leks are impacted by oil and gas activities.

Doherty evaluated the percent increase in inactive leks, and grouped the results by a range in the number of wells within 3.2 km (1 – 12, 13 – 39, 40 – 100, and 101 – 199). Doherty also stratified the results into Management Zones I and II to reflect differences in average lek size and intensity of development per Connelly et al. (2004). Doherty notes that lek size is larger in Zone II than I, and intensity of development is greater in Zone I than Zone II. The Montana HQT incorporates the results for MZ I because this MZ covers most of the state and is most applicable.

Doherty's findings demonstrate that impacts from oil and gas development across the state are consistent with those documented in southwest (Holloran 2005) and northeast (Walker et al. 2007) Wyoming. A time-lag showed higher rates of lek inactivity and steeper declines in bird abundance 4 years after than immediately following development. Potential impacts were indiscernible at 1 – 12 wells within 32.2-km^2 of a lek (~1 well/1.0-mi^2), a threshold of development compatible with conservation. Above this threshold land managers can expect to see rate of lek inactivity double at 13-39 wells, and jumped to >5 times that outside of widespread development at 40-100 wells in northeast Wyoming (Management Zone 1).

HOW THE TOTAL ANTHROPOGENIC SCORE IS CALCULATED

The Montana HQT Anthropogenic Score for oil and gas well pad density captures two metrics consistent with the literature to capture winter use and nesting/breeding near a lek. The research findings by Holloran et al. (2015) and Doherty et al. (2008) both note a decline in habitat use with increasing well pad density during the winter, which is not a lek centric measure. Therefore, the metric evaluates well pad density across a large landscape measured as well pad density in all core habitat surrounding the development. The analysis would use a moving windows analysis to measure well pad density per section extending to the exterior boundary of the core habitat.

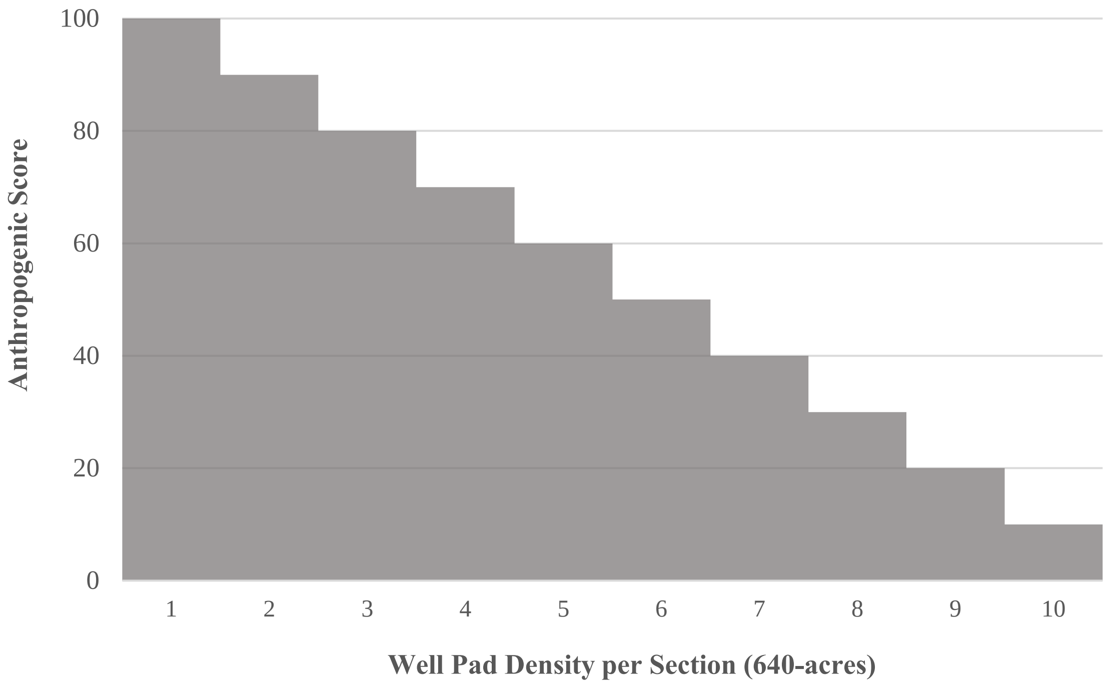

Figure B. 2. Anthropogenic Score for the Oil and Gas Well Density Anthropogenic Variable.

As previously noted, multiple authors and research have documented a decline in lek attendance with increasing well pad density with a certain distance from a lek. The Montana HQT measures the number of wells within a 3.2-km (2 mile) radius consistent with Doherty 2008, because it is a conservative estimate of the distance at which leks are impacted by oil and gas activities.

Table B. 1 identifies the proportional increase in lek inactivity between control leks (0 wells / 32.2-km^2) and those inside four categories of increasing intensity of energy development in Wyoming from 1997-2007. Note only the results from Management Zone I are displayed.

Table B. 1. Increase in lek inactivity with increasing number of wells.

Number of wells	4-year time lag
1-12	1.06
13-39	2.00
40-100	5.07
101-199	5.74*

* sample size was less than 5 leks, statistical analysis was not preformed

The number of wells in the categories identified by Doherty et al. (2008) was used to set the Anthropogenic Score levels for the Montana HQT within a 3.2-km buffer surrounding a lek (Table B. 2).

Data Layers: Proposed Oil & Gas Project Spatial Data (submitted by proponent)

GIS Steps for Anthropogenic Variable and Score Creation:

1. Create the Project Assessment Area:
    a. Direct Footprint: this is the exact shape and area of the submitted Proposed Oil & Gas Project.
    b. Indirect Impact: Create the Indirect Impact area by buffering the Direct Footprint of the Proposed Oil & Gas Project by 3.2-km.
    c. Project Assessment Area (PAA): This is the Direct Footprint *and* the Indirect Impact area.
2. Convert the Oil and Gas PAA layer to a point shapefile, delineating the centroid(s) and point(s) location(s) of the new proposed oil and gas well pads within the Direct Footprint.
3. Add a new field to the Oil and Gas PAA point shapefile called "count" and calculate the field =1. This field will be used in the next step to run the point statistics tool.
4. Run the Point Statistics Tool (3.2-km radius circle neighborhood, "SUM" statistics) on the "count" field in the Oil and Gas PAA point shapefile. The resulting layer (Well Pad Count raster) represents the number of oil and gas well pads within 3.2-km of each cell.
5. Using the Mask Tool, remove the Direct Footprint area from the Well Pad Count raster to create the Well Pad Count Indirect raster.
6. Convert the Direct Footprint layer to a raster and reclassify values to 0 to create the Direct Well Density Anthropogenic Score raster.
7. Reclassify the pixel values in the Well Pad Count Indirect raster to the associated Anthropogenic Score in Table B.2 to create the Indirect Well Density Anthropogenic Score raster.
8. Merge (Mosaic to New Raster Tool) the Direct Well Density Anthropogenic Score raster with the Indirect Well Density Anthropogenic Score raster to create the Oil & Gas Well Density Anthropogenic Score raster.
9. If a given project contains additional disturbance types (e.g., roads, transmission/ distribution lines), refer to the associated appendix for creation of additional Anthropogenic Score rasters.
10. Once all disturbance types for the proposed project have an Anthropogenic Score raster created, all Anthropogenic Score rasters are multiplied together to create the Total Anthropogenic Score for the Project Assessment Area for the proposed Oil & Gas project. See Section 5 for the complete calculation of the Raw HQT Score for Debit Projects.

Table B. 2. Anthropogenic Scores for well pads within a 3.2-km buffer of an active lek.

Number of wells	Anthropogenic Score	Doherty's findings
1-12	100	Potential impacts indiscernible at 1-12 wells within 32.2 km2 (< 1 well per 640 acres of land)
13-39	50	In MZ I, the rate of lek inactivity doubled at 13-39 wells.
40-100	20	In MZ 1, the rate of lek inactivity jumped to greater than 5 times that outside of widespread development.
> 101-199	0	Too few leks present in this category

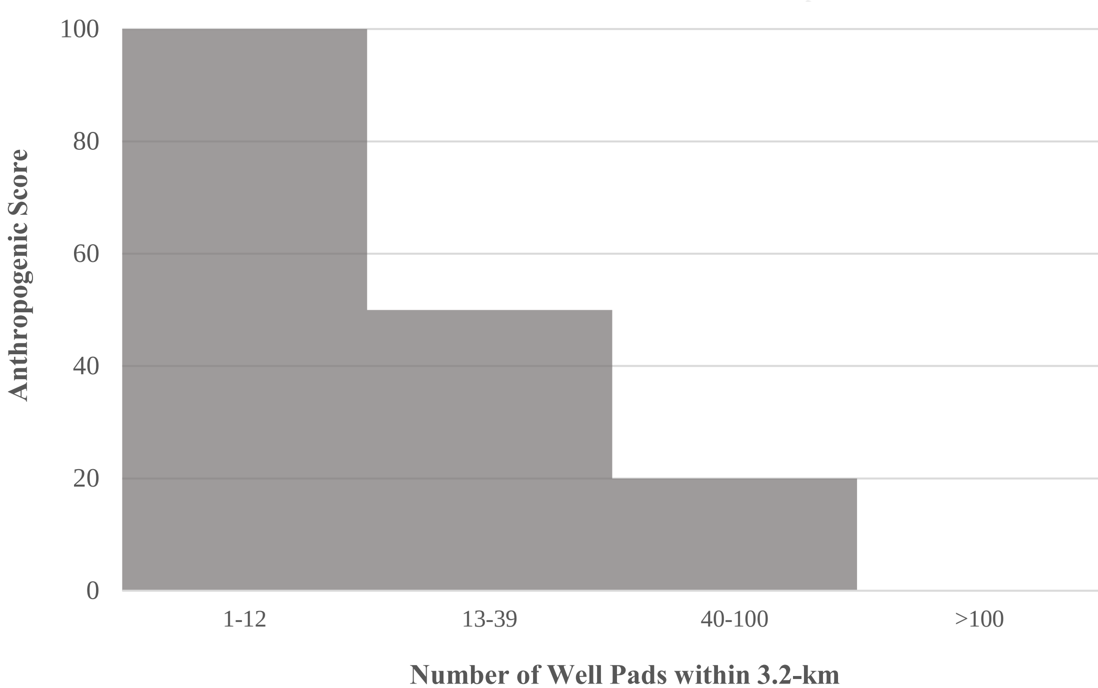

Figure B. 3. Adjustment of scores for number of well pads within a 3.2-km buffer.

Optional Third Level Assessment

Debit projects may have the option of performing Third Level Assessment surveys to collect site-specific data to inform the final HQT scores. This assessment must follow the peer-reviewed standards set forth in this document to ensure all such assessments are comparable, complete, and collect data useable within the Montana HQT framework.

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Appendix C. ANTHROPOGENIC VARIABLE: TALL STRUCTURES (COMMUNICATION TOWERS, COOLING TOWERS, AND WEATHER TOWERS)

When a new Tall Structure project is proposed, all infrastructure for the proposal is overlain on the Montana HQT Basemap. Other infrastructure for the proposed project may include roads, transmission/distribution lines, etc. Specific Anthropogenic Scores are calculated to generate the Total Anthropogenic Score for the new Tall Structure project (Figure C. 1). This project- specific score is multiplied by the Montana HQT Basemap Total to produce a project-specific Raw HQT Score (Section 3.2.3).

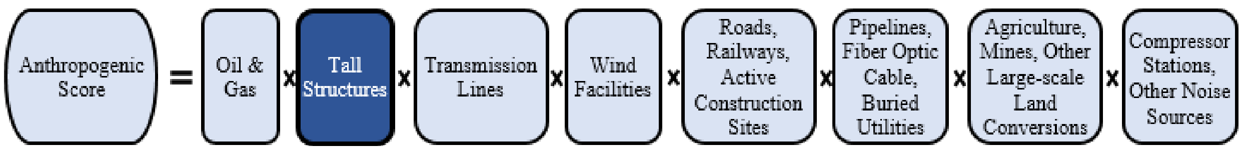

Figure C. 1. Equation for calculating the Anthropogenic Score for Tall Structure projects and any additional infrastructure.

SUPPORTING LITERATURE

While research is needed to fully assess the effects of tall structures (e.g., communication towers, cooling towers, weather towers), there is a growing body of evidence that Tall Structures impact GRSG, with recent studies providing support for earlier studies that found impacts are primarily from increased predation risks and fragmentation of habitat (Hanser 2018). Here, we consider impacts distinct to Tall Structures on the landscape that could provide avian perching or nesting subsidies. See Table C. 1 for a brief overview of the scientific literature relevant to the specific impacts for Tall Structures.

Anthropogenic structures, such as cooling towers, communication towers, and weather stations, provide perching and nesting subsidies for avian predators. Ravens have demonstrated a preference for nesting on anthropogenic structures over natural features (e.g., trees, cliffs; Coates 2014a, Howe et al. 2014). In western Wyoming and southeast Idaho, Bui (2010) and Howe et al. (2014) found resident territorial ravens were responsible for the majority of GRSG nest predation. Howe et al. (2014) reported breeding raven foraging was greatest within 0.57-km (0.35-miles) of their nests while Coates et al. (2014b) found concentrated raven foraging occurred out to 2.2-km (1.4-miles).

Tall Structures provide improved avian predator hunting efficiency in an otherwise relatively flat open landscape (Connelly 2004, Coates et al. 2014a, Dinkins et al. 2014a). Researchers have noted predator impacts on GRSG were reduced where habitat was contiguous and provided canopy cover (Bloomberg and Sedinger 2009, Braun 1998, Coates et al. 2014b, Coates and Delehanty 2010, Kolada et al. 2009). Avian predator impacts are a common mechanism of indirect impacts on GRSG between Tall Structures and Transmission/Distribution Structures (pers. comm. J. Kehmeier, SWCA, 18 September 2018), as both structures are capable of providing optimal raven nesting substrate. The advantages for ravens nesting on tall anthropogenic structures in areas otherwise void of tall features (e.g., trees) include increased visibility of potential prey and potential terrestrial predators with overall potential decreased predation due to nests being unreachable by terrestrial mammal predators. These factors combined, result in Tall Structures providing benefits to avian predators.

Negative lek trends were detected within 18.0-km (11.8-miles) of communication towers with most of the negative impacts occurring within approximately 13.0 to 15.0-km of a given tower (Johnson et al. 2011). Lek Trends are based on year and the maximum number of males observed and range from –1, indicating lek counts consistently declined over time, to +1, indicating lek counts consistently increased over time. The impact of 13.0 to 15.0-km is indicated from Figure 17.20 in Johnson et al. (2011) where Lek Trends increase with increasing distance to a given communication tower out to the inflection point of the curve (i.e., point along a curve where the curvature changes) occurring at approximately 13.0-km from a given tower (i.e., the inflection point; pers. comm. S. Hanser, USGS, 19 September 2018; pers. comm. M. Holloran, Operational Conservation LLC, 20 September 2018). While positive Lek Trends occur at distances less than 13.0-km, this does not mean the impacts from the communication tower cease prior to 13.0-km. A Lek Trend value of 0.0 is the mean value relative to this particular dataset. Thus, impacts are shown to continue beyond approximately 4.0 to 5.0-km where the upper confidence limit and the mean curves cross the y-axis at 0.0 and extend out to approximately 13.0 to 15.0-km.

Johnson et al. (2011) also reported negative impacts with the density of communication towers on GRSG Lek Trends at two spatial scales: 5-km (25-km^2) and 18-km (324-km^2). Leks experienced negative impacts with 1 or more towers located within 5-km of the lek. Additionally, recognizing the scale of the figures and accounting for the logarithmic transformation of the explanatory variables, there were negative impacts on Lek Trends when tower densities exceeded 1 tower within 18-km of a lek (pers. comm. M. Holloran, Operational Conservation LLC, 20 September 2018).

Knick et al. (2013), which corroborates findings from Johnson et al. (2011), found leks were absent where communication towers exceeded 0.08-towers/km^2 (this result is expressed as 0.08-km/km2 in the publication but expressing the communication tower impact as a linear density estimate was a typographical error and is correctly reported as "towers/km2"; pers. comm. Dr. Steve Hanser, 19 September 2018). Knick et al. (2013) also found that active leks had a mean density of 0.001-tower/km2 within 5-km of the lek, whereas historic/extirpated leks (or extirpated) had a mean tower density of 0.183-tower/km2 within 5-km of the lek. These results suggest that active leks remain on average further than 5-km of any communication tower and historic leks were within 5-km of ≥1 communication tower. Overall, negative impacts exist with very low densities of communication towers (≥0.0127 towers/km^2 [≥ 1 communication tower/25-km^2]) on the landscape (pers. comm. S. Hanser, USGS, 19 September 2018; pers. comm. M. Holloran, Operational Conservation LLC, 20 September 2018).

Wisdom et al. (2011) detected GRSG extirpated ranges within 12.0-km (7.5-miles) of communication towers, which was 2-times shorter than the distance between active leks and communication towers. The authors suggest the strong correlation between distance to communication towers and extirpated range of GRSG may be due in part because these structures are typically near human development and major highways. GRSG select nest sites and brood rearing habitat farther away from Tall Structures, partially based on a perceived risk of predation (Braun 1998, Dinkins et al. 2012, Dinkins et al. 2014b).

It is important to note that potential confounding effects that may exist should be put in context of the dataset and study area. The lek count dataset used for the analyses conducted in the Johnson et al. (2011) and Knick et al. (2013) studies was from 1997-2008. The majority of anthropogenic structures (e.g., roads, buildings) were in place well before the lek data collection began, which the authors suggest that the impacts from those structures on GRSG had already occurred on the landscape. In comparison, communication towers began appearing on the study area during the same time as the lek dataset, which suggests that GRSG were responding to presence of communication towers during the timeframe of the data collection. Therefore, the authors assert that the impacts from communication towers revealed through the analysis are valid and not likely confounded with other anthropogenic features (pers. comm. M. Holloran, Operational Conservation LLC, 20 September 2018).

Table C. 1. Variables pertinent and specific to the indirect impacts of Tall Structures documented in scientific peer-reviewed literature[1].

Variable	Metric for Consideration	Reference	Conclusion
Greater Sage-Grouse Responses to Tall Structures			
Negative GRSG Lek Trends			
Distance from structure	< 15.0-km of a cellular tower[2]	Johnson et al. 2011 (Figures 17.20, 17.21)[3]	GRSG leks are negatively impacted within 15.0-km of a communication tower.
Density of structures	> 1 tower within 5-km of lek		GRSG leks experience negative impacts when 1 or more towers are located within 5-km of the lek.
Mean Tower Density			
Active leks	$\bar{x}$ = 0.001-towers/km^2 (0.025-tower/25-km^2)	Knick et al. 2013 (Table 2)[3]	Most active leks are located beyond 5-km of a communication tower.
Historic leks (i.e., extirpated)	$\bar{x}$ = 0.183-towers/km^2 (4.5-towers/25-km^2)		Most historic/extirpated leks have at least 1 communication tower within 5-km of the lek location.
Areas void of active leks	0.08-towers/km^2 (2-towers/25-km^2) [footnote 4]		Active leks were absent from areas with communication tower densities greater than 2-towers/25-km^2.
Highest habitat suitability	< 0.010-towers/km^2 (density of 0.25-towers/25-km^2)		Habitat quality for GRSG was greatest in areas with tower densities less than 0.25-towers/25-km^2.
Mean Distance to Communication Tower			
Leks in occupied range	21-km	Wisdom et al. 2011 (Figure 18.4)	Active GRSG leks were located twice as far from communication towers than historical leks.
Historical leks in extirpated range	12-km		
Common Raven (and other avian predators) Ecology in Relation to Tall Structures			
Territorial Breeding Raven Behavior			
Territorial breeding raven foraging	< 0.57-km	Howe et al. 2014	Ravens utilize tall anthropogenic structures for nesting subsidies with that majority of their predation impact occurring within 2.2-km of the structure.
Concentrated raven foraging	< 2.2-km	Coates et al. 2014b	

[1] While the mechanism (e.g., raven predation) of indirect impacts on GRSG is common between Tall Structures and Transmission/Distribution Structures suggesting results reported for one structure type can be extrapolated to the other structure type (pers. comm. J. Kehmeier, SWCA, 18 September 2018), the Program has endeavored to reference literature in this section specific to Tall Structures. Note that Knick et al. (2013) and Wisdom et al. (2011) are referenced in both Tall Structures and Transmission/Distribution Structures sections because the authors of the two papers assessed impacts specific to each structure type.

[2] The inflection point shown in Figure 17.20 suggests negative impacts to GRSG Lek Trends out to approximately 13.0 to 15.0-km from the cellular tower (pers. comm. S. Hanser, USGS, 19 September 2018; pers. comm. M. Holloran, Operational Conservation LLC, 20 September 2018).

[3] The lek count dataset used for the analyses conducted in the Johnson et al. (2011) and Knick et al. (2013) studies was from 1997-2008. The majority of anthropogenic structures (e.g., roads, buildings) were in place well before the lek data collection began, which the authors suggest that the impacts from those structures on GRSG had already occurred on the landscape. In comparison, communication towers began appearing on the study area during the same time as the lek dataset, which suggests that GRSG were responding to presence of communication towers during the timeframe of the data collection. Therefore, the authors assert that the impacts from communication towers revealed through the analysis are valid and not likely confounded with other anthropogenic features (pers. comm. M. Holloran, Operational Conservation LLC, 20 September 2018).

[4] In Knick et al. (2013), a typographical error appears in the statement "…communication towers exceeded 0.08 km/km^2." This statement should read "…communication towers exceeded 0.08 towers/km^2" (pers. comm. S. Hanser, USGS, 19 September 2018).

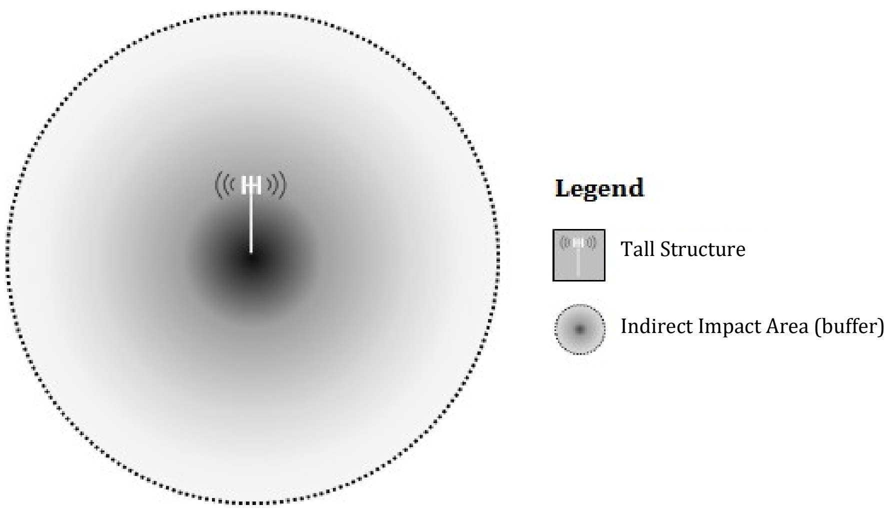

Figure C. 2. Conceptual diagram of the 6.0 or 3.0-km radius buffer applied to Tall Structures to establish the Indirect Impact area.

Nest vs. Non-Nest Facilitating Structures

Anthropogenic structures can support avian predator nesting and contribute to increased predation risk to GRSG. Tall structures may be designed and maintained as non-nest facilitating. Tall structures that do not facilitate nesting will be given an adjusted Anthropogenic Score (Figure C. 3). It is anticipated that the structural composition of communication towers would render these project types to be considered nest facilitating structures. However, proponents may endeavor to commit to certain actions that would keep these types of structures nest-free and thus receive the non-nest facilitating benefit in their Raw HQT Score calculation. Please note that even though a structure may be designated as non-nest facilitating, impacts still remain to GRSG through GRSG direct avoidance and as perching potential for avian predators.

Executive Order 12-2015

Executive Order 12-2015 provides specific guidance related to communication towers. Communication towers should be sited to minimize negative impacts on sage grouse or their habitats and should be located a minimum of 4-miles from active sage grouse leks.

The distances for assessment of the indirect impacts from Tall Structures will be 6.0-km (Figure C. 3). This distance is the radius that is used to establish the Indirect Impact Area used in the calculation of the Raw HQT Score (see below). For Tall Structures located beyond 4-miles of an active GRSG lek, the distance used to establish the Indirect Impact Area will be decreased from 6.0-km to 3.0-km. The distances of 6.0 and 3.0-km are very conservative estimates for indirect impacts from Tall Structures on GRSG. Through the ongoing Adaptive Management process, these distances will be revised and updated as new data and studies become available to supplement existing published research findings.

How the Total Anthropogenic Score is Calculated

Land cover, topography, and cumulative human activity contribute to the level of impacts from Tall Structures. Avoidance is modeled as loss of habitat that decreases linearly from 0.0 to 2.2-km (1.4-miles) to account for localized impacts from Tall Structures to GRSG. Population affects are modeled as loss of habitat functionality that decreases linearly from 2.2 to 6.0-km from the structure for Tall Structures located within 4-miles of an active sage grouse lek that are considered nest facilitating (Table C. 2, Figure C. 4). Population affects are modeled from 2.2 to 3.0-km from the structure for Tall Structures located > 4-miles from any sage grouse lek that are considered nest facilitating (Table C. 3, Figure C. 5). Tall Structures considered non-nest facilitating that are located within 4-miles of an active sage grouse lek will receive a 50% decrease in pixel scores (Table C. 4, Figure C. 6). Tall Structures considered non-nest facilitating that are located > 4-miles from any active sage grouse lek will receive a 75% decrease in pixel scores (Table C. 5, Figure C. 7).

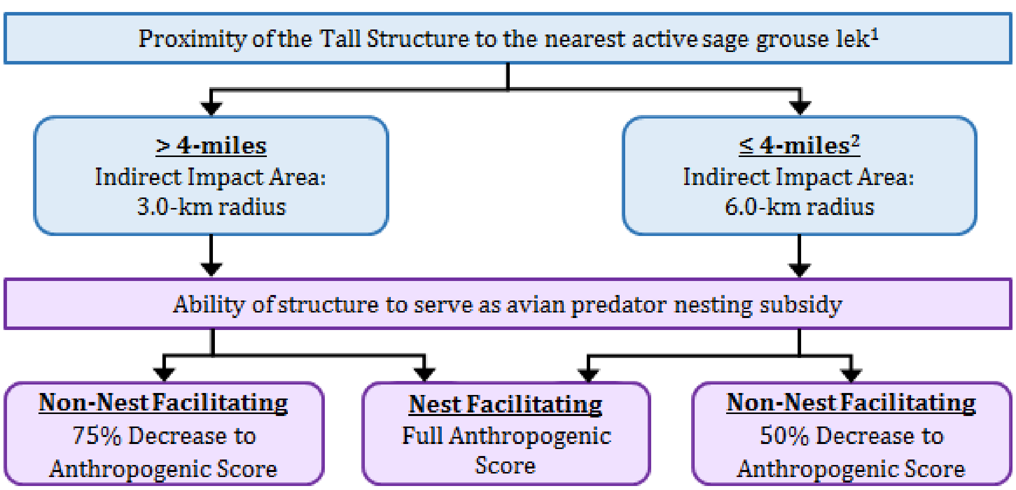

Figure C. 3. Flowchart for defining the Indirect Assessment Area for Tall Structures based on proximity to the nearest sage grouse lek and the application of a decrease to Anthropogenic Scores based on the structure design.

[1] The EO states that "communication towers should be located a minimum of 4 miles from active leks."

[2] If structure is ≤ 2-miles of an active sage grouse, see the Policy Guidance Document for how the EO would apply to the Raw HQT Score.

ANTHROPOGENIC SCORE & INDIRECT IMPACT AREAS FOR VARIOUS TALL STRUCTURE PROJECTS

Nest Facilitating Tall Structures ≤ 4.0 miles of a Lek

Table C. 2. Anthropogenic Scores for Tall Structures located within 4-miles of an active sage grouse that are considered nest facilitating structures for computing the Distance to Tall Structures Anthropogenic Variable.

Distance to Tall Structure (km)	Anthropogenic Score
0 – <0.3	19
0.3 – <0.6	29
0.6 – <0.8	39
0.8 – <1.1	49
1.1 – <1.4	58
1.4 – <1.7	68
1.7 – <2.0	78
2.0 – <2.3	87
2.3 – <3.6	87
3.6 – <6.0	97
≥ 6.0	100

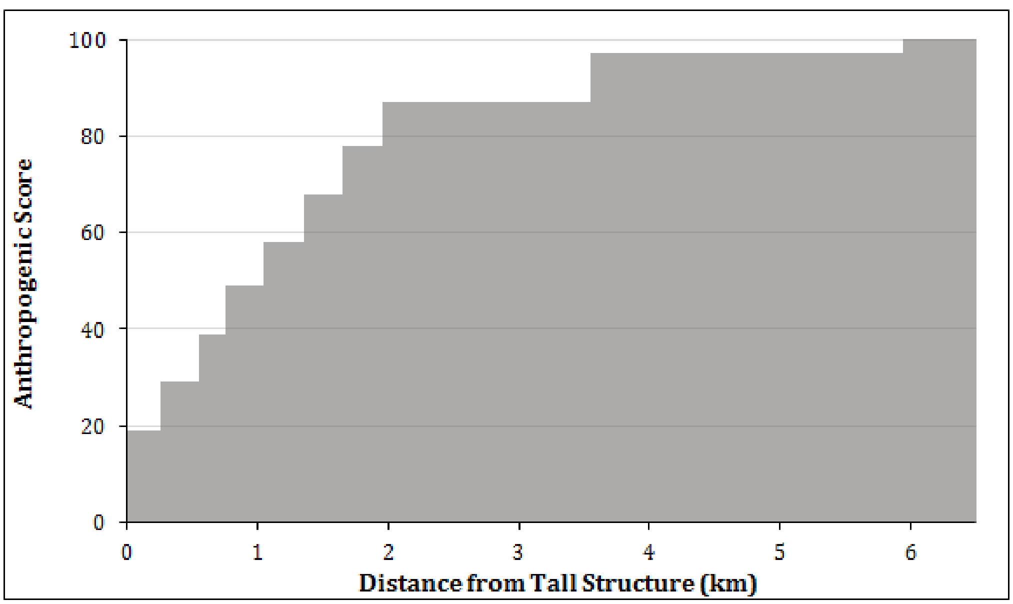

Figure C. 4. The Anthropogenic Score for Tall Structures located within 4-miles of an active sage grouse that are considered nest facilitating structures for computing the Distance to Tall Structures Anthropogenic Variable.

Nest Facilitating Tall Structures > 4.0 miles of a Lek

Table C. 3. Anthropogenic Scores for the Tall Structures located > 4-miles of an active sage grouse that are considered nest facilitating structures for computing the Distance to Tall Structures Anthropogenic Variable.

Distance to Tall Structure (km)	Anthropogenic Score
0 – <0.3	19
0.3 – <0.6	29
0.6 – <0.8	39
0.8 – <1.1	49
1.1 – <1.4	58
1.4 – <1.7	68
1.7 – <2.0	78
2.0 – <2.3	87
2.3 – <3.0	87
≥ 3.0	100

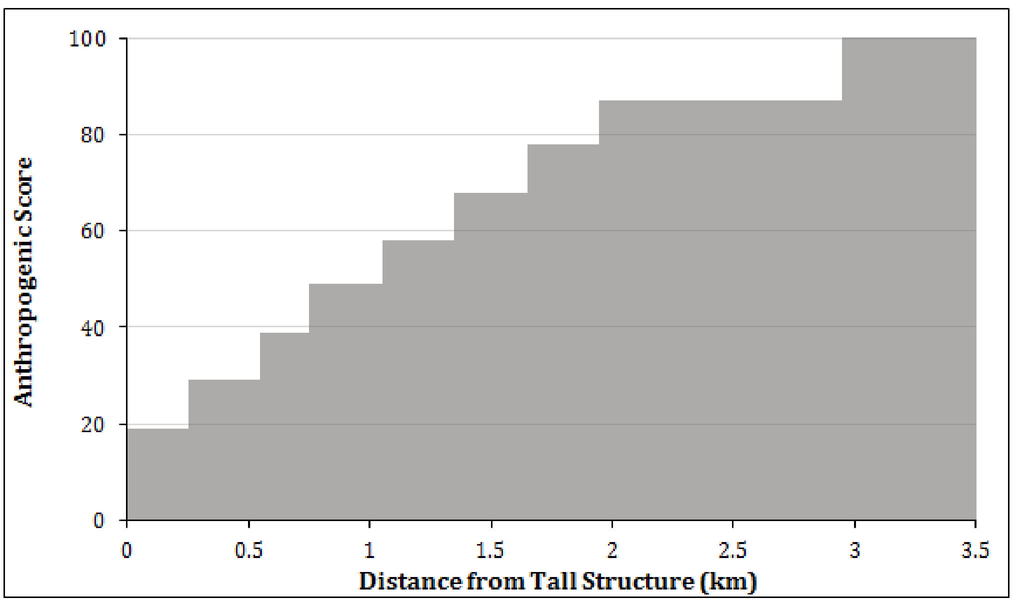

Figure C. 5. The Anthropogenic Score for Tall Structures located > 4-miles of an active sage grouse that are considered nest facilitating structures for computing the Distance to Tall Structures Anthropogenic Variable.

NON-Nest Facilitating Tall Structures ≤ 4.0 miles of a Lek

Table C. 4. Anthropogenic Scores for the Tall Structures located within 4-miles of an active sage grouse that are considered non-nest facilitating structures for computing the Distance to Tall Structures Anthropogenic Variable.

Distance to Tall Structure (km)	Anthropogenic Score
0 – <0.3	19
0.3 – <0.6	29
0.6 – <0.8	39
0.8 – <1.1	49
1.1 – <1.4	58
1.4 – <1.7	68
1.7 – <2.0	78
2.0 – <2.3	87
2.3 – <3.6	93.5
3.6 – <6.0	98.5
≥ 6.0	100

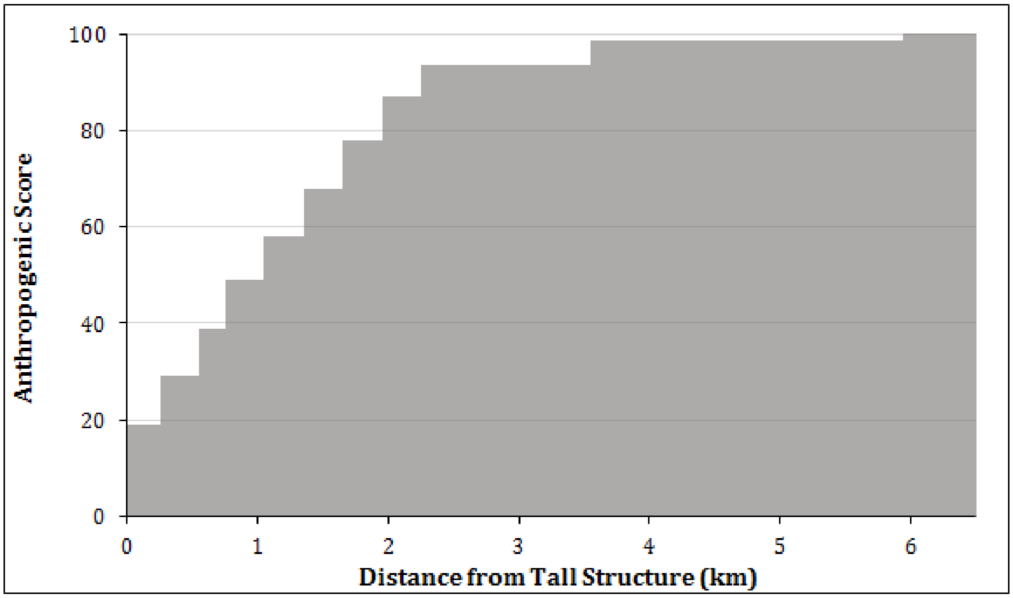

Figure C. 6. The Anthropogenic Score for Tall Structures located within 4-miles of an active sage grouse that are considered non-nest facilitating structures for computing the Distance to Tall Structures Anthropogenic Variable.

NON-Nest Facilitating Tall Structures > 4.0 miles of a Lek

Table C. 5. Anthropogenic Scores for the Tall Structures located > 4-miles of an active sage grouse that are considered non-nest facilitating structures for computing the Distance to Tall Structures Anthropogenic Variable.

Distance to Tall Structure (km)	Anthropogenic Score
0 – <0.3	19
0.3 – <0.6	29
0.6 – <0.8	39
0.8 – <1.1	49
1.1 – <1.4	58
1.4 – <1.7	68
1.7 – <2.0	78
2.0 – <2.3	87
2.3 – <3.0	93.5
≥ 3.0	100

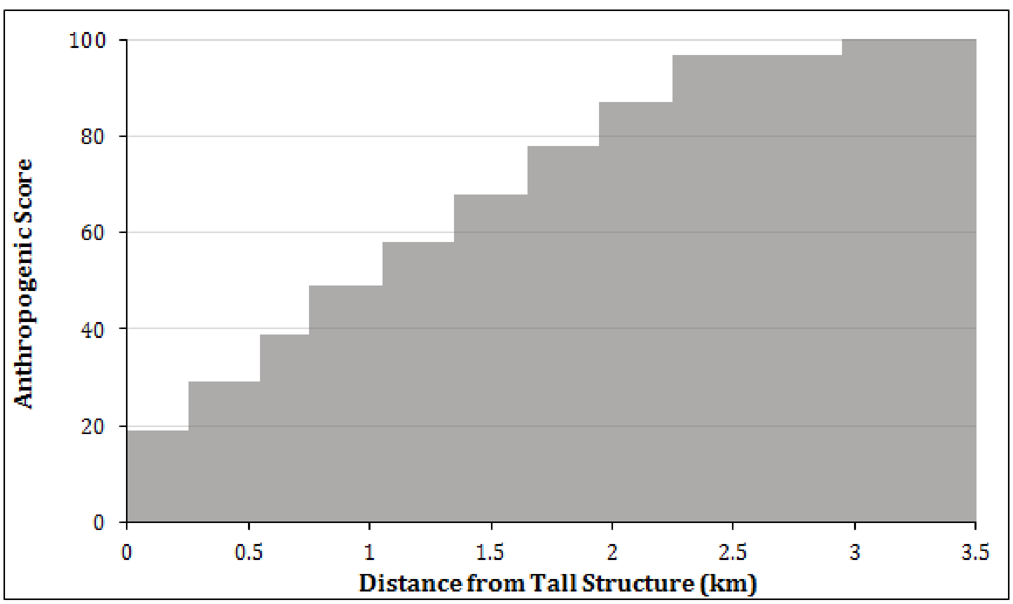

Figure C. 7. The Anthropogenic Score for Tall Structures located > 4-miles of an active sage grouse that are considered non-nest facilitating structures for computing the Distance to Tall Structures Anthropogenic Variable.

Data Layers: Proposed Tall Structure Project Spatial Data (submitted by proponent)

GIS Steps for Anthropogenic Variable and Score Creation:

1. Create the Project Assessment Area:
   a. Direct Footprint: this is the exact shape and area of the submitted Proposed Tall Structure Project.
   b. Indirect Impact: Create the Indirect Impact area by buffering the Direct Footprint of the Proposed Tall Structure Project by 6,000-m for Tall Structures located within 4-miles of an active sage grouse lek and 3,000-m for Tall Structures located > 4-miles of any active sage grouse lek.
   c. Project Assessment Area (PAA): This is the Direct Footprint *and* the Indirect Impact areas.
2. Run the Euclidean Distance Tool on the PAA layer with a maximum distance of 6,000-m for Tall Structures located within 4-miles of an active sage grouse lek, specifying the previous buffer as the extent in the environments settings to create an output Euclidean Distance Tall Structure Near Lek raster. Repeat this step for Tall Structures located > 4-miles of any active sage grouse lek using 3,000-m as the maximum distance and for the extent to create an output Euclidean Distance Tall Structure Far Lek raster.
3. Reclassify the pixel values in the Euclidean Distance Tall Structure Near Lek raster to the associated Anthropogenic Score in Table C. 2 to create the Distance to Tall Structure Near Lek Nest Anthropogenic Score raster. If the Tall Structure is considered non-nest facilitating, reclassify the pixel values in the Euclidean Distance Tall Structure Near Lek raster to the associated Anthropogenic Scores in Table C. 4 to apply the 50% decrease to pixel scores and create the Distance to Tall Structures Near Lek Non-Nest Anthropogenic Score raster. If the Tall Structure is located > 4-miles from an active sage grouse lek and considered nest facilitating, reclassify the Euclidean Distance Tall Structure Far Lek raster to the associated Anthropogenic Score in Table C. 3 to create the Distance to Tall Structure Far Lek Nest Anthropogenic Score raster. If the Tall Structure is located > 4-miles from an active sage grouse lek *and* considered non-nest facilitating, reclassify the Euclidean Distance Tall Structure Far Lek raster to the associated Anthropogenic Score in Table C. 5 to apply the 75% decrease to pixel scores and create the Distance to Tall Structures Far Lek Non-Nest Anthropogenic Score raster.
4. If a given project contains additional disturbance types (e.g., roads, transmission lines), refer to the associated appendix for creation of additional Anthropogenic Score rasters.
5. Once all disturbance types for the proposed project have an Anthropogenic Score raster created, all relevant Anthropogenic Score rasters are multiplied together to create the Total Anthropogenic Score for the Project Assessment Area for the proposed Tall Structure project.
6. See Section 5 for the complete calculation of the Raw HQT Score for Debit Projects.

Optional Third Level Assessment

Debit projects may have the option of performing Third Level Assessment surveys to collect site-specific data to inform the final HQT scores. This assessment must follow the peer-reviewed standards set forth in this document to ensure all such assessments are comparable, complete, and collect data useable within the Montana HQT framework.

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Appendix D. ANTHROPOGENIC VARIABLE: TRANSMISSION/ DISTRIBUTION STRUCTURES (Lines, Structures/ Poles, and/or Substations)

When a new Transmission/Distribution Structure project is proposed, all infrastructure for the proposal (including the lines and associated structures/poles and/or substation) is overlain on the Montana HQT Basemap. Other infrastructure for the proposed project may include roads, tall structures, etc. Specific Anthropogenic Scores are calculated to generate the Total Anthropogenic Score for the new Transmission/Distribution Structure project (Figure D. 1). This project-specific score is multiplied by the Montana HQT Basemap Total to produce a project-specific Raw HQT Score (Section 3.2.3).

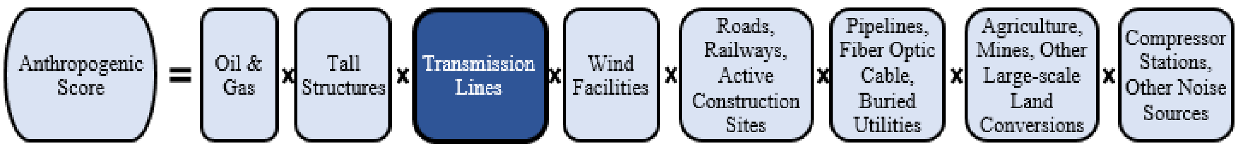

Figure D. 1. Equation for calculating the Anthropogenic Score for Transmission/Distribution Structure projects and any additional infrastructure.

SUPPORTING LITERATURE

Transmission/Distribution Structures are composed of lines and associated structures (i.e., poles, towers) and may also include substations. The linear characteristics of Transmission Structures result in both Direct and Indirect Impacts to GRSG populations through habitat fragmentation and increased predation. The effects of Transmission Lines on GRSG have been considered in several recent studies of habitat use and lek attendance (e.g., Walker et al. 2007, Dinkins et al. 2014b, Knick et al. 2013, LeBeau 2012, Johnson et al. 2011, Hanser et al. 2011, Gillan et al. 2013, Shirk et al. 2015, Gibson et al. *in press*, Hanser et al. 2018). Most of these studies grouped larger Transmission Structures with smaller Distribution Structures and telephone lines. See Table C. 1 for a brief overview of the scientific literature relevant to the specific impacts for Tall Structures.

<u>Transmission Lines</u>

A spatial analysis of GRSG telemetry data from west-central Idaho detected significantly fewer occurrences of GRSG within 600-m of lines than was predicted by the null model (Gillan et al. 2013); however, the change in the magnitude of use was not evaluated (J. Gillan, New Mexico State University, personal communication with A. Widmer, SWCA, 7/7/2015). Models of GRSG habitat use derived from the locations of GRSG scat (i.e., pellets) in the Wyoming Basin Ecoregional Assessment areas considered biotic, abiotic, and anthropogenic effects and identified distance to transmission line to be a significant predictor (Hanser et al. 2011). The results of the study indicate an avoidance effect that decreases with distance from the line. However, the size, number, location, and configuration of transmission lines evaluated were not described by Hanser et al. (2011). Expert opinion-based models of GRSG movement developed in Washington State predicted that transmission lines would significantly reduce GRSG movement to distances greater than 500-m; spatial patterns in gene flow and lek activity were consistent with model predictions (Washington Wildlife Habitat Connectivity Working Group [WHCWG] 2012; Shirk et al. 2015). These results provide evidence of Transmission Line impacts suggesting that avoidance behavior has the potential to result in a population-level effect.

Gibson et al. (*in press*) quantified the effects of the Falcon-to-Gondor 345 kV Transmission Line in Nevada on two GRSG populations over 10 years of operation. This study provides strong evidence of Transmission Line effects to GRSG demographic parameters (female survival, nest site selection and success, and brood survival), largely in part because of the long-term duration of the study, the large sample (GRSG locations and habitat measurements), and the statistical analysis that isolated the effects of the Transmission Line from the effects of habitat quality and other covariates (e.g., roads). The authors identified several demographic parameters that were affected by the Transmission Line, and variation in the magnitude of the effect was largely explained by raven abundance. The authors also took the analysis a step further to estimate the impact that Transmission Lines have on females, nests, and chicks at the population level through assessing individual vital rates (e.g., survival rates, success rates). Individual vital rates varied markedly with response to transmission and distribution structures, including with responses to fluctuation in raven abundances (Table C. 1). Overall, Gibson et al. (*in press*) suggests that negative impacts to GRSG exist out to 10.0-km from a Transmission Line and out to 7.5-km for all power lines (including Distribution Lines).

Using lek attendance as a surrogate for population size, the authors estimated that population growth was reduced by 3% directly below the Transmission Line and the effect decreased linearly with distance to 0% at 10-km from the Falcon-to-Gondor Transmission Line. Population growth was reduced by 8% directly below "all power lines" (Transmission Lines and Distribution Lines grouped) and the effect decreased linearly with distance to 0% at 7.5-km.

Two Indirect Impact zones were defined for the Transmission/Distribution Structure Anthropogenic Score:

- Avoidance (0-m to 600-m for all line sizes)
- Decreased Population Growth (lines >116 kV: 0-m to 6,000-m; lines ≤116 kV: 0-m to 3,000-m)

Avoidance is a behavioral response by individual GRSG that has been documented in proximity to Transmission/Distribution Structures. Avoidance results in decreased use of habitat in areas within 600-m of a Transmission/Distribution Structure. The Avoidance effect increases proportionally with the number of Transmission/Distribution Structures, where the structures are sited less than 1,000-m apart.

Decreased Population Growth does not describe individual behavioral characteristics, but instead is a result of changes in population demographics (e.g., nest success, brood survival, female survival) that lead to a population level impact described in Gibson et al. (*in press*). Based on this study, Decreased Population Growth effects occur up to 10-km on either side of a Transmission Line. Raven abundance was the primary mechanism identified for the Decreased Population Growth effect in Gibson et al. (*in press*). However, Transmission Lines may also increase hunting efficiency for mammalian predators due to the edge effect created by removing sagebrush in the corridor. Where Decreased Population Growth effect zones overlap or where one zone overlaps with an Avoidance effect zone, the larger effect value is modeled.

Avoidance and Decreased Population Growth effects occur across all seasons, apply to all GRSG age- sex classes (e.g., adult females, juvenile males, chicks), and occur for the Construction and Operation phases of a project. The magnitude of the Indirect Impact is described for each zone below in the "How the Total Anthropogenic Score is Calculated" section.

<u>Transmission Structures/Poles</u>

Anthropogenic structures such as Transmission Structures/Poles (includes lattice structures) provide perching and nesting subsidies for avian predators. Ravens have demonstrated a preference for nesting on anthropogenic structures over natural features with Transmission Structures the most common structure utilized for nesting (Coates 2014a, Howe 2014, Knight and Kawashima, 1993). Raptor nests built on Transmission Structures are protected from mammalian predators affording greater nest success (Steenhof et al. 1993).

Transmission structures and poles support raven colonization by providing an anthropogenic nesting substrate in areas where natural elevated features are limited (Coates et al. 2014a, Howe et al. 2014, Knight and Kawashima 1993, Steenhof et al. 1993). Raptors begin nesting on Transmission Structures within one year of construction and will return to the same area each year (termed nest-site fidelity; (Steenhof et al. 1993). Highly territorial, breeding ravens exploit anthropogenic features common to transmission corridors and are more likely to predate sage grouse nests more often than migrant raven (Bui et al. 2010). Territorial breeding ravens forage within an average of 570.0 to 707.3-m (0.35 to 0.44- mi) of their nests (Howe et al. 2014) while Coates et al. (2014b) found concentrated raven foraging occurred out to 2.2- km (1.4-mi). Increased raven abundance has been detected near transmission facilities and probability of raven occurrence was detected out to 27.0-km (16.78-mi; Coates et al. 2014b).

Avian predator impacts are a common mechanism of indirect impacts on GRSG between Transmission/ Distribution Structures and Tall Structures (pers. comm. J. Kehmeier, SWCA, 18 September 2018), as both structures are capable of providing optimal raven nesting substrate. The advantages for ravens nesting on tall anthropogenic structures in areas otherwise void of tall features (e.g., trees) include increased visibility of potential prey and potential terrestrial predators with overall potential decreased predation due to nests being unreachable by terrestrial mammal predators.

<u>Substations</u>

Substations are included in the Transmission Structure section because they share similar height and structural components with other transmission features (e.g., Lines and Poles/Lattice) that have effects on GRSG documented in literature as discussed above. Such aspects of Substations make them attractive perching and nesting structures for predatory avian species. Because there is wide variation in substation size, composition, and noise production, the Anthropogenic Score specifically for Substations may be adjusted on a project-specific basis while the Program completes the development for Substations.

<u>All Transmission/Distribution Structures (Lines, Structures/Poles, & Substations)</u>

Transmission Lines and Substations are included in the digitized Existing Anthropogenic Surface Disturbance layer incorporated into the HQT Basemap and compose the Transmission Structure Anthropogenic Variable. Structures are included where visible from aerial imagery and captured throug h heads-up digi tizing at a scale of 1:4,000-m (DNRC 2017). At this scale, Transmission Lines of ≥115-kV may be included in the digitized Existing Anthropogenic Surface Disturbance layer incorporated into the HQT Basemap. Transmission/Distribution Lines and associated structures/poles and Substations are the features included in the debit calculations where these features would be new disturbance and are part of a debit project.

Burton and Mueller (2006) and Ratcliffe (1997) found raven nests up to 1-km apart. For the purposes of this docu ment, Transmission/Distribution Structures will be considered as co-located if they are within 1-km of each other.

NEST VS. NON-NEST FACILITATING STRUCTURES

Anthropogenic structures can support avian predator nesting and contribute to increased risk to GRSG. Transmission/Distribution Structures/Poles may be designed and maintained as non-nest facilitating. Transmission/Distribution Structures/Poles that do not facilitate nesting activities of avian predators will be given an adjusted Anthropogenic Score (Figure D. 2).

EXECUTIVE ORDER 12-2015

Executive Order 12-2015 provides specific guidance related to Transmission/Distribution Structures that states such structures should be buried to minimize negative impacts on GRSG or their habitats *and* located a minimum of 4-miles from active GRSG leks. The distances for assessment of the indirect impacts from Transmission/Distribution Structures will be based on voltage size of the aboveground electrical line (Figure D. 2). The distance for the Indirect Impact Area for voltage sizes > 116-kV will be 6.0-km from the electrical line direct footprint. The distance for the Indirect Impact Area for voltage sizes ≤ 116-kV will be 3.0-km from the electrical line direct footprint. The distances of 6.0 and 3.0-km are very conservative estimates for indirect impacts for all Transmission/Distribution Structure voltage sizes. Through the ongoing Adaptive Management process, these distances will be revised and updated as new data and studies become available to supplement existing published research findings.

Table C. 1. Variables pertinent and specific to the indirect impacts of Transmission/Distribution Structures documented in scientific peer-reviewed literature[1].

Variable	Metric for Consideration	Reference	Conclusion
Greater Sage-Grouse Responses to Transmission/Distribution Structures			
GRSG Avoidance Responses			
⬇ pellet count	< 0.5-km of power lines	Hanser et al. 2011	GRSG either avoided or showed decreased use in areas within 0.6-km of power lines (depending on study, may or may not include distribution lines).
Individual avoidance	< 0.6-km of transmission lines	Gillan et al. 2013	
Infrequent use	0.6-km of power lines	Braun 1998	
Areas void of leks	< 1.0-km of distribution lines (approx. 12-kV)	Stonehouse et al. 2013	Leks were absent from areas within 1.0-km of distribution lines (~ 12-kV) and from areas within 6.0-km of transmission lines (115-kV).
	< 6.0-km of transmission line (115-kV)	Stonehouse et al. 2015	
Lek extirpation	< 6.0-km of transmission lines	Wisdom et al. 2010 (Figure 18.4)	Extirpated leks were on average 6.0-km from a transmission line, which was 2.5 times shorter than the average distance (15.0-km) for active leks. Active leks are located further from transmission lines than extirpated leks.
GRSG occurrence	Greatest at distances >10.0-km from transmission line	Shirk et al. 2015	GRSG presence increased with increasing distance from transmission lines. Maximum presence occurred in areas > 10.0-km from transmission lines.
Habitat function	Habitat function ⬆ with distance to 230-kV Transmission line	LeBeau et al. 2018	Within 2-km of 230-kV transmission line, habitat function (mean relative probability of use and survival) increased with increasing distance to the line.
Transmission Line (includes 115-kV lines)			
GRSG re-nest probability	Probability ⬆ with ⬇ distance from transmission line out to 10-12.5-km	Gibson et al. *In Press* (Table 18, Figure 4)	GRSG are more likely to re-nest closer to transmission lines. Re-nesting propensity decreases with increasing distance to transmission lines.

GRSG nest-site selection	Selection ↑ with ↑ distance to transmission line out to 3-km	Gibson et al. *In Press* (Table 18, Figure 6)	GRSG select areas further from transmission lines for nesting and brood-rearing activities.
Brood-site habitat selection	Selection ↑ with ↑ distance to power line out to 5.0-km	Gibson et al. *In Press* (Table 18, Figure 8)	
All Power Lines (includes transmission lines and distribution lines)			
GRSG nest-site selection	Selection ↑ with ↑ distance to power line out to 10-km or greater	Gibson et al. *In Press* (Table 18, Figure 6)	GRSG select areas further from any power line sizes for nesting and brood-rearing activities.
Brood-site habitat selection	Selection ↑ with ↑ distance to power line out to 7.5-km	Gibson et al. *In Press* (Table 18, Figure 8)	
Individual GRSG Vital Rates			
Transmission Line (>115-kV)			
GRSG nest survival	↑ linearly with ↑ distance to transmission line out to 12.5-km	Gibson et al. *In Press* (Table 18, Figure 7)	Nest survival increased with increasing distance from transmission lines
Age-sex class survival rates			
Pre-fledging chick	Chick survival ↓ with ↑ distance to transmission line out to 10-km	Gibson et al. *In Press* (Table 18, Figure 11)	Chick survival was positively associated with transmission lines. Adult female and adult male survivals increased with increasing distance from transmission lines.
Adult female	Female survival ↑ with ↑ distance to transmission line out to 7.5-km		
Adult male	Male survival ↑ with ↑ distance to any power line out to 5.0-km		
All Power Lines (includes Distribution Lines)			
Age-sex class survival rates			
Pre-fledging chick	Chick survival ↓ with ↑ distance to transmission line out to 5.0-km	Gibson et al. *In Press* (Table 18, Figure 11)	Chick survival was positively associated with any power lines. Adult female and adult male survivals increased with increasing distance from any power lines.
Adult female	Female survival ↑ with ↑ distance to transmission line out to 2.5-km		
Adult male	Male survival ↑ with ↑ distance to any power line out to 5.0-km		
Impacts to Population Growth Rates			
Transmission Line (>115-kV)			
Annual population growth rate	Growth rate ↑ with ↑ distance to power line out to 5.0-km	Gibson et al. *In Press* (Table 18, Figure 13, 14)	GRSG population growth rate increased with increasing distance from any power line with overall impacts detected out to 10-km of transmission lines 115-kV.
Overall impacts	< 10-km of the structures		

All Power Lines (includes Distribution Lines)			
Annual GRSG recruitment	Growth rate ↑ with ↑ distance to power line out to 5.0-km	Gibson et al. *In Press* (Table 18, Figure 14)	GRSG population growth rate increased with increasing distance from any power line with overall impacts detected out to 7.5-km of any power line size.
Overall impacts	< 7.5-km of the structures		
Mean Power Line Density Impacts			
Active leks	$x\bar{x}$ = 0.025-km/km^2	Knick et al. 2013 (Table 2)	Active leks were located in areas with lower power line densities than extirpated leks. GRSG habitat quality was highest in areas with power line densities < 1.5-km/25-km^2.
Historic leks (i.e., extirpated)	$x\bar{x}$ = 0.144-km/km^2		
Areas void of active leks	≥ 0.20-km/km^2		
Highest habitat suitability	< 0.06-km/km^2		
Common Raven (and other avian predators) Ecology in Relation to Transmission/Distribution Structures			
Raven Foraging/Predation			
Territorial breeding raven foraging	< 0.57-km	Howe et al. 2014	Territorial breeding ravens foraged within 0.57-km of their nest.
Raven disturbance of GRSG leks (e.g., raven presence at leks)	↑ linearly at 50% chance disturbance with ↓ distance at 20-km from transmission line	Gibson et al. *In Press* (Figure 15)	The probability of ravens disturbing a GRSG lek was greater for leks closer to the transmission line than leks further away. Leks ≤20-km of the transmission line had at least a 50% chance greater disturbance risk than leks >20-km of the transmission line.
GRSG nest survival rates			
High raven abundance	Nest survival ↑ by 0.014/km from transmission line	Gibson et al. *In Press* (Figure 9)	As raven abundance increases, nest survival decreases at higher rates with decreasing distance to transmission lines.
Average raven abundance	Nest survival ↑ by 0.006/km from transmission line	Gibson et al. *In Press* (Figure 9)	
Raven predation risk	1 individual raven/10-km results in 26% ↑ in risk of raven predation	Coates et al. 2010 (Table 3, Figure 2)	For every 1 individual raven increase per 10-km stretch of transmission line, there is a 26% increase in raven predation risk for GRSG.
Raven Probability of Presence/Occurrence (e.g., territorial nesting pairs, perching individuals, transient individuals)			
Raven selection probability	Selection detected out to 11.7-km from power lines	Coates et al. 2014b (Figure 2)	Raven selection probability was greatest within 11.7-km of power lines with the highest probability of selection within 2.2-km of power lines. Within 2.2-km of a power line, raven probability of presence
	Highest probability of selection occurred < 2.2-km of power lines		

Within 2.2-km of power line	Raven occurrence ↓ by 12.2% for every 1.0-km from power lines		decreased by 12.2% for every 1.0-km from the power line. From 2.2-km to 11.7-km, raven probability of presence decreased by 1.9% for every 1.0-km from power lines.
From 2.2-km to 11.7-km	Raven occurrence ↓ by 1.9% for every 1.0-km from power lines		
Raven probability of occurrence	Raven occurrence ↓ by 8.9% for every 1.0-km from a GRSG lek	Coates et al. 2016	Ravens preferred areas near GRSG leks with an almost 9% decrease in probability of raven presence for every 1.0-km away from leks.
Territorial Breeding Raven Behavior			
Average distance between raven nests	1.0-km	Ratcliffe 1997	Territorial ravens nest approximately 1.0-km away from the next nearest raven nest. This supports the co-location concept for transmission/distribution structures when the indirect impact mechanism is based on raven predation.
	0.85-km (± 0.17-km)	Burton & Mueller 2006	

1 While the mechanism (e.g., raven predation) of indirect impacts on GRSG is common between Transmission/ Distribution Structures and Tall Structures suggesting results reported for one structure type can be extrapolated to the other structure type (pers. comm. J. Kehmeier, SWCA, 18 September 2018), the Program has endeavored to reference literature in this section specific to Transmission/Distribution Structures. Note that Knick et al. (2013) and Wisdom et al. (2011) are referenced in both Transmission/Distribution Structures and Tall Structures sections because the authors of the two papers assessed impacts specific to each structure type, individually.

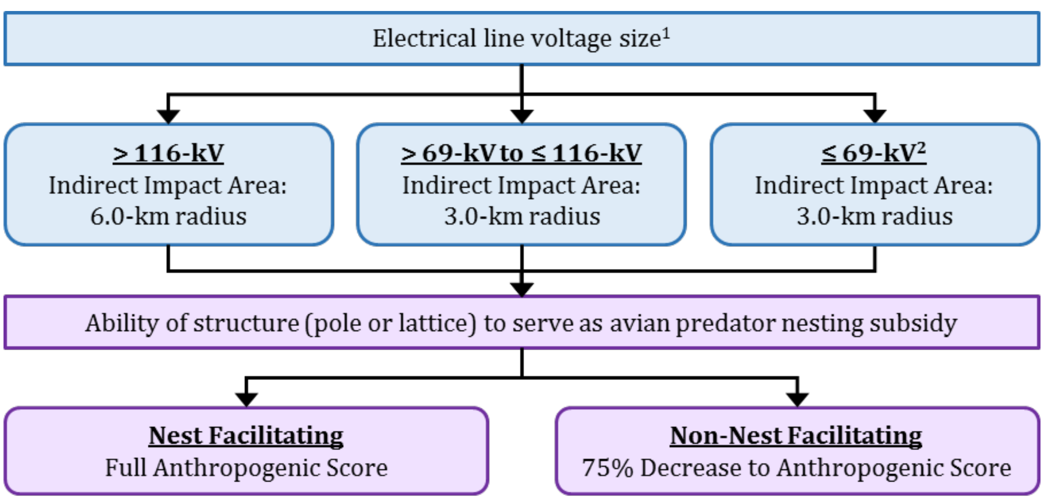

Figure D. 2. Flowchart for defining the Indirect Assessment Area for Transmission/Distribution projects based on electrical line voltage size and the application of a decrease to Anthropogenic Scores based on the structure design.

1 If the Line is 4-miles or less of an active sage grouse lek, the line should be buried. Regardless of location and proximity to active sage grouse leks, buried electrical lines will receive no impact for the project's Operation Phase.

2 Electrical lines with voltage sizes < 35-kV may be exempt from the EO and would not receive a Raw HQT Score.

How the Anthropogenic Score is Calculated

Avoidance (0-m to 600-m; applied to all Transmission/Distribution Structures

Reduced use of habitat (i.e., avoidance) near Transmission/Distribution Structures is greatest directly under the line, decreasing out to 600-m based on peer-reviewed literature. Avoidance is modeled as a loss in habitat functionality that decreases linearly from 75% loss immediately below the line to 0% loss 600-m from the line.[15] The Anthropogenic Score is calculated as [1-1.25(0.6 - x)], where 'x' is the distance from the Transmission/Distribution Structure (Figure D. 3).

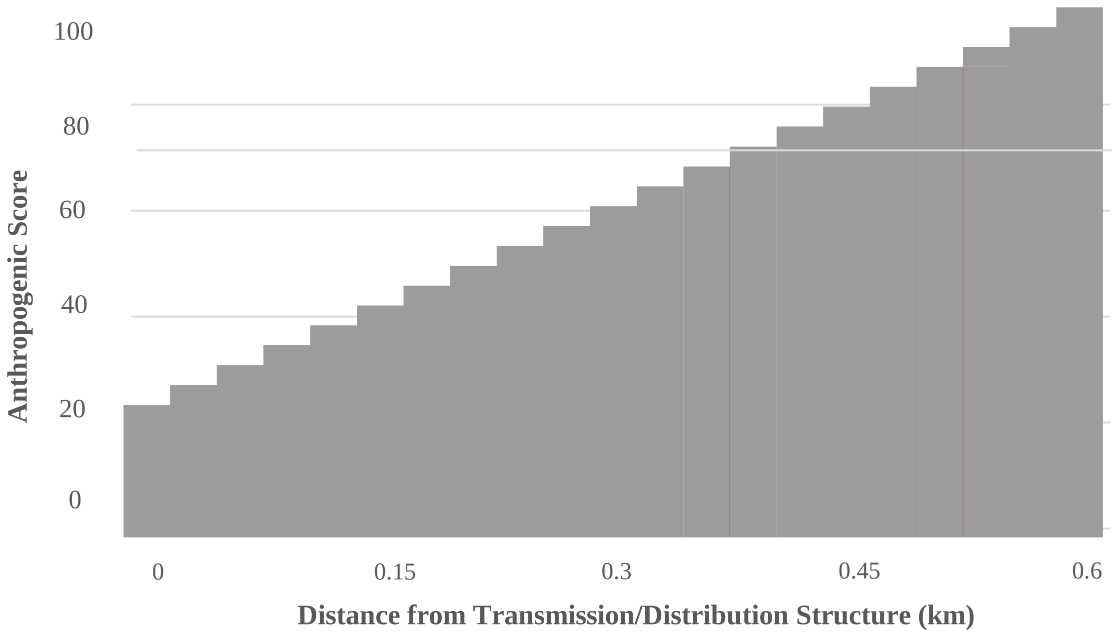

Figure D. 3. The Anthropogenic Scores for habitat avoidance with proximity (km) to the Transmission/Distribution Structure Anthropogenic Variable.

Decreased Population Growth (distance of effect dependent on line voltage)

Transmission Structure Voltages > 116-kV (0-m to 6,000-m)

Decreased Population Growth near Transmission Structures > 116-kV is modeled in all GRSG habitat as a loss of habitat functionality that decreases linearly from 3% directly below the line to 0% loss 6,000 m (6.0 km) from the line[16]. The Anthropogenic Score is calculated as [1-0.003(6-x)], where ‘x’ is the distance (km) from the structure.

For Transmission Structures considered non-nest facilitating, the pixel scores will decrease by 75% (Figure D. 2). This results in less impact calculated in the HQT and a lower Raw HQT Score.

[15] Professional judgment was used to develop the 75% reduction in use immediately below the line with the likelihood of use increasing with increasing distance from the transmission line.

[16] The effects of transmission lines are being modeled, not the effects of “all power lines”. Distribution line data is not available for the entire analysis area. Without accurate and complete distribution line data, the baseline condition with existing power lines could not be accurately characterized and the baseline habitat scores would be inaccurate.

Transmission/Sub-Transmission Structure Voltages > 69-kV to ≤ 116-kV (0-m to 3,000-m)

Decreased Population Growth near Transmission/Sub-Transmission Structures > 69-kV to ≤ 116-kV is modeled in all GRSG habitat as a loss of habitat functionality that decreases linearly from 3% directly below the line to 0% loss 3,000 m (3.0 km) from the line. The Anthropogenic Score is calculated as [1-0.003(3-x)], where 'x' is the distance (km) from the structure.

For Transmission/Sub-Transmission Structures considered non-nest facilitating, the pixel scores will decrease by 75% (Figure D. 2). This results in less impact calculated in the HQT and a lower Raw HQT Score.

Sub-Transmission/Distribution Structure Voltages ≤ 69-kV (0-m to 3,000-m)

Decreased Population Growth near Sub-Transmission/Distribution Structures ≤ 69-kV is modeled in all GRSG habitat as a loss of habitat functionality that decreases linearly from 3% directly below the line to 0% loss 3,000 m (3.0 km) from the line. The Anthropogenic Score is calculated as [1-0.003(3-x)], where 'x' is the distance (km) from the structure.

For Transmission/Distribution Structures considered non-nest facilitating, the pixel scores will decrease by 75% (Figure D. 2). This results in less impact calculated in the HQT and a lower Raw HQT Score.

NOTE: The EO states that Distribution Structures with line voltages ≤ 35-kV may be exempt.

Data Layers: Proposed Transmission/Distribution Structure Project Spatial Data (submitted by proponent)

GIS Steps for Anthropogenic Variable and Score Creation:

1. Create the Project Assessment Area:
    a. Direct Footprint: this is the exact shape and area of the submitted Proposed Transmission/Distribution Structure Project.
    b. Indirect Impact: Create the Indirect Impact area by buffering the Direct Footprint of the Transmission/Distribution Structure by 6.0-km for structures with voltages > 116-kV and by 3.0-km for structures with voltages ≤ 116-kV.
    c. Project Assessment Area (PAA): This is the Direct Footprint *and* the Indirect Impact areas specific to the Transmission/Distribution Structure and associated features.
2. Run the Euclidean Distance Tool on the PAA Transmission/Distribution Structure layer with a maximum distance of 6.0-km for voltages > 116-kV and of 3.0-km for voltages ≤ 116-kV, specifying the previous corresponding buffer as the extent in the Environment Settings to create an output Transmission/Distribution Structure 6km raster and Transmission/ Distribution 3km raster, respectively.
3. Reclassify the pixel values in the Transmission/Distribution Structure 6km raster and Transmission/Distribution 3km raster to the associated Anthropogenic Scores in Table D. 2 (Figure D. 4) and Table D. 4 (Figure D. 6), respectively, for structures considered nest facilitating to create the Transmission/Distribution Structure 6km Nest Anthropogenic Score raster and Transmission/Distribution Structure 8km Nest Anthropogenic Score raster, respectively. For structures considered non-nest facilitating, reclassify the pixel values in the

the Transmission/Distribution Structure 6km raster and Transmission/Distribution 3km raster to the associated Anthropogenic Scores in Table D. 3 (Figure D. 5) and Table D. 5 (Figure D. 7), respectively, to create the Transmission/Distribution Structure 6km Non-Nest Anthropogenic Score raster a nd Transmission/ Distribution Structure 3km Non-Nest Anthropogenic Score raster, respectively. See Table D. 6 (Figure D. 8) for Anthropogenic Scores for nest facilitating Sub-Transmission/Distribution Structures and Table D. 7 (Figure D. 9) for non-nest facilitating Sub-Transmission/Distribution Structures.

4. If a given project contains additional disturbance types (e.g., roads, tall structures), refer to the associated appendix for creation of additional Anthropogenic Score rasters.
5. Once all disturbance types for the proposed project have an Anthropogenic Score raster created, all Anthropogenic Score rasters are multiplied together to create the Total Anthropogenic Score for the Project Assessment Area for the Proposed Transmission/ Distribution Structure project. See Section 5 for the complete calculation of the Raw HQT Score for Debit Projects.

OPTIONAL THIRD LEVEL ASSESSMENT

Debit projects may have the option of performing Third Level Assessment surveys to collect site-specific data to inform the final HQT scores. This assessment must follow the peer-reviewed standards set forth in this document to ensure all such assessments are comparable, complete, and collect data useable within the Montana HQT framework.

ANTHROPOGENIC SCORE & INDIRECT IMPACT AREAS FOR VARIOUS TRANSMISSION/ DISTRIBUTION STRUCTURE PROJECT

Nest Facilitating Transmission Structures > 116-kV

Table D. 2. Anthropogenic Scores for Transmission Structures > 116-kV that are considered nest facilitating structures for computing the Distance to Transmission/Distribution Structures Anthropogenic Variable.

Distance (km) to Transmission Structures	Anthropogenic Score
0 – 0.1	25
> 0.1 – 0.2	38
> 0.2 – 0.3	50
> 0.3 – 0.4	63
> 0.4 – 0.5	75
> 0.5 – 0.6	88
> 0.6 – 3.333	98
> 3.333 – 6	99
≥ 6.0	100

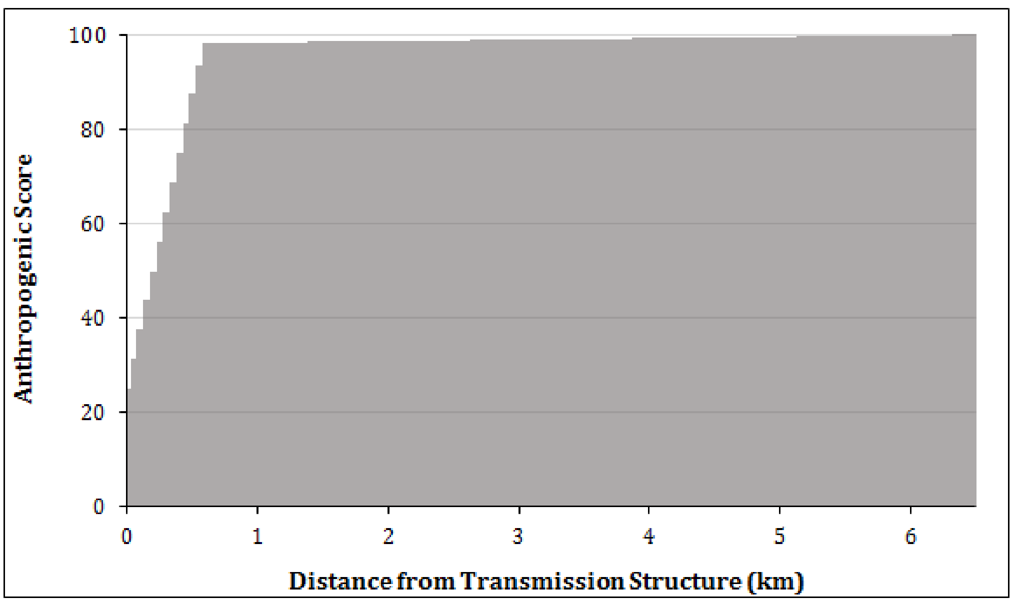

Figure D. 4. The Anthropogenic Score for Transmission Structures > 116-kV that are considered nest facilitating structures for computing the Distance to Transmission/ Distribution Structures Anthropogenic Variable.

NON-Nest Facilitating Transmission Structures > 116-kV

Table D. 3. Anthropogenic Scores for Transmission Structures > 116-kV that are considered non-nest facilitating structures for computing the Distance to Transmission/ Distribution Structures Anthropogenic Variable.

Distance (km) to Transmission Structures	Anthropogenic Score
0 – 0.1	25
> 0.1 – 0.2	38
> 0.2 – 0.3	50
> 0.3 – 0.4	63
> 0.4 – 0.5	75
> 0.5 – 0.6	88
> 0.6 – 3.333	99.6
> 3.333 – 6	99.8
≥ 6.0	100

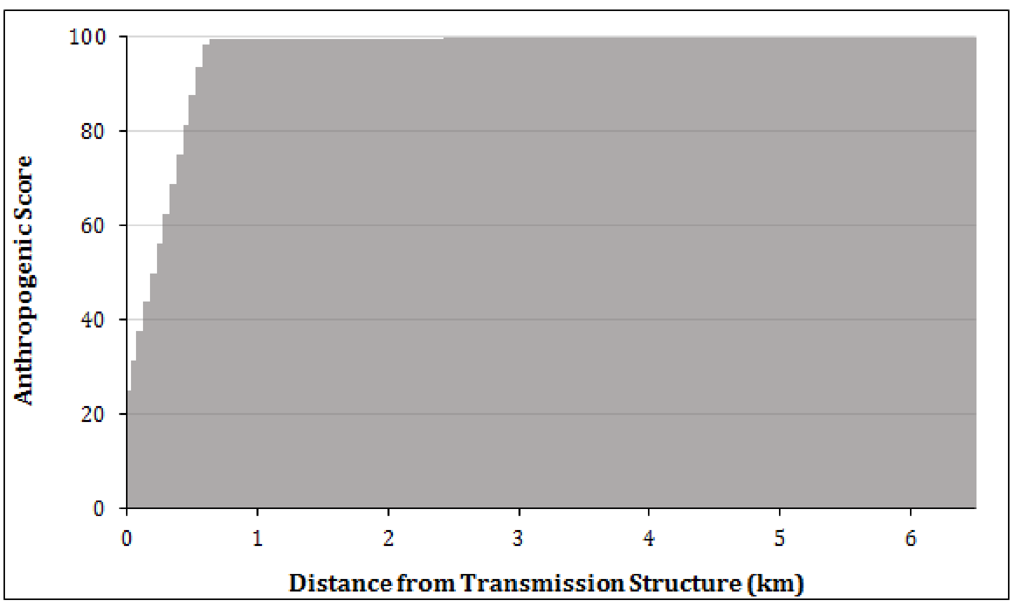

Figure D. 5. The Anthropogenic Score for Transmission Structures > 116-kV that are considered non-nest facilitating structures for computing the Distance to Transmission/ Distribution Structures Anthropogenic Variable.

Nest Facilitating Transmission Structures > 69-kV to ≤ 116-kV

Table D. 4. Anthropogenic Scores for Transmission/Sub-Transmission Structures > 69-kV to ≤ 116-kV that are considered nest facilitating structures for computing the Distance to Transmission/Distribution Structures Anthropogenic Variable.

Distance (km) to Transmission/ Sub-Transmission Structures	Anthropogenic Score
0 – 0.1	25
> 0.1 – 0.2	38
> 0.2 – 0.3	50
> 0.3 – 0.4	63
> 0.4 – 0.5	75
> 0.5 – 0.6	88
> 0.6 – 3.0	99
≥ 3.0	100

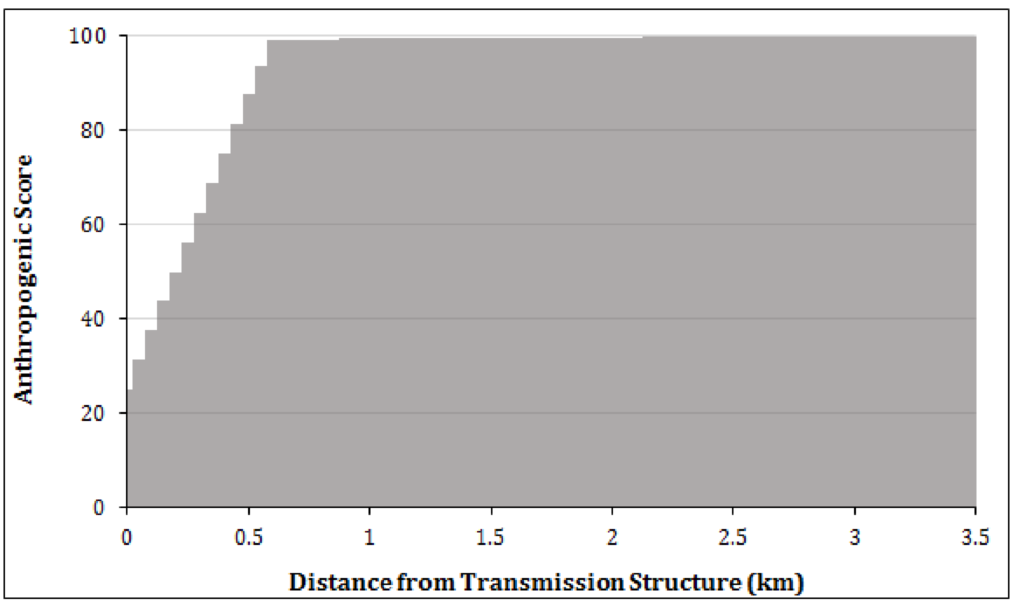

Figure D. 6. The Anthropogenic Score for Transmission/Sub-Transmission Structures > 69-kV to ≤ 116-kV that are considered nest facilitating structures for computing the Distance to Transmission/Distribution Structures Anthropogenic Variable.

NON-Nest Facilitating Transmission Structures > 69-kV to ≤ 116-kV

Table D. 5. Anthropogenic Scores for Transmission/Sub-Transmission Structures > 69-kV to ≤ 116-kV that are considered non-nest facilitating structures for computing the Distance to Transmission/Distribution Structures Anthropogenic Variable.

Distance (km) to Transmission/ Sub-Transmission Structures	Anthropogenic Score
0 – 0.1	25
> 0.1 – 0.2	38
> 0.2 – 0.3	50
> 0.3 – 0.4	63
> 0.4 – 0.5	75
> 0.5 – 0.6	88
> 0.6 – 3.0	99.8
≥ 3.0	100

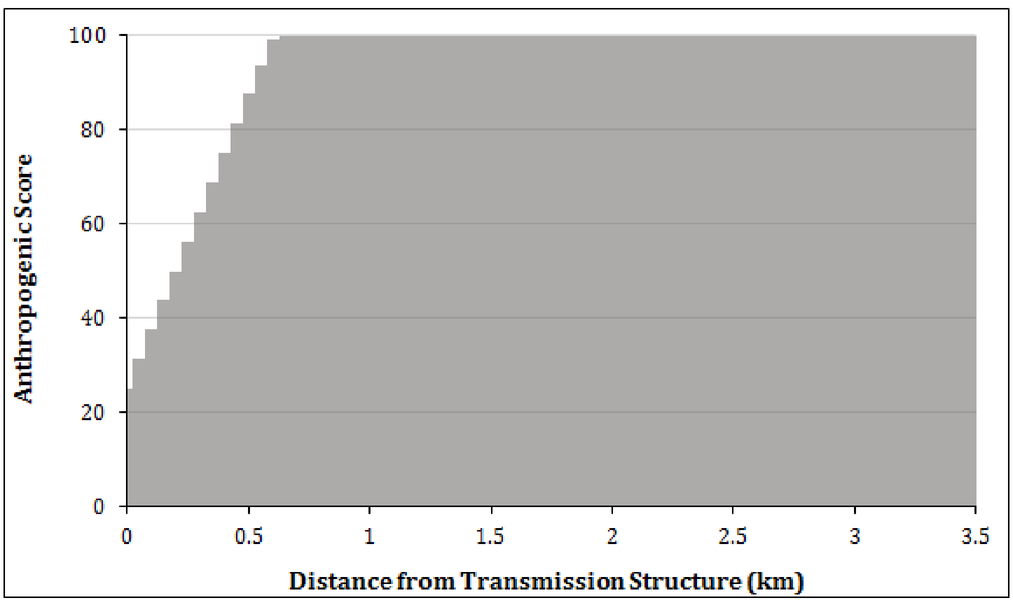

Figure D. 7. The Anthropogenic Score for Transmission/Sub-Transmission Structures > 69-kV to ≤ 116-kV that are considered non-nest facilitating structures for computing the Distance to Transmission/Distribution Structures Anthropogenic Variable.

Nest Facilitating Transmission Structures ≤ 69-kV

Table D. 6. Anthropogenic Scores for Sub-Transmission/Distribution Structures ≤ 69-kV that are considered nest facilitating structures for computing the Distance to Transmission/ Distribution Structures Anthropogenic Variable.

Distance (km) to Sub-Transmission/ Distribution Structures	Anthropogenic Score
0 – 0.1	25
> 0.1 – 0.2	38
> 0.2 – 0.3	50
> 0.3 – 0.4	63
> 0.4 – 0.5	75
> 0.5 – 0.6	88
> 0.6 – 3.0	99
≥ 3.0	100

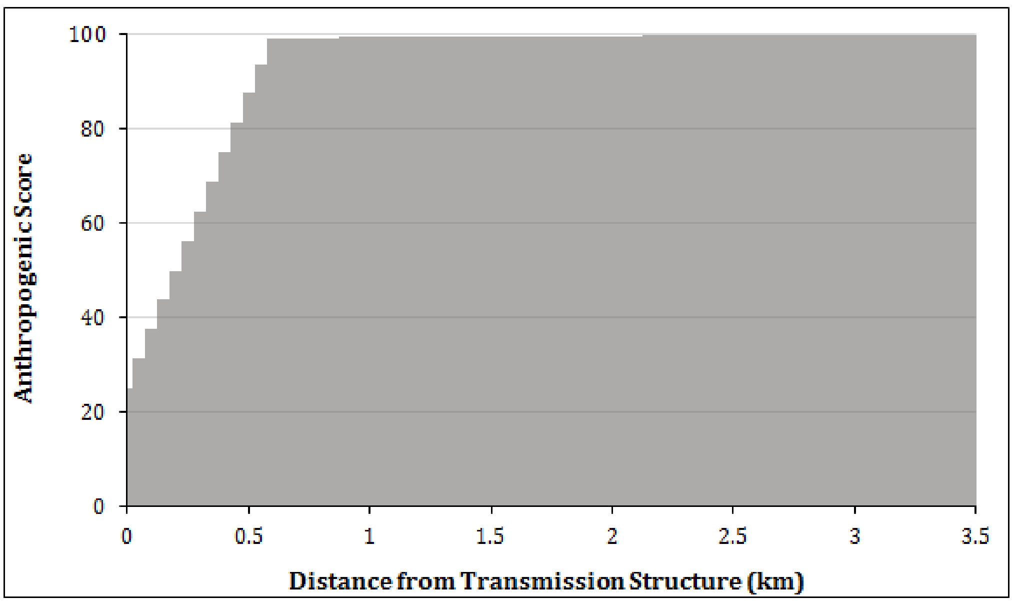

Figure D. 8. The Anthropogenic Score for Sub-Transmission/Distribution Structures ≤ 69-kV that are considered nest facilitating structures for computing the Distance to Transmission/ Distribution Structures Anthropogenic Variable.

NON-Nest Facilitating Transmission Structures ≤ 69-kV

Table D. 7. Anthropogenic Scores for Sub-Transmission/Distribution Structures ≤ 69-kV that are considered non-nest facilitating structures for computing the Distance to Transmission/ Distribution Structures Anthropogenic Variable.

Distance (km) to Sub-Transmission/ Distribution Structures	Anthropogenic Score
0 – 0.1	25
> 0.1 – 0.2	38
> 0.2 – 0.3	50
> 0.3 – 0.4	63
> 0.4 – 0.5	75
> 0.5 – 0.6	88
> 0.6 – 3.0	99.8
≥ 3.0	100

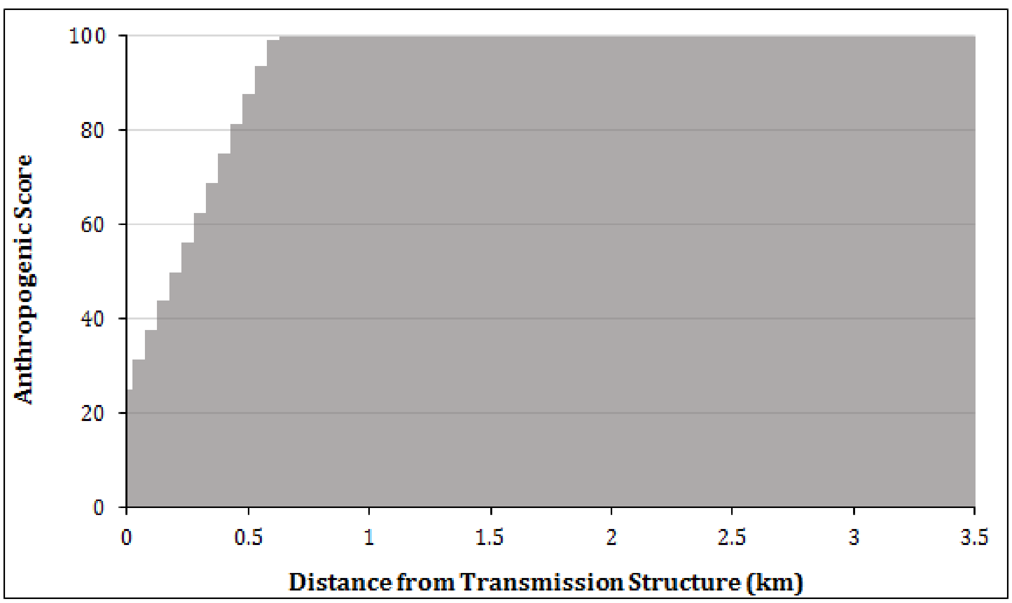

Figure D. 9. The Anthropogenic Score for Sub-Transmission/Distribution Structures ≤ 69-kV that are considered non-nest facilitating structures for computing the Distance to Transmission/Distribution Structures Anthropogenic Variable.

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Appendix E. ANTHROPOGENIC VARIABLE: WIND FACILITIES

When a new Wind Facility project is proposed, all infrastructure for the proposal is overlain on the Montana HQT Basemap. Other infrastructure for the proposed project may include roads, tall structures, etc. Specific Anthropogenic Scores are calculated to generate the Total Anthropogenic Score for the new Wind Facility project (Figure E. 1). This project-specific score is multiplied by the Montana HQT Basemap Total to produce a project-specific Raw HQT Score (Section 3.2.3).

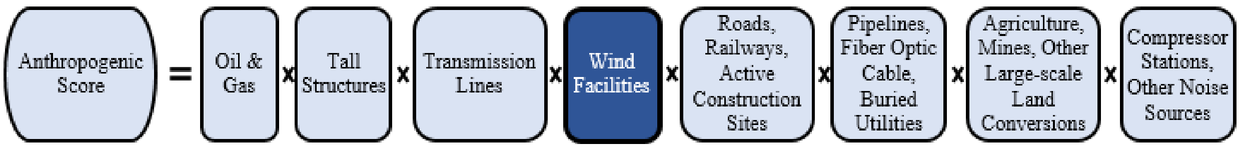

Figure E. 1. Equation for calculating the Anthropogenic Score for Wind Facility projects and any additional infrastructure.

SUPPORTING LITERATURE

LeBeau (2012) detected no decrease in habitat use with proximity to turbines by hens in the nesting, brood rearing, or summer seasons in southern Wyoming. While there was no effect to hen survival relative to wind energy infrastructure (LeBeau et al. 2014), LeBeau (2012) detected a decreased probability of nest and brood survival with proximity to turbine out to approximately 5-km, and speculated that the effect may be attributed to increased predation due to the presence of human development and edge effects. LeBeau et al. (2014) asserts that by locating wind turbines at distances greater than 5-km from nesting and brood-rearing habitats should reduce the negative impacts in the short-term posed by wind energy development.

In the same study area, LeBeau et al. (2017) determined that the percent area disturbed by wind facility infrastructure is a stronger predictor of impacts to GRSG than distance to turbine. This pattern suggests that use in some seasons occurs around the edge of the facility and in less densely developed areas, but less so within the facility. The relative probability of GRSG selecting brood-rearing and summer habitats decreased as percentage of surface disturbance associated with the facility infrastructure increased out to approximately 1.2-km, and this relationship strengthened after a 3-year lag time. Wind facility disturbance in the study area ranged 0 to 2.7%; a 2% disturbance resulted in a 60% reduction in the probability of habitat use. The percentage of surface disturbed did not affect selection of nest sites, or survival of hens, nests, or brood (LeBeau et al. 2017).

HOW THE TOTAL ANTHROPOGENIC SCORE IS CALCULATED

Because of the limited scientific research on the effects of wind energy, a conservative approach was used to develop scores for this habitat modifier variable. The percentage of the surface area disturbed by wind energy facilities within 1.5-km will be used to determine scores (Table E. 1) following the results described in LeBeau et al. (2017). A 60% reduction in habitat function (score = 0.4) will be applied when wind energy infrastructure disturbs 2-3% of the area in a 1.5-km moving window (LeBeau et al. 2017). Remaining scores were determined by fitting a logarithmic curve centered on the 60% reduction value at 2% (Table E. 1; Figure E. 2).

Table E. 1. Anthropogenic Scores for the Wind Facility Anthropogenic Variable.

Percent Disturbance from Wind Energy Infrastructure within 1.5-km moving window (%)	Anthropogenic Score
0 – <0.5	100
0.5– <2	70
2 – <3	40
3 – <4	20
≥4	10

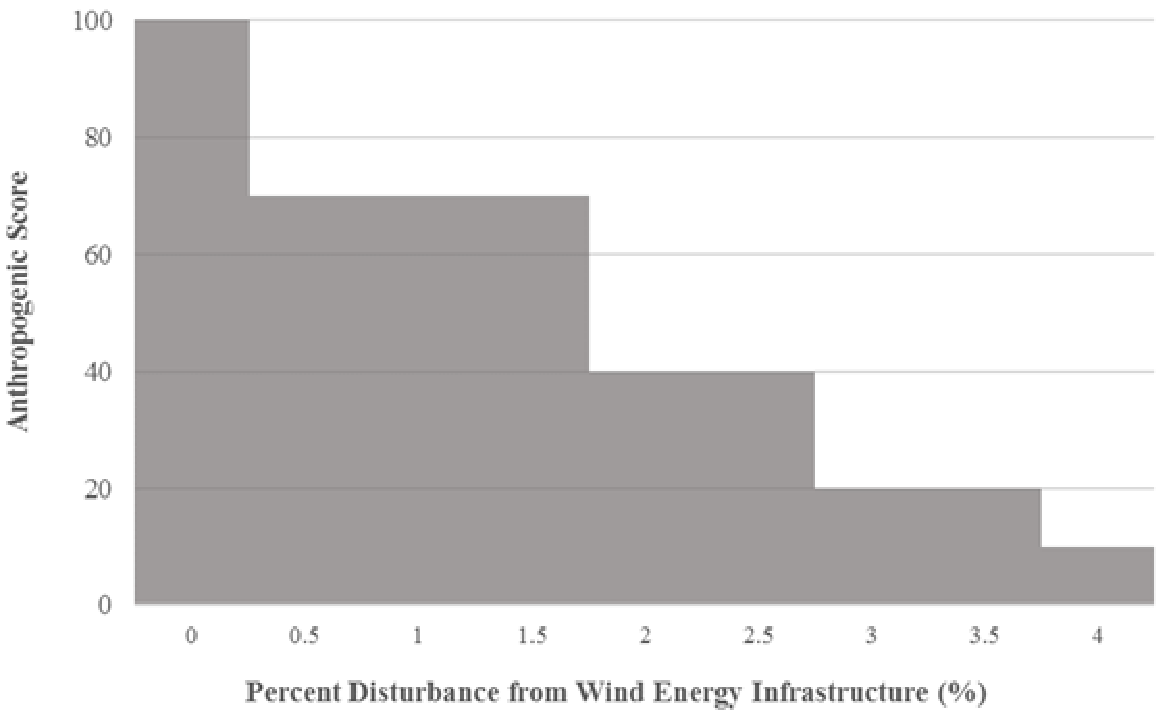

Figure E. 2. The Anthropogenic Score for the Wind Facilities Anthropogenic Variable. Line is logarithmic curve used to develop scores for this Anthropogenic Score.

<u>Data Layers:</u> Proposed Wind Facility Project Spatial Data (submitted by proponent)

<u>GIS Steps for Anthropogenic Variable and Score Creation:</u>

1. Create the Project Assessment Area:
    a. Direct Footprint: this is the exact shape and area of the submitted Proposed Wind Facility Project.
    b. Indirect Impact: Create the Indirect Impact area by buffering the Direct Footprint of the Proposed Wind Facility Project by 1.5-km.
    c. Project Assessment Area (PAA): This is the Direct Footprint *and* the Indirect Impact area.

2. Convert the Wind Facility PAA layer to a raster, giving all cells within the Direct Footprint boundary a value of "1" to create the "Wind Facility Project" raster.
3. Use the Focal Statistics Tool with a 1.5-km radius circle neighborhood (e.g., moving window) and select "SUM statistics" option to create a "Wind Facility Sum" raster that represents the number of cells surrounding a particular cell that are categorized as a Wind Facility Project (pixel value = 1).
4. Convert the new raster to data type "float" to allow for decimal places for calculation of percentages.
5. Divide the resulting raster by the maximum possible number of cells within a 1.5-km radius circle to create the "Wind Facility Percent Disturbance" raster. This maximum value will be dependent on cell size used, so script in a variable equal to: "float(arcpy.GetRasterProperties_management(windfacilityfloat, "MAXIMUM").getOutput(0))" to plug into the Division step.
6. Using the Mask Tool, remove the Direct Footprint area from the Wind Facility Percent Disturbance raster to create the Wind Facility Percent Disturbance Indirect raster.
7. Convert the Direct Footprint layer to a raster and reclassify values to 0 to create the Direct Wind Facility Anthropogenic Score raster.
8. Reclassify the pixel values in the Wind Facility Percent Disturbance Indirect raster to the associated Anthropogenic Score in Table E.1 to create the Indirect Wind Facility Percent Anthropogenic Score raster.
9. Merge (Mosaic to New Raster Tool) the Direct Wind Facility Anthropogenic Score raster with the Indirect Wind Facility Percent Anthropogenic Score raster to create the Wind Facility Percent Anthropogenic Score raster.
10. If a given project contains additional disturbance types (e.g., roads, transmission lines), refer to the associated appendix for creation of additional Anthropogenic Score rasters.
11. Once all disturbance types for the proposed project have an Anthropogenic Score raster created, all Anthropogenic Score rasters are multiplied together to create the Total Anthropogenic Score for the Project Assessment Area for the proposed Wind Facility project. See Section 5 for the complete calculation of the Raw HQT Score for Debit Projects.

Optional Third Level Assessment

Debit projects may have the option of performing Third Level Assessment surveys to collect site-specific data to inform the final HQT scores. This assessment must follow the peer-reviewed standards set forth in this document to ensure all such assessments are comparable, complete, and collect data useable within the Montana HQT framework.

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Appendix F. ANTHROPOGENIC VARIABLE: ROADS, RAILWAYS, AND ACTIVE CONSTRUCTION SITES

When a new Road, Railway, or Active Construction phase of a project is proposed, all infrastructure for the proposal is overlain on the Montana HQT Basemap. Other infrastructure for the proposed project may include transmission lines, tall structures, etc. Specific Anthropogenic Scores are calculated to generate the Total Anthropogenic Score for the new Road, Railway, or Active Construction phase project (Figure F. 1. Equation for calculating the Anthropogenic Score for Roads, Railroads and active construction projects and any additional infrastructure). This project-specific score is multiplied by the Montana HQT Basemap Total to produce a project-specific Raw HQT Score (Section 3.2.3).

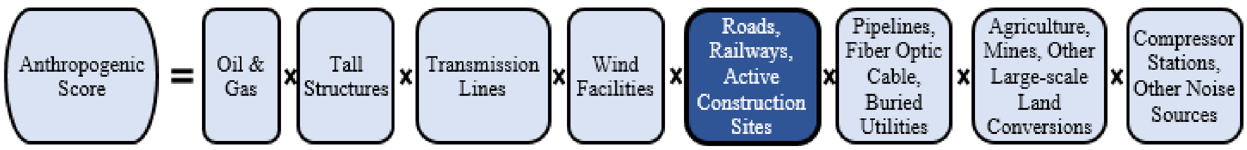

Figure F. 1. Equation for calculating the Anthropogenic Score for Roads, Railroads, and Active Construction Sites projects and any additional infrastructure.

SUPPORTING LITERATURE

Research on the effects of roads on GRSG indicates that there are variable levels of disturbance based on distance to roads, size of roads, traffic frequency, and associated noise. For instance, in Colorado, Rogers (1964) mapped 120 leks regarding distance from roads and found that 42% of leks were over 1.6-km from the nearest improved road, but that 26% of leks were within about 90-m of a county or state highway, and two leks were on a small dirt road. Connelly et al. (2004) also note the use of roads for lek sites. LeBeau (2012) found evidence for avoidance of roads by hens in the nesting and brood rearing seasons at one study site, but not the other; avoidance by hens was documented at both sites during the summer season only. Similarly, Pruett et al. (2009) found that lesser prairie-chickens (*Tympanuchus pallidicinctus*) avoided one of the two highways in the study by 100-m; however, some prairie-chickens crossed roads and had home ranges that overlapped the highways, thus roads did not completely exclude them from neighboring habitat.

In contrast, Craighead Beringia South (2008) reported results from a 2007 to 2009 study of GRSG seasonal habitat use in Wyoming. Results indicate that GRSG avoid areas within approximately 100-m of paved roads. Similarly, Knick et al. (2013) found that high value lek habitats had <1.0-km/km^2 of secondary roads, <0.05-km/km^2 of highways, and <0.01-km/km^2 of interstate highways. Research by Holloran (2005) found that traffic occurring on roads within 1.3-km of a lek during early morning strutting activity was related to significant declines in male attendance. Johnson et al. (2011) examined the correlation between trends in lek attendance and the environmental and anthropogenic features within 5- and 18-km buffers around leks. They found that lek attendance declined over time with length of interstate highway within 5-km, although the authors note that this trend was based on relatively few data points and no pre-highway data were available for comparison. Interstate highways >5-km away and smaller state and federal highways had little or no effect on trends in lek attendance.

Seasonal and daily timing of traffic and its associated noise is an important aspect of managing disturbance of GRSG because animal behaviors such as attracting mates, or males competing on leks, often occur in the morning or evening, the same time as rush hour traffic. The frequency of the sound waves produced by traffic on roads can mask these important behavioral communications, which occur at the same or similar frequencies (Blickley and Patricelli 2012). This masking effect can also interfere with hens' communication with their chicks throughout their seasonal habitats located away from leks, and can occur throughout the day (Lyon and Anderson 2003). Widespread noise may contribute to decreases in abundance of many species near roads (Forman and Deblinger 2000).

A related source of disturbance is intermittent traffic on smaller roads. This type of activity and noise may be more difficult for species to habituate to due to its unpredictable nature (Blickley et al. 2012). Blickley and her team played sounds mimicking noise disturbances found in energy production areas, resulting in a reduction in lek attendance of 73% for road noise, and 29% for drilling noise. Research by Lyon and Anderson (2003) found that even light vehicular traffic (1 to 12 vehicles/day) increased the distance of nests from lek sites and substantially reduced nest initiation rates.

HOW THE TOTAL ANTHROPOGENIC SCORE IS CALCULATED

Based on these studies and professional judgement based on effects of similar disturbance types, buffer estimates were made for GRSG avoidance of roads, railways and active construction sites. Buffers account for Indirect Impacts from a project, in this instance noise and human activity, which can extend far beyond the project area itself (Blickley and Patricelli 2010). Habitats located within 250-m of a high-traffic road (>6,000 AADT [annual average daily traffic][17]), such as an interstate highway or high-traffic federal or state highway or a mainline railway, are considered to provide no functional habitat to GRSG due to traffic and associated noise/human disturbance (Table F. 1; Figure F. 2).

Likewise, habitats within 25-m of a moderate-traffic road (a low-traffic highway) or spur railway are considered to provide no functional habitat (Table F. 1; Figure F. 3). Habitats within these buffers are adjusted by a factor of 0.0 for a final functional habitat score of 0.0. Those habitats located farther than 3,200-m (high-traffic road) and 500-m (moderate-traffic road) were considered to be outside the range of disturbance to GRSG and were assigned an Anthropogenic Score of 100.0.

New construction or new activities on two-track roads, ranch roads, resource roads, or other roads receiving light traffic will be assessed on a case-by-case basis. Adjustments to distance buffers, consideration of using a road density approach, or further refinement of road volume categories will be explored as research in these areas becomes available.

The Montana HQT places a larger adjustment on habitats that are bisected by all types of large roadways and mainline railways. Adjustments are higher for projects that typically have higher traffic levels and risk to greater GRSG (e.g., mortality from collision, noise disturbance) than less-utilized project types that generally have less traffic and implied risk.

[17] This cutoff was determined by examining the AADT of roads and identifying natural break points occurring between Interstate highways, major U.S. and State Highways, and other road types.

A moderate-traffic road Anthropogenic Score will also be applied around project footprints for the duration of active construction of other project types to account for increased traffic, disturbance, and human presence of the landscape.

<u>Data Layers:</u> Proposed Road, Railway, or Active Construction Site Project Spatial Data (submitted by proponent)

<u>GIS Steps for Anthropogenic Variable and Score Creation:</u>

1. Create the Project Assessment Area:
    a. Direct Footprint: this is the exact shape and area of the submitted Proposed Road, Railway, or Active Construction Site Project.
        i. The buffer used for Moderate-traffic Roads will be applied to all projects that include an active construction phase.
        ii. The Anthropogenic Scores for the Active Construction phase of a given project will be multiplied by the project-specific scores to compute the Anthropogenic Score for the Construction phase.
        iii. The buffer and associated Anthropogenic Scores for the Active Construction phase will be removed once the project enters the Operations phase.
    b. Indirect Impact: Create the Indirect Impact area by buffering the Direct Footprint of the Proposed Road, Railway, or Active Construction Site Project by 3,500-m for large roadways and mainline railways or by 500-m for moderate-traffic roads and active construction sites.
    c. Project Assessment Area (PAA): This is the Direct Footprint *and* the Indirect Impact areas.
2. Run the Euclidean Distance Tool on the PAA layer with a maximum distance of 3,500-m for large roadways and mainline railways or by 500-m for moderate-traffic roads and active construction sites. Specify the previous buffer, respectively, as the extent in the Environment Settings to create an output "Euclidean Distance Road, Railway, or Active Construction Site" raster.
3. Reclassify the pixel values in the Euclidean Distance Road, Railway, or Active Construction Site raster to the associated Anthropogenic Score in Table F.1 to create the "Distance to Road, Railway, or Active Construction Site Anthropogenic Score" raster.
4. If a given project contains additional disturbance types (e.g., oil & gas well pads, tall structures), refer to the associated Anthropogenic Variable appendix for creation of additional Anthropogenic Score rasters.
5. Once all disturbance types for the proposed project have an Anthropogenic Score raster created, all Anthropogenic Score rasters are multiplied together to create the Total Anthropogenic Score for the Project Assessment Area for the proposed Road, Railway, or Active Construction Site project. See Section 5 for the complete calculation of the Raw HQT Score for Debit Projects.

Table F. 1. Anthropogenic Scores for the Distance to Roads, Railways, and Active Construction Sites Anthropogenic Variable.

Disturbance Categories	Anthropogenic Score				
	100	**75**	**50**	**25**	**0**
Distance to high-traffic road (>6,000 AADT), mainline railway (km)	≥3.2	1.6 – <3.2	1.0 – <1.6	0.25 – <1.0	<0.25
Distance to moderate-traffic road (i.e., county roads, low traffic highways), spur rail, active construction site (km). Does not include two-tracks.	≥0.50	0.30 – <0.50	0.10 – <0.30	0.025 – <0.10	<0.025

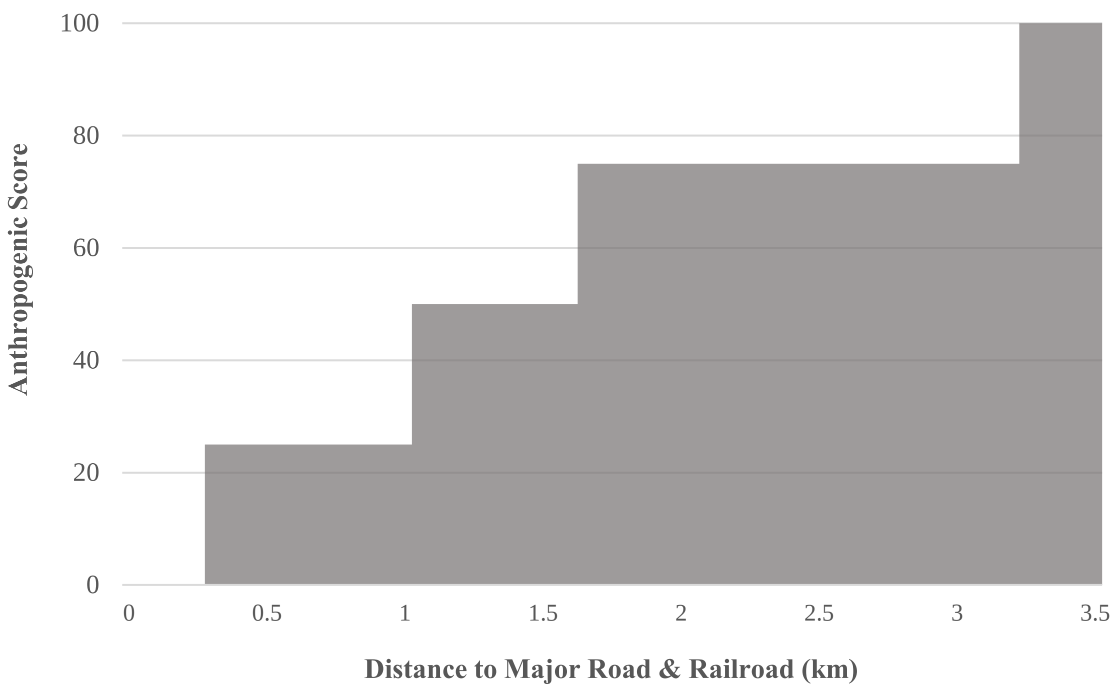

Figure F. 2. The Anthropogenic Score for the Distance to Major Roads and Railroads Anthropogenic Variable.

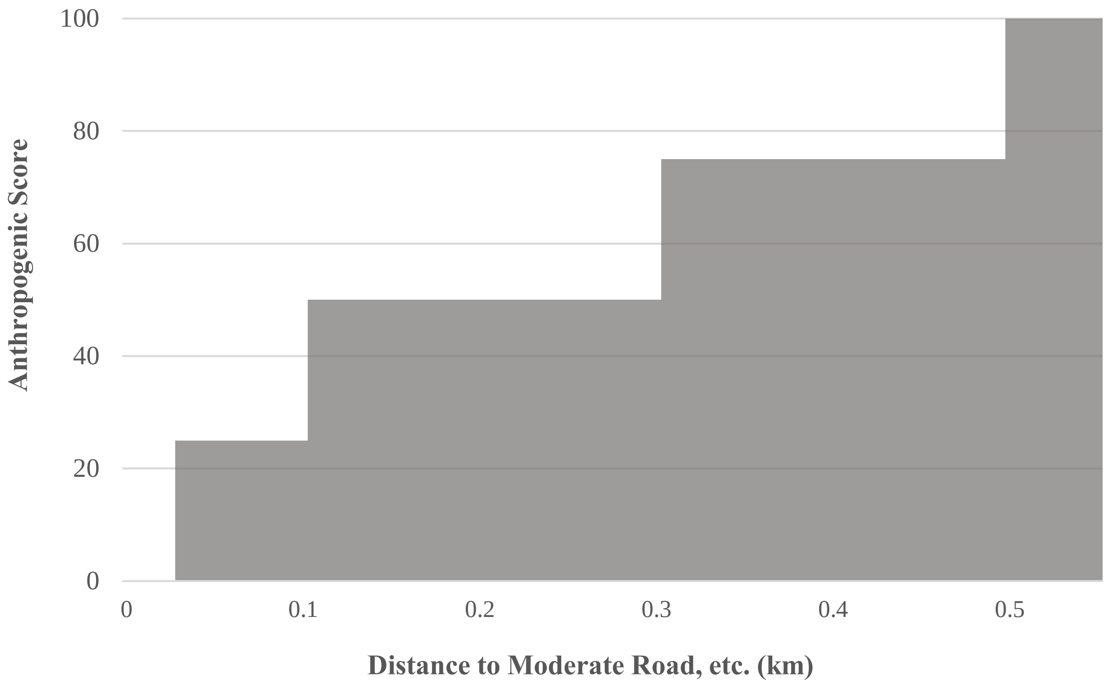

Figure F. 3. The Anthropogenic Score for the Distance to Moderate Road and Spur Rail Anthropogenic Variable.

OPTIONAL THIRD LEVEL ASSESSMENT

Debit projects may have the option of performing Third Level Assessment surveys to collect site-specific data to inform the final HQT scores. This assessment must follow the peer-reviewed standards set forth in this document to ensure all such assessments are comparable, complete, and collect data useable within the Montana HQT framework.

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Appendix G. ANTHROPOGENIC VARIABLE: PIPELINES, FIBER OPTIC CABLES, AND OTHER BURIED UTILITIES

When a new Pipeline, Fiber Optic Cable, or other Buried Utility project is proposed, all infrastructure for the proposal is overlain on the Montana HQT Basemap. Other infrastructure for the proposed project may include roads, tall structures, etc. Specific Anthropogenic Scores are calculated to generate the Total Anthropogenic Score for the new pipeline, fiber optic, or buried utility project (Figure G. 1. Equation for calculating the Anthropogenic Score for Pipeline, Fiber Optic Cable, or other Buried Utility projects and any additional infrastructure.). This project-specific score is multiplied by the Montana HQT Basemap Total to produce a project-specific Raw HQT Score (Section 3.2.3).

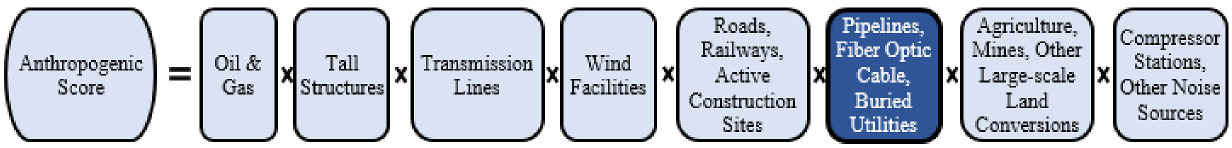

Figure G. 1. Equation for calculating the Anthropogenic Score for Pipelines, Fiber Optic Cables, and Other Buried Utilities projects and any additional infrastructure.

SUPPORTING LITERATURE

Major or minor pipelines, buried fiber optic cable, and other types of buried utilities projects have in common a high level of surface disturbance and human activity during the construction phase, followed immediately by the reclamation phase for the recovery of vegetated habitat. The operations phase is different from most project types in that, although the lifetime of the project would be considered permanent (longer than 25 years), a buried pipeline or cable typically creates a temporary *surface* disturbance. The temporary surface disturbance occurs during the construction phase requiring and results in a relatively brief overall disturbance phase because the operations for a buried feature are sub-surface and do not impact GRSG or their habitat at that point. This would effectively allow buried projects to move directly from the construction phase immediately into the reclamation phase.

It is important for the Montana HQT to accurately quantify the initial disturbance, however, and then estimate the timeframe for the reestablishment of native vegetation. Depending on the type of project, surface disturbance could be a corridor of several hundred feet using backhoes and tracked equipment for a major gas pipeline and associated activities, or minimal disturbance for fiber optic cable or other utilities using a single cable plow or micro-trenching machine. After the construction phase, the primary concern for GRSG habitat conservation is controlling for invasive weeds or erosion within the disturbance area.

Relatively few studies have been conducted on the Indirect Impacts of pipelines on GRSG distribution. We are not aware of any studies specifically addressing effects of buried utilities, but the common characteristic is the duration of the construction and reclamation phases. Where the effects of pipelines have been considered, the results are inconclusive because the pipelines are included as one factor among several potential explanatory variables, many of which have confounding effects since they are often co-located with other infrastructure (Knick et al. 2013, Johnson et al. 2011).

HOW THE TOTAL ANTHROPOGENIC SCORE IS CALCULATED

Since the construction phase of this disturbance activity disturbance is similar to that of a moderate-traffic road, these projects can be modeled using the same Indirect Impacts buffer (Table G. 1; Figure G. 2).

Data Layers: Proposed Pipeline, Fiber Optic Cable, or other buried Utilities Project Spatial Data (submitted by proponent)

GIS Steps for Anthropogenic Variable and Score Creation:

1. Create the Project Assessment Area:
    a. Direct Footprint: this is the exact shape and area of the submitted Proposed Pipeline, Fiber Optic Cable, or other buried Utilities Project.
    b. Indirect Impact: Create the Indirect Impact area by buffering the Direct Footprint of the Proposed Pipeline, Fiber Optic Cable, or other buried Utilities Project by 500-m.
    c. Project Assessment Area (PAA): This is the Direct Footprint *and* the Indirect Impact areas.
2. Run the Euclidean Distance Tool on the PAA layer with a maximum distance of 500-m. Specify the previous buffer as the extent in the Environment Settings to create an output "Euclidean Distance Pipeline, Fiber Optic Cable, or other buried Utilities" raster.
3. Reclassify the pixel values in the Euclidean Distance Pipeline, Fiber Optic Cable, or other buried Utilities raster to the associated Anthropogenic Score in Table G.1 to create the "Distance to Pipeline, Fiber Optic Cable, or other buried Utilities Anthropogenic Score" raster.
4. If a given project contains additional disturbance types (e.g., oil & gas well pads, tall structures), refer to the associated Anthropogenic Variable appendix for creation of additional Anthropogenic Score rasters.
5. Once all disturbance types for the proposed project have an Anthropogenic Score raster created, all Anthropogenic Score rasters are multiplied together to create the Total Anthropogenic Score for the Project Assessment Area for the proposed Pipeline, Fiber Optic Cable, or other buried Utilities project. See Section 5 for the complete calculation of the Raw HQT Score for Debit Projects.

Table G. 1. Anthropogenic Scores for the Distance to Pipelines, Fiber Optic Cables, and Other Buried Utilities Anthropogenic Variable during the Construction Phase.

Disturbance Categories	Anthropogenic Score				
	100	**75**	**50**	**25**	**0**
Distance to disturbance during year(s) of construction (km)	≥0.5	0.3 – <0.5	0.1 – <0.3	0.025 – <0.1	<0.025

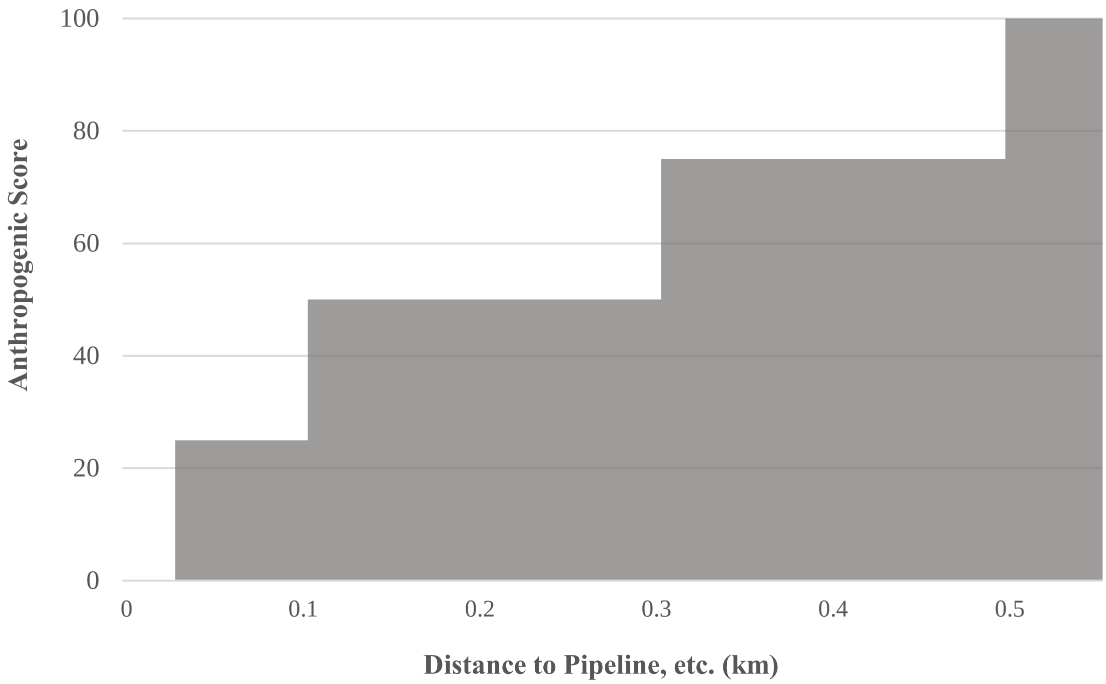

Figure G. 2. The Anthropogenic Score for the Distance to Pipelines, Fiber Optic Cables, and Other Buried Utilities Anthropogenic Variable during construction.

Optional Third Level Assessment

Debit projects may have the option of performing Third Level Assessment surveys to collect site-specific data to inform the final HQT scores. This assessment must follow the peer-reviewed standards set forth in this document to ensure all such assessments are comparable, complete, and collect data useable within the Montana HQT framework.

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Appendix H. ANTHROPOGENIC VARIABLE: AGRICULTURE, MINES, AND OTHER LARGE-SCALE LAND CONVERSION PROCESSES

When a new Agriculture, Mine, or other Large-scale Land Conversion project is proposed, all infrastructure for the proposal is overlain on the Montana HQT Basemap. Other infrastructure for the proposed project may include roads, tall structures, etc. Specific Anthropogenic Scores are calculated to generate the Total Anthropogenic Score for the new Agriculture, Mine, or other Large-scale Land Conversion project (Figure H. 1). This project-specific score is multiplied by the Montana HQT Basemap Total to produce a project-specific Raw HQT Score (Section 3.2.3).

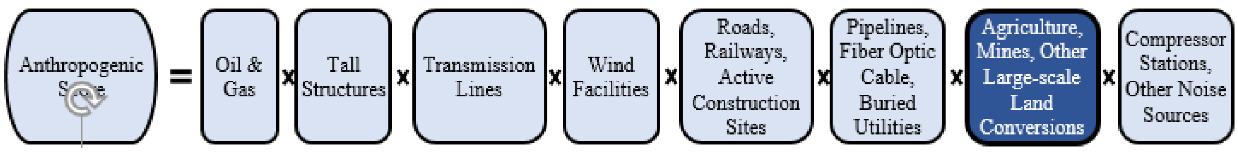

Figure H. 1. Equation for calculating the Anthropogenic Score for Agriculture, Mines, and Other Large-scale Land Conversion projects and any additional infrastructure.

SUPPORTING LITERATURE

Conversion of GRSG habitat to agricultural lands is another source of habitat loss and degradation of habitat value at the landscape scale (e.g., Knick et al. 2013, Smith et al. 2016, Aldridge et al. 2008). This same conversion process may also be present for other moderate to large-scale land uses, including mining. The effects of mines on GRSG have not been specifically studied and are likely to vary widely based on the type of mine (e.g., surface or below ground) and infrastructure. Removal of vegetation during surface mining would likely make the area unsuitable for GRSG and may be similar to the conversion of sagebrush to agriculture.

In their survey of lek locations throughout the western half of the species range, Knick et al. (2013) found that the percent agriculture varied widely across individual lek locations, but <2% of the leks were in areas surrounded by >25% agriculture within a 5.0-km radius, and 93% by <10% agriculture. Smith et al. (2016) found that cropland effects manifest at a spatial scale of 32.2-km^2 in eastern Montana, northeastern Wyoming, and North and South Dakota, and that a 10-percentage point increase in cropland is associated with a 51% reduction in lek density. Aldridge et al. (2008) estimated that GRSG were extirpated from areas of their range when more than 25% of current habitat was in cultivated cropland. These findings suggest that approximately 25% cropland constitutes an upper threshold for GRSG breeding habitat.

HOW THE TOTAL ANTHROPOGENIC SCORE IS CALCULATED

Based upon the findings noted above, the HQT score evaluates percent agriculture within a 3.2-km buffer (as documented by Smith et al. 2016), and the score is reduced as the proportion of the surrounding landscape that is converted to other land uses increases. Habitats surrounded by <10% agriculture, mining, or other land conversion types within 3.2-km have no reduction in value in the model, consistent with the finding by Knick et al. (2013). The HQT score is reduced by 50% for habitats with 10–25% agriculture (or other land conversion) consistent with Smith et al. (2016). As only 2% of leks were found with >25% agriculture and extirpation is likely, the HQT score goes to zero at 25% land conversion (Table H. 1).

Table H. 1. Anthropogenic Scores for the Agriculture, Mines, and Other Large-scale Land Conversion Activities Anthropogenic Variable.

Percent agriculture within a 3.2-km radius	Anthropogenic Score
0 – <10	100.0
10 – <25	50.0
25 – <40	12.5
40 – <60	5.0
≥60	0.0

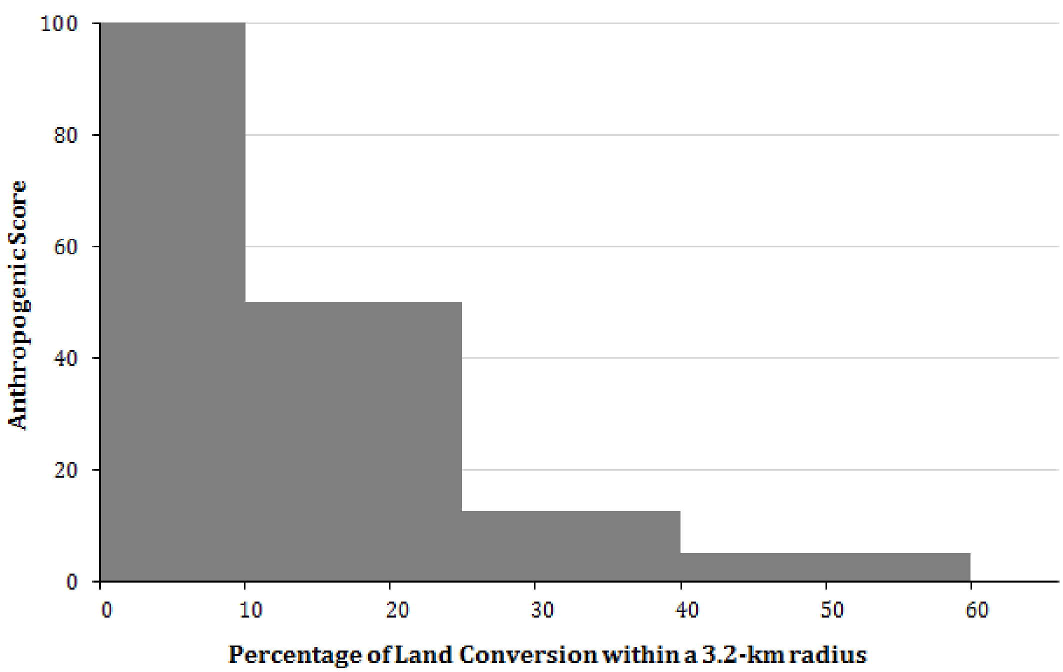

Figure H. 2. The Anthropogenic Score for the Agriculture, Mining, and Other Large-scale Land Conversion Processes Anthropogenic Variable.

<u>Data Layers:</u> Proposed Agriculture, Mine, and/or other Large-scale Land Conversion Project Spatial Data (submitted by proponent)

<u>GIS Steps for Anthropogenic Variable and Score Creation:</u>

1. Create the Project Assessment Area:
    a. Direct Footprint: this is the exact shape and area of the submitted Proposed Agriculture, Mine, and/or other Large-scale Land Conversion Project.

   b. Indirect Impact: Create the Indirect Impact area by buffering the Direct Footprint of the Proposed Agriculture, Mine, and/or other Large-scale Land Conversion Project by 3.2-km.
   c. Project Assessment Area (PAA): This is the Direct Footprint *and* the Indirect Impact area.
2. Convert the Agriculture, Mine, and/or other Large-scale Land Conversion PAA layer to a raster, giving all cells within the Direct Footprint boundary a value of "1" to create the "Agriculture, Mine, and/or other Large-scale Land Conversion Project" raster.
3. Use the Focal Statistics Tool with a 3.2-km radius circle neighborhood (e.g., moving window) and select "SUM statistics" option to create a "Agriculture, Mine, and/or other Large-scale Land Conversion SUM" raster that represents the number of cells surrounding a particular cell that are categorized as Agriculture, Mine, and/or other Large-scale Land Conversion Project (pixel value = 1).
4. Convert the new raster to data type "float" to allow for decimal places for calculation of percentages.
5. Divide the resulting raster by the maximum possible number of cells within a 3.2-km radius circle to create the "Agriculture, Mine, and/or other Large-scale Land Conversion Percent Disturbance" raster. This maximum value will be dependent on cell size used, so script in a variable equal to: "float(arcpy.GetRasterProperties_management(agminefloat, "MAXIMUM").getOutput(0))" to plug into the Division step.
6. Using the Mask Tool, remove the Direct Footprint area from the Agriculture, Mine, and/or other Large-scale Land Conversion Percent Disturbance raster to create the Agriculture, Mine, and/or other Large-scale Land Conversion Percent Disturbance Indirect raster.
7. Convert the Direct Footprint layer to a raster and reclassify values to 0 to create the Direct Agriculture, Mine, and/or other Large-scale Land Conversion Anthropogenic Score raster.
8. Reclassify the pixel values in the Agriculture, Mine, and/or other Large-scale Land Conversion Percent Disturbance Indirect raster to the associated Anthropogenic Score in Table H.1 to create the Indirect Agriculture, Mine, and/or other Large-scale Land Conversion Percent Anthropogenic Score raster.
9. Merge (Mosaic to New Raster Tool) the Direct Agriculture, Mine, and/or other Large-scale Land Conversion Anthropogenic Score raster with the Indirect Agriculture, Mine, and/or other Large-scale Land Conversion Percent Anthropogenic Score raster to create the Agriculture, Mine, and/or other Large-scale Land Conversion Percent Anthropogenic Score raster.
10. If a given project contains additional disturbance types (e.g., roads, transmission lines), refer to the associated appendix for creation of additional Anthropogenic Score rasters.
11. Once all disturbance types for the proposed project have an Anthropogenic Score raster created, all Anthropogenic Score rasters are multiplied together to create the Total Anthropogenic Score for the Project Assessment Area for the proposed Agriculture, Mine, and/or other Large-scale Land Conversion project. See Section 5 for the complete calculation of the Raw HQT Score for Debit Projects.

Optional Third Level Assessment

Debit projects may have the option of performing Third Level Assessment surveys to collect site-specific data to inform the final HQT scores. This assessment must follow the peer-reviewed standards set forth in this document to ensure all such assessments are comparable, complete, and collect data useable within the Montana HQT framework.

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Appendix I. ANTHROPOGENIC VARIABLE: COMPRESSOR STATIONS & OTHER NOISE PRODUCING SOURCES

When a new Compressor Station or other Noise Producing project is proposed, all infrastructure for the proposal is overlain on the Montana HQT Basemap. Other infrastructure for the proposed project may include roads, tall structures, etc. Specific Anthropogenic Scores are calculated to generate the Total Anthropogenic Score for the new Compressor Station or other Noise Producing project (Figure I. 1). This project-specific score is multiplied by the Montana HQT Basemap Total to produce a project-specific Raw HQT Score (Section 3.2.3).

Anthropogenic Score = Oil & Gas x Tall Structures x Transmission Lines x Wind Facilities x Roads, Railways, Active Construction Sites x Pipelines, Fiber Optic Cable, Buried Utilities x Agriculture, Mines, Other Large-scale Land Conversions x Compressor Stations, Other Noise Sources

Figure I. 1. Equation for calculating the Anthropogenic Score for Compressor Stations and Other Noise Producing projects and any additional infrastructure.

SUPPORTING LITERATURE

Noise disturbance has been documented in literature to have deleterious effects on greater sage-grouse (*Centrocercus urophasianus*; hereafter GRSG) activities. Recent research has demonstrated that noise from natural gas development negatively affects GRSG abundance, stress levels, and behaviors. Other types of anthropogenic noise sources are similar to gas-development noise and, thus, the response by GRSG is likely to be similar. The results of research suggest that effective management of the natural soundscape is critical to the conservation and protection of GRSG (Patricelli et al. 2013). Acoustic communication is very important in the reproductive behaviors of GRSG, and energy exploration and development activities generate substantial noise (Blickley and Patricelli 2012). Female GRSG use male vocalizations to find males on the lek (Gibson 1989), and, during courtship, females assess male vocalizations and other aspects of male display when choosing a mate (Wiley 1973, Gibson and Bradbury 1985, Gibson 1996, Patricelli and Krakauer 2010). Noise produced from natural gas development primarily is due to drilling rigs, compressors, generators, and traffic on access roads. These noise sources are loudest in frequencies (i.e., pitch) <2.0-kHz (Blickley and Patricelli 2012). Male GRSG produce acoustic signals in a similar frequency range, between 0.2 – 2.0-kHz, so the potential exists for industrial noises to mask GRSG communication. Such a disruption in GRSG communication may interfere with the ability of females to find and choose mates and ultimately negatively affect mating success (Blickley and Patricelli 2012).

For a prey species, such as GRSG, noise may also increase predation risk by masking the sounds of approaching predators (e.g., coyote, badger), and contribute to behavioral disruptions such as elevated heart rate, interrupted rest, and increased stress levels, all of which may affect health and reproduction or cause avoidance of noisy areas (Patricelli et al. 2013).

The MT EO 12-2015 threshold for noise states: New project noise levels, either individual or cumulative, should not exceed 10-dBA (as measured by L50) above baseline noise at the perimeter of an active lek from 6:00 p.m. to 8:00 a.m. during the breeding season (March 1 - July 15). Patricelli et al. (2013) notes that 10-dB is a significant increase in the amount of noise. For an animal vocalizing to communicate with potential mates or offspring, a 10-dB increase in noise levels corresponds to a 10-fold decrease in the active space of the vocalization. This same increase in noise will lead to up to a 3-fold decrease in the detection distance between 2 receivers (Barber et al. 2009). This means that, in a noisy environment, the receiver must be 3 times closer to hear a vocalization than in quiet conditions, and perhaps more critically, a predator would be able to approach 3 times closer in noisy conditions before it was detected by a GRSG (Patricelli et al. 2013).

Blickley et al. (2012) found a 29% decrease in lek attendance due to continuous natural gas drilling rigs (<2.0-kHz) up to 400-m away over the course of three breeding seasons. The effect of the noise was immediate and sustained, having the potential to affect the size and persistence of the local population. The declines in male attendance observed on the Blickley noise-playback study were immediate and sustained throughout the 3-year experiment (Blickley et al. 2012a), and elevated stress hormones were observed in both the second and third years of noise playback (Blickley et al. 2012b), indicating that GRSG do not adapt to increased noise levels over time (Patricelli et al. 2013).

Holloran (2005) found observational evidence that noise may be at least partly responsible for impacts from natural gas development on GRSG populations in the Pinedale Anticline Project Area, Wyoming. Juvenile males avoided leks located near natural-gas drilling sites, even if the leks previously had high attendance by males (Holloran et al. 2010). These effects were more pronounced downwind of the drilling sites where noise levels were higher, suggesting that noise contributed substantially to these declines (Holloran 2005 in Patricelli et al. 2013).

HOW THE TOTAL ANTHROPOGENIC SCORE IS CALCULATED

The Montana HQT model assumes that effects from noise at stationary sources such as drill rigs, compressors, and substations are greatest near the source, and attenuate with distance, which corresponds to effects measured by Blickley et al. (2012) for drilling rigs on lek attendance (Table I. 1). There is no habitat value within 0 to 50-m of the noise source (Anthropogenic Score = 0). Within 50 to 100-m of the noise source, 50% of habitat value is lost (i.e., Anthropogenic Score= 50), and within 100 to 400-m, 30% of the habitat value is lost (i.e., Anthropogenic Score = 70). This value returns over a distance of 400-m; beyond 400-m, there is no further decrease in habitat value (i.e., Anthropogenic Score = 100). The effects of noise production (and, conversely, noise mitigation techniques) have the potential to vary greatly by source, type, and location. This variable may be changed to better represent this variability in the future as required to maintain consistency with the best available science.

<u>Data Layers:</u> Proposed Compressor Station and/or other Noise Producing Source Project Spatial Data (submitted by proponent)

<u>GIS Steps for Anthropogenic Variable and Score Creation:</u>

1. Create the Project Assessment Area:
    a. Direct Footprint: this is the exact shape and area of the submitted Proposed Compressor Station and/or other Noise Producing Source Project.
    b. Indirect Impact: Create the Indirect Impact area by buffering the Direct Footprint of the Proposed Compressor Station and/or other Noise Producing Source Project by 400-m.

c. Project Assessment Area (PAA): This is the Direct Footprint *and* the Indirect Impact areas.

2. Run the Euclidean Distance Tool on the PAA layer with a maximum distance of 400-m. Specify the previous buffer as the extent in the Environment Settings to create an output "Euclidean Distance Compressor Station and/or other Noise Producing Source" raster.
3. Reclassify the pixel values in the Euclidean Distance Compressor Station and/or other Noise Producing Source raster to the associated Anthropogenic Score in Table I.1 to create the "Distance to Compressor Station and/or other Noise Producing Source Anthropogenic Score" raster.
4. If a given project contains additional disturbance types (e.g., oil & gas well pads, tall structures), refer to the associated Anthropogenic Variable appendix for creation of additional Anthropogenic Score rasters.
5. Once all disturbance types for the proposed project have an Anthropogenic Score raster created, all Anthropogenic Score rasters are multiplied together to create the Total Anthropogenic Score for the Project Assessment Area for the proposed Compressor Station and/or other Noise Producing Source project. See Section 5 for the complete calculation of the Raw HQT Score for Debit Projects.

Table I. 1. Anthropogenic Scores for the Distance to Noise Source Anthropogenic Variable.

Distance (km)	**Anthropogenic Score**
0 – 0.05	0
>0.05 – 0.10	50
>0.10 – 0.40	70
>0.40	100

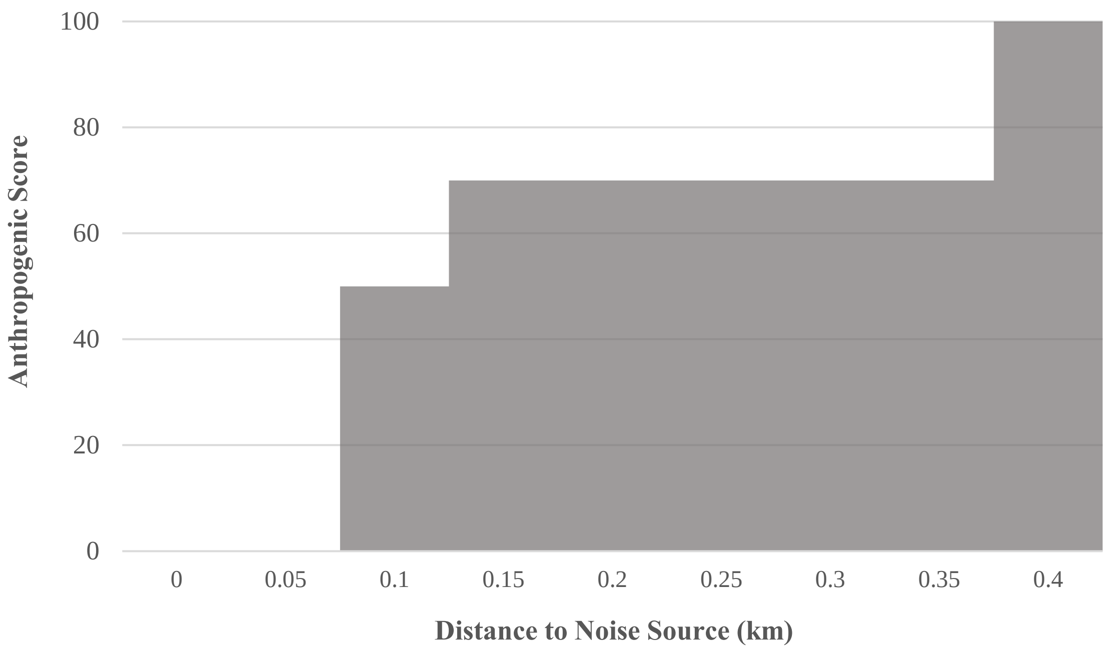

Figure I. 2. The Anthropogenic Score for the Distance to Noise Source (e.g., compressor station, road traffic, etc.) Anthropogenic Variable.

Optional Third Level Assessment

Debit projects may have the option of performing Third Level Assessment surveys to collect site-specific data to inform the final HQT scores. This assessment must follow the peer-reviewed standards set forth in this document to ensure all such assessments are comparable, complete, and collect data useable within the Montana HQT framework.

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Appendix J. CREDIT PROJECT HABITAT IMPROVEMENT THROUGH PRESERVATION, RESTORATION, AND ENHANCEMENT

An important aspect of the GRSG habitat conservation strategy is the 1) preservation of existing habitat, 2) restoration of degraded habitats, and 3) enhancement of lower quality habitats to provide better quality habitat or to increase seasonal habitat capacity. Of these three approaches, only preservation does not incorporate the element of time in the Raw HQT Score because the landscape is not expected to be altered.

Preservation efforts, such as perpetual conservation easements or term leases, seek to conserve the remaining large blocks of intact habitat. Montana still has large tracts of intact sagebrush habitats that provide year-round habitat for GRSG. Sagebrush ecosystems are difficult to restore to suitable conditions for GRSG, and the cost and human effort needed to do so is increasing over time (Fuhlendorf et al. 2017, Arkle et al. 2014). These intact areas can be preserved through conservation easements or term lease agreements [MCA § 76-22-112 (2017)], which, typically eliminate anthropogenic causes of habitat loss and fragmentation, such as cultivation and subdivision.

Enhancement requires an increase or improvement in quality, value, or extent of sage grouse habitat that has been degraded, or could be managed to increase the value of that habitat over its current value (BLM 2016). For credit projects, this approach can be used to increase existing credits by improving the habitat quality or function to GRSG

Restoration can be defined as the process of assisting the recovery of a resource (including its values, services, and/or functions) that has been degraded, damaged, or destroyed to the condition that would have existed if the resource had not been degraded, damaged, or destroyed (BLM 2016). Restored lands are eligible to receive grants from the Stewardship Fund [MCA § 76-22-110 (2017)]. Examples include the re-establishment of suitable GRSG habitat on abandoned mining claims, abandoned industrial sites, heavily impacted livestock areas, removal of conifers, eradication of invasive plant species, removal of abandoned transmission lines and towers, or restoration of wet meadows that are currently not functioning properly.

Restoration can recover areas degraded or lost to a variety of disturbances and return them to suitable GRSG habitat (Pyke 2011). These areas can be important links for connectivity, provide important mesic habitat for late summer brood rearing, or provide other seasonal habitat components, thereby increasing the value of surrounding, intact sagebrush lands. Restoration can be achieved by treating vegetation at a site-specific scale, although effects of coordinated projects at a regional scale are less understood (Stiver et al. 2015). Two types of vegetation treatments that have resulted in successful habitat restoration for GRSG are conifer removal and reductions of shrub overstory cover to restore native perennial grasses and forbs. Vegetation treatment may also be used to create fuel brake networks to protect sensitive sagebrush habitats from wildfire (Stiver et al. 2015).

Conifer removal can quickly restore lost or degraded sagebrush habitat. GRSG avoid areas of relatively low-density conifer encroachment because conifers can provide roosting and nesting structure for avian predators (Fuhlendorf et al. 2002, Doherty et al. 2010, Knick et al. 2013, Prochazka et al. 2017, Severson et al. 2017a). Research has shown that removal of encroaching conifers in sagebrush habitats can provide almost immediate gain in GRSG use of the treated habitat (Miller et al. 2017, Severson et al. 2017b), and improvement in snow persistence, water retention, and vegetation growth (Kormos et al. 2017).

Effective restoration of GRSG habitat can be challenging and difficult to achieve. The timeframe and success of a restoration project should be informed by local successful restoration projects or plant growth research data if possible. Restoration of sagebrush is a difficult and slow process due to abiotic variation, long-term weather patterns, short-lived seedbanks, and the long generation time of sagebrush. Disturbed soils and vegetation can increase the difficulty in restoring sagebrush depending on local conditions (Monsen 2005).

GRSG are sagebrush obligate species, and as such are more sensitive to habitat fragmentation, degradation, and alteration than are generalist species (Saab and Rich 1997, Julliard et al. 2003, Colles et al. 2009). This makes preservation, restoration, and enhancement projects important management tools in maintaining and increasing GRSG populations and habitat in Montana. Research provides a good understanding of GRSG habitat selection on an annual basis to inform these projects. Walker et al. (2016) mapped seasonal habitats for GRSG and found that areas selected in all seasons had a mix of habitats with a sagebrush component, less rugged topography, and less non-sagebrush habitat. The grouse in the study selected sagebrush and sagebrush-grassland at intermediate elevations during breeding and winter, and more diverse sagebrush habitats at higher elevations in summer and fall.

Knick et al. (2013) modeled annual GRSG habitat with human use influences across their range. The model indicated that GRSG required sagebrush-dominated landscapes containing minimal levels of human land use. GRSG used relatively arid regions characterized by shallow slopes, even terrain, and low amounts of forest, grassland, and agriculture in the surrounding landscape. Baxter et al. (2017) had similar results when analyzing resource selection in mechanically-altered habitats (to increase sagebrush-grass-forb habitats), finding that GRSG selected areas that were distant from trees, paved roads, and powerlines, and on more gentle slopes. Continued research in this area will help inform effective management options to improve GRSG habitat in strategic and effective locations in or near Core Areas in Montana.

For restoration or enhancement projects, sagebrush seeding or planting may be desirable. The timeframes necessary for full recovery of sagebrush varies widely in the literature. Bunting et al. (2002) stated that recovery times of sagebrush communities vary, and may be as short as 15 years for mountain big sagebrush or as long as 50 to 75 years for Wyoming big sagebrush. Cooper et al. (2007) looked at post-fire recovery of sagebrush shrub-steppe communities in central and southeast Montana and found that full recovery of Wyoming big sagebrush took over 100 years and that recovery of mountain big sagebrush cover took slightly more than 30 years. They found that the mean recovery rate for Wyoming big sagebrush canopy cover was 0.16% per year in the study area, and the fastest recovery rate was 0.72% per year (Cooper et al. 2007). Wambolt et al. (2001) reported 72% recovery of Wyoming big sagebrush after 32 years at one site in southwestern Montana, and 96% recovery after only 9 years at another site. Baker (2006) found that recovery times for mountain big sagebrush ranged from 35 to 100 years, and that recovery times for Wyoming big sagebrush ranged from 50 to 120 years. The success of conservation actions carried out by a Credit Provider are likely site-specific, highly dependent on the existing quality of the vegetation and level of prior degradation received from anthropogenic or natural disturbances.

THE HQT CALCULATION PROCESS FOR PRESERVATION, RESTORATION, AND ENHANCEMENT PROJECTS

Regardless of the type of credit site project (preservation, restoration, or enhancement), accurately measuring and documenting changes in the Raw HQT Score at different project milestones and phases will be an important aspect for all credit projects. Verification of baseline site conditions are instrumental for credit projects. The initial verification of site conditions will be used to adjust the Project HQT Basemap. By comparing the adjusted Project HQT Basemap to the theoretical maximum HQT Score, the maximum amount of uplift that can be expected for a given site is calculated. Mutually agreed upon standards must be used to evaluate habitat changes over time.

Preservation

Preservation projects can include conservation easements or term leases where the terms are based on managing future development on the property to preserve high quality GRSG habitat. For preservation credit projects, the Project Assessment Area is the property boundary or the conservation easement or term lease boundary. The Project HQT Basemap is extracted from the Montana HQT Basemap based on the Project Assessment Area footprint (Figure J. 1). The pixel values within the Project HQT Basemap are then averaged and the result is multiplied by the total area (acres) of the Project Assessment Area. The result is then multiplied by the number of years defined for the easement (perpetual conservation easements: 100 years; term lease easements: number of years of the lease). For credit projects, a Third Level Assessment will be required. The Raw HQT Score can be adjusted up or down, based on the results. The result is the Final Raw HQT Score, which represents the Functional Acres gained as the Predicted Uplift for the life of the project. See Figure J. 1.

Montana HQT – Flowchart for Preservation Projects

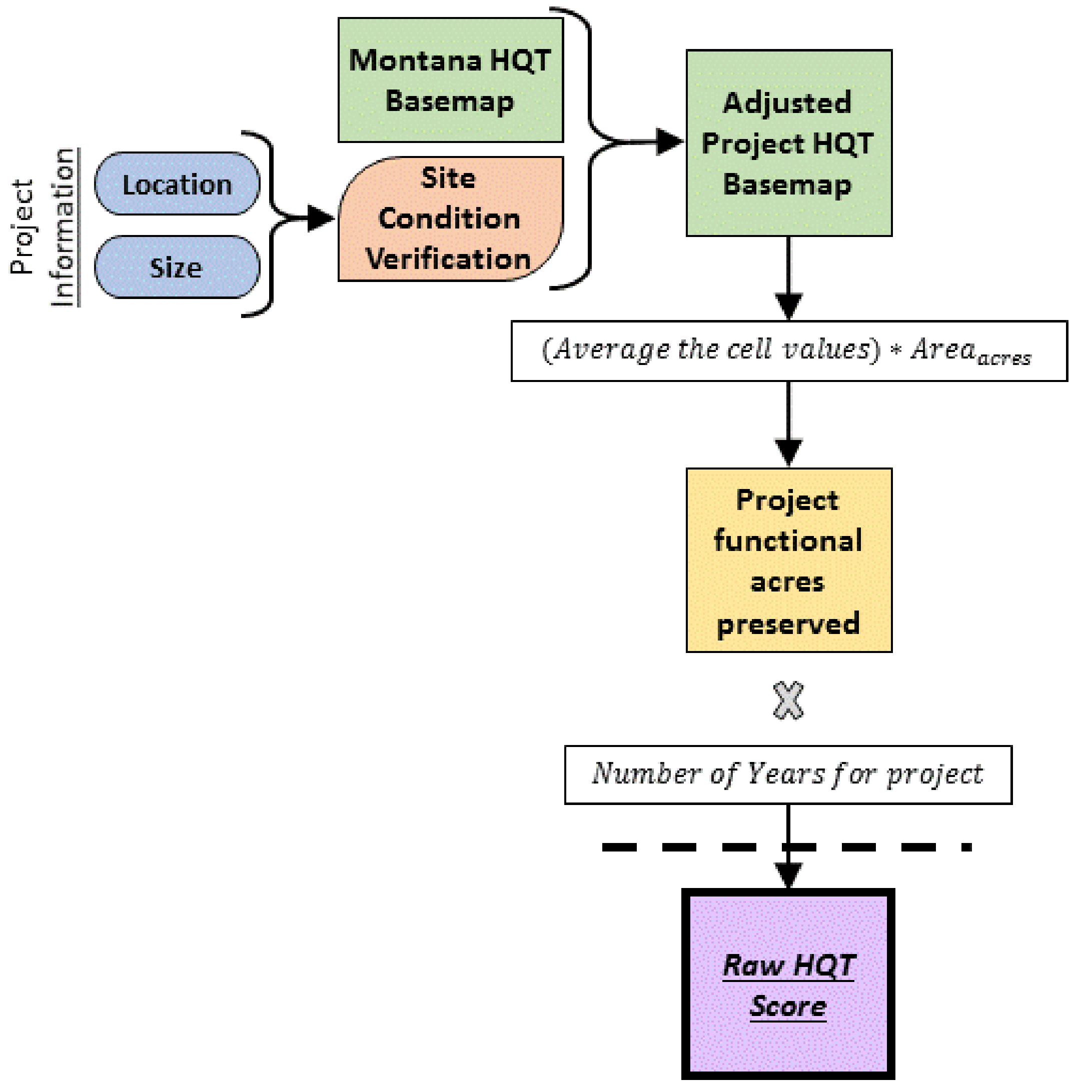

Figure J. 1. Flowchart for the development of the Raw HQT Score for Preservation Projects.

Restoration and Enhancement

Each restoration credit project will develop a Project Management Plan that outlines the location and project-specific objectives, timeframe, conservation actions, and monitoring plans. Additional content for Project Management Plans may include a detailed species list for reseeding of native grasses, forbs, and sagebrush, and a planting schedule, a weed control plan, and standards for measuring successful restoration (see Section 2.4.1 in the *Policy Guidance Document* for specifics on Site Performance Standards). The Project Assessment Area for restoration and enhancement projects is the property boundary. Because the spatial resolution of the input data used to develop the Montana HQT Basemap is too coarse to delineate some of the features (e.g., individual conifer trees, invasive species) a Third Level Assessment is required for all a Credit Provider may be interested in removing from the landscape, Credit Providers should contemplate local knowledge of the credit project sites.

The Third Level Assessment will verify on the ground conditions and adjust the Project HQT Basemap. The Adjusted Project HQT Basemap will serve as the benchmark for which subsequent restoration success will be compared (Figure J. 2). From the Adjusted Project HQT Basemap, a theoretical maximum Raw HQT Score will be predicted by adjusting the sagebrush habitat variables to their maximum value (i.e., 100). The difference calculated between the theoretical maximum Raw HQT Score and Adjusted Project HQT Basemap will quantify the Predicted Uplift that can be expected for a given site.

The Predicted Uplift, derived from the Final Raw HQT Score will then be divided by the total number of years for the restoration or enhancement project to provide the predicted Raw HQT Score (Functional Acres gained) at each milestone year. The milestone years will coincide with the phases in the credit release schedule defined in the *Policy Guidance Document*. The Raw HQT Scores for the milestone years will be compared with site verification reports to determine the degree of success based on the project's Site Performance Standards.

For restoration and preservation projects, credit releases occur when a Performance Standard defined in the Project Management Plan is achieved and coincide with the phases defined in the Credit Release Schedule, which is informed by the predicted Raw HQT Scores for the milestone years.

Montana HQT – Flowchart for Restoration & Enhancement Projects

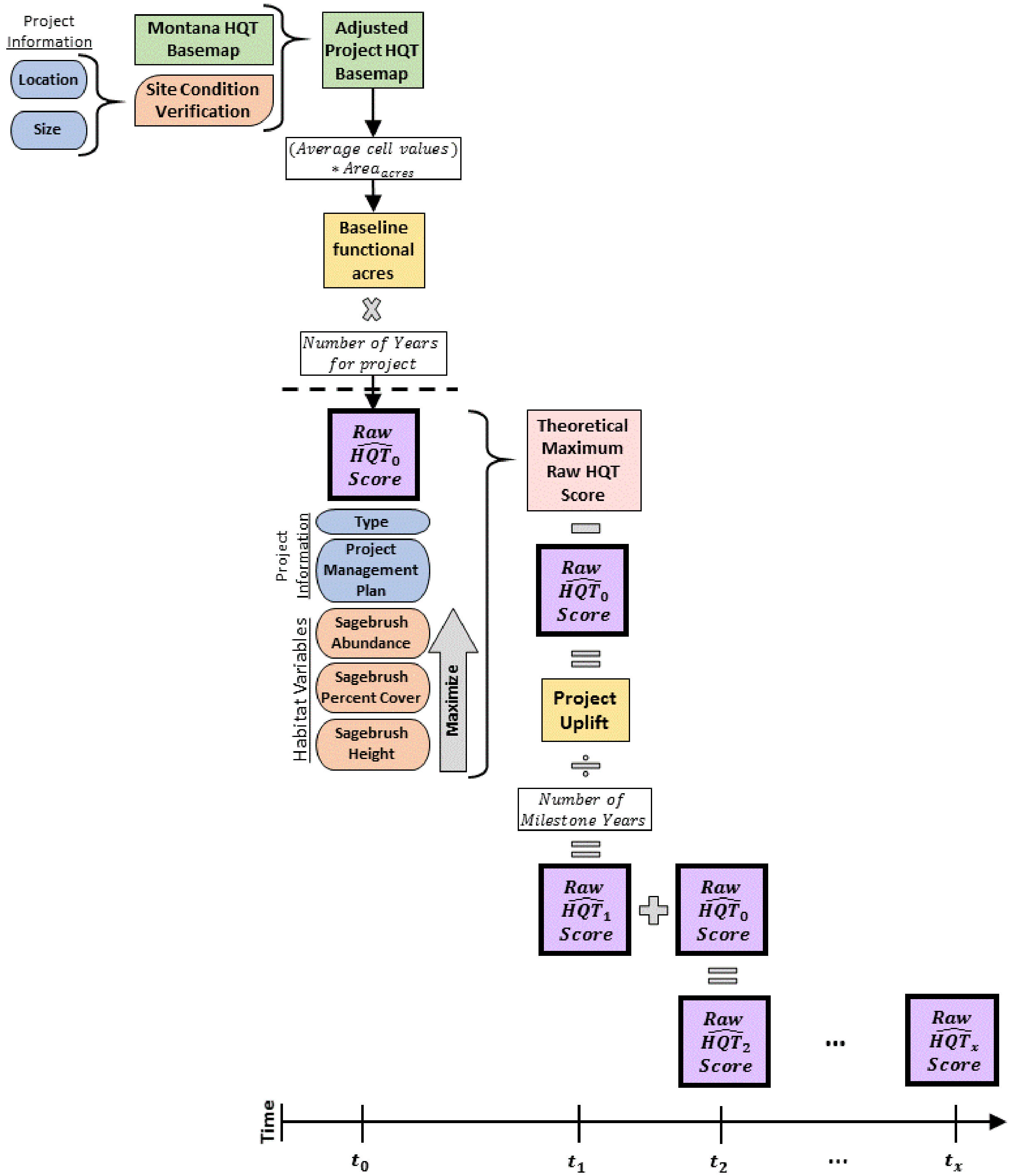

Figure J. 2. Flowchart for the development of the Raw HQT Scores for Restoration and Enhancement Projects.

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Appendix K. DEBIT PROJECT HABITAT RECOVERY THROUGH RECLAMATION

Reclamation is the habitat recovery approach available for project developers to bring development sites back to pre-project conditions. Reclamation is addressed in the EO 12-2015 for Core Area and General Habitat, stating that "reclamation should re-establish native grasses, forbs, and shrubs during interim and final reclamation to achieve cover, species composition, and life form diversity commensurate with the surrounding plant community or desired ecological condition to benefit [GRSG] and replace or enhance [GRSG] habitat" to the degree that environmental conditions allow. Control for noxious and invasive plant species is required during reclamation.

GRSG are sagebrush obligate species, and as such are more sensitive to habitat fragmentation, degradation, and alteration than are generalist species (Saab and Rich 1997, Julliard et al. 2003, Colles et al. 2009). This makes reclamation an important management tool in maintaining and increasing GRSG populations and habitat in Montana. Research provides a good understanding of GRSG habitat selection on an annual basis to inform these projects. Walker et al. (2016) mapped seasonal habitats for GRSG and found that areas selected in all seasons had a mix of habitats with a sagebrush component, less rugged topography, and less non-sagebrush habitat. The grouse in the study selected sagebrush and sagebrush-grassland at intermediate elevations during breeding and winter, and more diverse sagebrush habitats at higher elevations in summer and fall.

Knick et al. (2013) modeled annual GRSG habitat with human use influences across their range. The model indicated that GRSG required sagebrush-dominated landscapes containing minimal levels of human land use. GRSG used relatively arid regions characterized by shallow slopes, even terrain, and low amounts of forest, grassland, and agriculture in the surrounding landscape. Baxter et al. (2017) had similar results when analyzing resource selection in mechanically-altered habitats (to increase sagebrush-grass-forb habitats), finding that GRSG selected areas that were distant from trees, paved roads, and powerlines, and on more gentle slopes. Continued research in this area will help inform effective management options to improve GRSG habitat in strategic and effective locations in or near Core Areas in Montana.

The timeframes necessary for full recovery of sagebrush varies widely in the literature. Bunting et al. (2002) stated that recovery times of sagebrush communities vary, and may be as short as 15 years for mountain big sagebrush or as long as 50 to 75 years for Wyoming big sagebrush. Cooper et al. (2007) looked at post-fire recovery of sagebrush shrub-steppe communities in central and southeast Montana and found that full recovery of Wyoming big sagebrush took over 100 years and that recovery of mountain big sagebrush cover took slightly more than 30 years. They found that the mean recovery rate for Wyoming big sagebrush canopy cover was 0.16% per year in the study area, and the fastest recovery rate was 0.72% per year (Cooper et al. 2007). Wambolt et al. (2001) reported 72% recovery of Wyoming big sagebrush after 32 years at one site in southwestern Montana, and 96% recovery after only 9 years at another site. Baker (2006) found that recovery times for mountain big sagebrush ranged from 35 to 100 years, and that recovery times for Wyoming big sagebrush ranged from 50 to 120 years. Assuming the practices of mowing and crushing vegetation have less negative impacts on vegetation recovery, mowed and crushed vegetation are expected to recover more quickly than cleared habitat.

How the HQT Calculates the Return of Functional Acres Lost Through the Implementation of the Reclamation Phase

Reclamation is an important consideration for debit projects when determining the return of Habitat Function over the life of the project. As vegetation reclamation takes hold, Habitat Function increases (Table K. 1). Accounting for reclamation activities over time requires consideration of the expected restoration success and timeframe for each vegetation community. It also must consider the type of impact (cleared, mowed, crushed) to the vegetation. Crushed vegetation generally recovers sooner than mowed and cleared vegetation. Cleared vegetation generally requires the longest recovery time. To account for the differences in the vegetation recovery rates, restoration recovery timeframes have been developed for each of these scenarios (Table K. 1). As necessary, these recovery timeframes will be updated as additional data become available.

To calculate functional acres lost during this phase, the Montana HQT uses the LANDFIRE data layer (USGS 2010) which is a component of the Montana HQT Basemap. The Montana HQT Basemap is combined with the Project Assessment Area to define vegetation data that is specific to the project area. The process removes any vegetation types not present in the project area, and therefore the resulting timeframe estimate is more accurate.

Recovery timeframes for cleared vegetation were estimated as the average time to obtain Class A and Class B seral stages among the specific vegetation types within the aggregate in LANDFIRE Rapid Assessment Modeling and Mapping Zones: Northern and Central Rockies, Great Basin, and Northwest (U.S. Geological Survey). Seral stages used in LANDFIRE are described by the overall structural component and successional progression to a climax plant community (potential vegetation type [PVT]): class A is low cover, low height; and class B is high cover, low height.

The reclamation component of the Raw HQT Score will calculate the vegetation growth rate over time after the infrastructure is completely removed from the project footprint (i.e., direct project assessment area) and vegetation recovery begins. Mutually agreed upon standards must be used to evaluate habitat changes over time.

Table K. 1. Percent of baseline Functional Habitat score present in each year of reclamation by habitat and disturbance type.

Years After Implementation of Reclamation (Reclamation Milestone)	Cleared Habitat	Mowed Habitat	Drive and Crush Habitat
0 (Year of Implementation)	• 0% of all vegetation communities	• 0% of agriculture, developed, badland/break, grassland, and riparian/wetland • 0% of remaining classes	• 0% of ag, developed, badland/break, grassland, and riparian/wetland • 0% of remaining classes
1 year	• 100% of agricultural and wetland • 20% of grassland and riparian • 5% shrub • 1% of low and big sagebrush	• 100% of agricultural, wetland, grassland, and riparian • 10% shrub and low sagebrush • 2% of big sagebrush	• 100% of agricultural, wetland, grassland, and riparian • 20% shrub and low sagebrush • 7% of big sagebrush
5 years	• 100% of agricultural, wetland, grassland, and riparian • 25% shrub • 5% of low and big sagebrush	• 100% of agricultural, wetland, grassland, and riparian • 50% shrub and low sagebrush • 10% of big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush • 33% of big sagebrush
10 years	• 100% of agricultural, wetland, grassland, riparian, and shrub • 10% of low and big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush • 20% of big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush • 67% of big sagebrush
15 years	• 100% of agricultural, wetland, grassland, riparian, and shrub • 15% of low and big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush • 30% of big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush, big sagebrush
25 years	• 100% of agricultural, wetland, grassland, riparian, and shrub • 20% of low and big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush • 40% of big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush, big sagebrush
50 years	• 100% of agricultural, wetland, grassland, riparian, and shrub • 50% of low and big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush, big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush, big sagebrush
75 years after Reclamation	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush, big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush, big sagebrush	• 100% of agricultural, wetland, grassland, and riparian, shrub and low sagebrush, big sagebrush

Incorporating Reclamation in the Montana HQT for Debit Projects: Processes and Timeline

The Montana HQT incorporates a Reclamation Phase for Debit Projects and utilizes the 2016 Montana Landcover dataset to determine the regeneration timeline of vegetation located in the Direct Impact area of submitted projects.

For Debit Projects, the Montana HQT assumes that once a project reaches its end of operations, it is removed from the landscape. At this stage in the model, the Landcover dataset is extracted to the direct footprint of the removed project. The resulting Landcover Extract layer is then reclassified according to the coded value of its pixels, which corresponds to a specific land cover type.

Depending on the land cover type, a percentage of the recovery coefficient value is selected according to a predetermined reclassification table developed from Table K. 1. This is done at each milestone recovery year (MRY; i.e., 1, 5, 10, 15, 25, 50, 75). Once this coefficient is assigned, the extracted and reclassified Landcover values for each pixel are multiplied by the original HQT Basemap pixel scores in the Direct Impact area.

Hypothetical Recovery Timelines for Four Vegetation Pixels

Below are examples of the standard recovery timelines for four individual pixels classified as Agriculture, Grassland, Non-sagebrush Shrub, and Big Sagebrush. The recovery rates of the four vegetation types assumes the Recover Rates for cleared vegetation defined in Table K. 1.

Assuming these example pixels have no Indirect Effects from other anthropogenic disturbances on the landscape, they were assigned the following hypothetical HQT scores:

- Agriculture – 0
- Grassland – 50
- Non-sagebrush Shrub – 70
- Big Sagebrush – 85

The recovery timeline for these four vegetation types is:

Table K. 2. Milestone Recovery Year (MRY) and the percent of the pixel that is recovered.

MRY	Year 1	Year 5	Year 10	Year 15	Year 25	Year 50	Year 75
Percent of Pixel Recovered							
Agriculture	100%	100%	100%	100%	100%	100%	100%
Grassland	20%	100%	100%	100%	100%	100%	100%
Non-sagebrush Shrub	5%	25%	100%	100%	100%	100%	100%
Big Sagebrush	1%	5%	10%	15%	20%	50%	100%

Due to being within the hypothetical Debit Project's Direct Impact area, the HQT scores for these 4 hypothetical pixels were all devalued to HQT scores of 0.0 during construction and operations. As displayed in Table K. 3, the recovery rates of different vegetation types are combined with the HQT scores and result in Agriculture reaching full recovery soonest, followed by Grassland, Non-sagebrush Shrub, and lastly, Big Sagebrush.

Table K. 3. Milestone Recovery Year (MRY), % Recovery, HQT Recovery Equation, and the New HQT Score.

Vegetation Type	MRY						
	1	5	10	15	25	50	75
Agriculture ($HQT_{basemap}$=0)							
% Recovery	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Equation	=1.00*0	=1.00*0	=1.00*0	=1.00*0	=1.00*0	=1.00*0	=1.00*0
New HQT Score	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grassland ($HQT_{basemap}$=50)							
% Recovery	0.20	1.00	1.00	1.00	1.00	1.00	1.00
Equation	=0.20*50	=1.00*50	=1.00*50	=1.00*50	=1.00*50	=1.00*50	=1.00*50
New HQT Score	10.00	50.00	50.00	50.00	50.00	50.00	50.00
Non-sagebrush Shrub ($HQT_{basemap}$=70)							
% Recovery	0.05	0.25	1.00	1.00	1.00	1.00	1.00
Equation	=0.05*70	=0.25*70	=1.00*70	=1.00*70	=1.00*70	=1.00*70	=1.00*70
New HQT Score	3.50	17.50	70.00	70.00	70.00	70.00	70.00
Big Sagebrush ($HQT_{basemap}$=85)							
% Recovery	0.01	0.05	0.10	0.15	0.20	0.50	1.00
Equation	=0.01*85	=0.05*85	=0.10*85	=0.15*85	=0.20*85	=0.50*85	=1.00*85
New HQT Score	0.850	4.25	8.50	12.75	17.00	42.50	85.00

POTENTIAL FOR ACCELERATED RECLAMATION FOR DEBIT PROJECTS TO DECREASE THE RAW HQT SCORE

Some Debit Projects may desire and have the ability to implement and carry out an Accelerated Reclamation Phase where full recovery of the vegetation to pre-project baseline conditions is achieved prior to the 75 years for the standard Reclamation timeframe. Such Debit Projects still have the option to pay in full for the accumulation of debits for the full 75 years of standard reclamation or opt-in for phased payment approaches defined mathematically here in the HQT Technical Manual and discussed pragmatically in the *Guidance Policy Document*.

The output results from the Montana HQT include HQT scores and geospatial figures for each Milestone Recovery Year (MRY) and for the total Reclamation Phase for any given Debit Project. While the Montana HQT calculates HQT results for the full 75 years of reclamation, Debit Projects may have the opportunity to secure credits at each MRY when implementing Accelerated Reclamation. This enables Debit Projects to document the reclamation progress and the successful recovery of vegetation to pre-project baseline conditions. This phased payment approach will require re-running of the HQT at each MRY to reflect the most current state of vegetation recovery and how it compares to the standard 75 years for recovery. Re-running the HQT at each MRY may require the given Debit Project to acquire and provide to the Program robust field data and up-to-date pre-processed remote sensing data to accurately reflect vegetative composition and cover at each MRY.

The vegetation within the Direct Impact area of a given Debit Project may be considered fully recovered at any of the MRYs when that vegetation has attained the same Habitat Function as calculated by the HQT for MRY 75 of the standard Reclamation Phase. It has been the Program's experience to date, that a significant portion of the total Functional Acres lost are returned during MRYs 1 through 25, if the Debit Project's Direct Impact area is not primarily composed of sagebrush.

For more information on the pragmatic implementation of Accelerated Reclamation and associated phased payments please refer to the *Guidance Policy Document*.

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Appendix L. DESIGNATION OF LAND COVER TYPES AS SUITABLE OR UNSUITABLE

Table L. 1. Land Cover types that are designated as Unsuitable are removed from the Montana HQT Basemap as per the definitions in EO 12-2015. Anthropogenic disturbance related land cover types are listed here as suitable because they are more accurately captured in the digitized Existing Anthropogenic Surface Disturbance.

Land Cover Classification Scheme			HQT Model Designation
Land Cover Class (Broadest scale)	**Land Cover Category (Intermediate scale)**	**Ecological System (Most detailed scale)**	
Alpine Systems	Alpine Grassland and Shrubland	Alpine Dwarf-Shrubland	Unsuitable
Alpine Systems	Alpine Grassland and Shrubland	Alpine Turf	Unsuitable
Alpine Systems	Alpine Sparse and Barren	Alpine Bedrock and Scree	Unsuitable
Alpine Systems	Alpine Sparse and Barren	Alpine Fell-Field	Unsuitable
Alpine Systems	Alpine Sparse and Barren	Alpine Ice Field	Unsuitable
Forest and Woodland Systems	Conifer-dominated forest and woodland (mesic-wet)	Rocky Mountain Mesic Montane Mixed Conifer Forest	Unsuitable
Forest and Woodland Systems	Conifer-dominated forest and woodland (mesic-wet)	Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	Unsuitable
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Great Plains Ponderosa Pine Woodland and Savanna	Unsuitable
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	Unsuitable
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Rocky Mountain Foothill Limber Pine - Juniper Woodland	Unsuitable
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Rocky Mountain Foothill Woodland-Steppe Transition	Unsuitable
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Rocky Mountain Lodgepole Pine Forest	Unsuitable
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Rocky Mountain Montane Douglas-fir Forest and Woodland	Unsuitable
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Rocky Mountain Ponderosa Pine Woodland and Savanna	Unsuitable
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Rocky Mountain Poor Site Lodgepole Pine Forest	Unsuitable
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Unsuitable
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Rocky Mountain Subalpine Woodland and Parkland	Unsuitable

Forest and Woodland Systems	Deciduous dominated forest and woodland	Aspen Forest and Woodland	Unsuitable
Forest and Woodland Systems	Deciduous dominated forest and woodland	Great Plains Wooded Draw and Ravine	Unsuitable
Forest and Woodland Systems	Deciduous dominated forest and woodland	Mountain Mahogany Woodland and Shrubland	Unsuitable
Forest and Woodland Systems	Mixed deciduous/coniferous forest and woodland	Aspen and Mixed Conifer Forest	Unsuitable
Grassland Systems	Lowland/Prairie Grassland	Great Plains Mixedgrass Prairie	Suitable
Grassland Systems	Lowland/Prairie Grassland	Great Plains Sand Prairie	Suitable
Grassland Systems	Montane Grassland	Rocky Mountain Lower Montane, Foothill, and Valley Grassland	Suitable
Grassland Systems	Montane Grassland	Rocky Mountain Subalpine-Montane Mesic Meadow	Suitable
Grassland Systems	Montane Grassland	Rocky Mountain Subalpine-Upper Montane Grassland	Suitable
Human Land Use	Agriculture	Cultivated Crops	Suitable*
Human Land Use	Agriculture	Pasture/Hay	Suitable*
Human Land Use	Developed	Commercial/Industrial	Suitable*
Human Land Use	Developed	Developed, Open Space	Suitable*
Human Land Use	Developed	High Intensity Residential	Suitable*
Human Land Use	Developed	Interstate	Suitable*
Human Land Use	Developed	Low Intensity Residential	Suitable*
Human Land Use	Developed	Major Roads	Suitable*
Human Land Use	Developed	Other Roads	Suitable*
Human Land Use	Developed	Railroad	Suitable*
Human Land Use	Developed	Wind Turbine	Suitable*
Human Land Use	Mining and Resource Extraction	Coal Bed Methane	Suitable*
Human Land Use	Mining and Resource Extraction	Gas and Gas Storage	Suitable*
Human Land Use	Mining and Resource Extraction	Injection	Suitable*
Human Land Use	Mining and Resource Extraction	Oil and Oil and Gas	Suitable*
Human Land Use	Mining and Resource Extraction	Quarries, Strip Mines and Gravel Pits	Suitable*
Open Water / Wetland and Riparian Systems	Bog or Fen	Rocky Mountain Subalpine-Montane Fen	Suitable
Open Water / Wetland and Riparian Systems	Depressional Wetland	Great Plains Closed Depressional Wetland	Suitable
Open Water / Wetland and Riparian Systems	Depressional Wetland	Great Plains Open Freshwater Depression Wetland	Suitable
Open Water / Wetland and Riparian Systems	Depressional Wetland	Great Plains Prairie Pothole	Suitable
Open Water / Wetland and Riparian Systems	Depressional Wetland	Great Plains Saline Depression Wetland	Suitable

Open Water / Wetland and Riparian Systems	Depressional Wetland	Rocky Mountain Wooded Vernal Pool	Unsuitable
Open Water / Wetland and Riparian Systems	Floodplain and Riparian	Greasewood Flat	Suitable
Open Water / Wetland and Riparian Systems	Floodplain and Riparian	Great Plains Floodplain	Suitable
Open Water / Wetland and Riparian Systems	Floodplain and Riparian	Great Plains Riparian	Suitable
Open Water / Wetland and Riparian Systems	Floodplain and Riparian	Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	Suitable
Open Water / Wetland and Riparian Systems	Floodplain and Riparian	Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	Suitable
Open Water / Wetland and Riparian Systems	Floodplain and Riparian	Rocky Mountain Subalpine-Montane Riparian Shrubland	Suitable
Open Water / Wetland and Riparian Systems	Floodplain and Riparian	Rocky Mountain Subalpine-Montane Riparian Woodland	Suitable
Open Water / Wetland and Riparian Systems	Forested Marsh	Rocky Mountain Conifer Swamp	Unsuitable
Open Water / Wetland and Riparian Systems	Herbaceous Marsh	Emergent Marsh	Suitable
Open Water / Wetland and Riparian Systems	Open Water	Geysers and Hot Springs	Unsuitable
Open Water / Wetland and Riparian Systems	Open Water	Open Water	Unsuitable
Open Water / Wetland and Riparian Systems	Wet meadow	Alpine-Montane Wet Meadow	Unsuitable
Recently Disturbed or Modified	Harvested Forest	Harvested forest-grass regeneration	Suitable
Recently Disturbed or Modified	Harvested Forest	Harvested forest-shrub regeneration	Suitable
Recently Disturbed or Modified	Harvested Forest	Harvested forest-tree regeneration	Unsuitable
Recently Disturbed or Modified	Insect-Killed Forest	Insect-Killed Forest	Unsuitable
Recently Disturbed or Modified	Introduced Vegetation	Introduced Riparian and Wetland Vegetation	Suitable
Recently Disturbed or Modified	Introduced Vegetation	Introduced Upland Vegetation - Annual and Biennial Forbland	Suitable
Recently Disturbed or Modified	Introduced Vegetation	Introduced Upland Vegetation - Annual Grassland	Suitable
Recently Disturbed or Modified	Introduced Vegetation	Introduced Upland Vegetation - Perennial Grassland and Forbland	Suitable
Recently Disturbed or Modified	Introduced Vegetation	Introduced Upland Vegetation - Shrub	Suitable
Recently Disturbed or Modified	Recently burned	Burned Sagebrush	Suitable

Recently Disturbed or Modified	Recently burned	Post-Fire Recovery	Suitable
Recently Disturbed or Modified	Recently burned	Recently burned forest	Unsuitable
Recently Disturbed or Modified	Recently burned	Recently burned grassland	Suitable
Recently Disturbed or Modified	Recently burned	Recently burned shrubland	Suitable
Shrubland, Steppe and Savanna Systems	Deciduous Shrubland	Great Plains Shrubland	Suitable
Shrubland, Steppe and Savanna Systems	Deciduous Shrubland	Rocky Mountain Lower Montane-Foothill Shrubland	Suitable
Shrubland, Steppe and Savanna Systems	Deciduous Shrubland	Rocky Mountain Montane-Foothill Deciduous Shrubland	Suitable
Shrubland, Steppe and Savanna Systems	Deciduous Shrubland	Rocky Mountain Subalpine Deciduous Shrubland	Suitable
Shrubland, Steppe and Savanna Systems	Sagebrush Steppe	Big Sagebrush Steppe	Suitable
Shrubland, Steppe and Savanna Systems	Sagebrush Steppe	Montane Sagebrush Steppe	Suitable
Shrubland, Steppe and Savanna Systems	Sagebrush-dominated Shrubland	Big Sagebrush Shrubland	Suitable
Shrubland, Steppe and Savanna Systems	Sagebrush-dominated Shrubland	Low Sagebrush Shrubland	Suitable
Shrubland, Steppe and Savanna Systems	Scrub and Dwarf Shrubland	Mat Saltbush Shrubland	Suitable
Shrubland, Steppe and Savanna Systems	Scrub and Dwarf Shrubland	Mixed Salt Desert Scrub	Suitable
Sparse and Barren Systems	Bluff, Badland and Dune	Active and Stabilized Dune	Suitable
Sparse and Barren Systems	Bluff, Badland and Dune	Great Plains Badlands	Suitable
Sparse and Barren Systems	Bluff, Badland and Dune	Shale Badland	Suitable
Sparse and Barren Systems	Cliff, Canyon and Talus	Great Plains Cliff and Outcrop	Unsuitable
Sparse and Barren Systems	Cliff, Canyon and Talus	Rocky Mountain Cliff, Canyon and Massive Bedrock	Unsuitable
Sparse and Barren Systems	Cliff, Canyon and Talus	Wyoming Basin Cliff and Canyon	Unsuitable

* The Human Land Use Land Cover Classes are designated as Suitable here because they are better captured in the digitized Existing Anthropogenic Surface Disturbance layer.

Appendix N. LIST OF ACRONYMS

AADT	Annual average daily traffic
AIM	Assessment Inventory and Monitoring
BLM	Bureau of Land Management
EDF	Environmental Defense Fund
GRSG	Greater sage-grouse
HAF	Habitat Assessment Framework
HQT	Habitat Quantification Tool
LPI	Line-point intercept
MCA	Montana Code Annotated
MRLC	Multi-Resolution Land Characteristics Consortium
MSGOT	Montana Sage Grouse Oversight Team
FWP	Montana Sage Grouse Work Group
MTFWP	Montana Fish, Wildlife, and Parks
MTNHP	Montana Natural Heritage Program
NLCD	National Land Cover Database
NNHP	Nevada Natural Heritage Program
PVT	Potential vegetation type
SETT	Sagebrush Ecosystem Technical Team
WHCWG	Washington Wildlife Habitat Connectivity Working Group