

Wilderness Character
in Rocky Mountain National Park
Preliminary identification of measures and indicators





ON THIS PAGE

Moss growing between rocks below a seep on the trail from Thunder Lake to Boulder Grand Pass.

Photograph by: Colin Leslie

ON THE COVER

On the trail to Lion Lake No 1. Chiefs Head Peak in the background.

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Summary

This report presents findings from a case study application of wilderness character monitoring to the Rocky Mountain National Park Wilderness. This study is one of two studies conducted under a cooperative agreement between Rocky Mountain National Park and Colorado State University, Department of Human Dimension and Natural Resources. Results from this study, along with its complimentary study, “Assessing Wilderness Soundscapes” were initially compiled as a master’s thesis for the primary author. This report serves as the formal presentation of results from this study for Rocky Mountain National Park.

The purpose of this study to evaluate wilderness character within Rocky Mountain National Park Wilderness. Wilderness character is composed of five related but distinct qualities: untrammeled, natural, undeveloped, solitude or primitive and unconfined recreation, and other features of values. Collectively these qualities represent the range of biophysical, experiential and symbolic ideals that define wilderness character. Identifying measures and indicators for each of these qualities is an important first step to developing a full and long term wilderness character monitoring program. To that extent, this effort was successful and an extensive list of measures and indicators were identified that can aid Rocky Mountain National Park in moving forward with a wilderness character monitoring program.

While many guidelines have been developed to help with the identification and selection of measures and indicators, few studies have been published to date detailing the actual process in a real world scenario. Therefore, this study serves as a reference of potential measures identified for Rocky Mountain National Park Wilderness, as well as an account of the specific methods used in the selection and refinement of those measures. It is important to note that the potential measures identified in this study are not intended as a final accounting of all relevant measure. The measures collected during this study represent the collaborative effort of numerous natural resource professionals from a variety of government and non-government groups. However, it is both likely and recommended that findings from this study be closely reviewed should Rocky Mountain National Park choose to move forward with a formal wilderness character monitoring plan.

Potential/recommended measures have been reported in the results section of this study. A full list of all measures, including those which were not recommended has been provided in Appendix A, along with criteria that can provide insight into the inclusion or exclusion of any particular measure. This report concludes with a discussion section including additional recommendations and insight into the current and future selection of measures for wilderness character in Rocky Mountain National Park Wilderness.

Introduction

The Wilderness Act of 1964 established the preservation of wilderness character as a primary goal of the Act. Our understanding of the degree to which wilderness designation and stewardship

has been successful in preserving wilderness character however has, until recently, remained tenuous at best. This deficiency has largely been the result of two challenges faced by wilderness managers: 1) the lack of an explicit definition of wilderness character and 2) a framework for assessing it.

The need for an assessment framework focusing specifically on wilderness character led to the development of *Keeping it Wild: An Interagency Strategy to Monitor Trends in Wilderness Character Across the National Wilderness Preservation System* (Landres et al., 2008). This interagency strategy addressed some of the challenges faced by wilderness managers by providing both a consistent definition of wilderness character along with a framework for assessing it, Wilderness Character Monitoring (WCM).

Wilderness character is “the combination of biophysical, experiential, and symbolic ideals that distinguishes wilderness from other lands” (Landres et al., 2008). In order to measure and track these ideals, WCM offers up a framework for the systematic selection, monitoring and reporting of data pertinent to wilderness character (Landres et al., 2008). Since it was first introduced in 2008, WCM has generated a growing level of interest and application among the wilderness community. However, despite the growing list of wilderness areas to which WCM has been applied, no case studies have yet been published documenting the process of applying WCM to a wilderness area.

Anecdotal evidence suggests that WCM offers a number of benefits for wilderness managers over alternative wilderness assessments; primarily the robust assessment of wilderness qualities through the utilization of existing management and research data. By utilizing existing data, the need to allocate additional financial or personnel resources should be minimized and thus facilitate more widespread integration of WCM.

While the merits of this approach are commendable, the lack of published case studies raises a number of unanswered questions. Two questions, pertaining to the use of existing data, are of particular interest and the focus of this study. First, is utilizing only existing data robust enough to adequately capture and evaluate qualities of wilderness character? Second, what criteria can be used to identify the best existing data for capturing and evaluating qualities of wilderness character?

The following section on wilderness character background offers a high level overview of the wilderness character concept and the WCM framework. This section has been included to facilitate the interpretation of results from this study including individual discrete data sources identified for Rocky Mountain National Park. Those who are already familiar with the wilderness character framework, particularly as it has been applied within the National Park Service, may wish to skip directly to the methods section.

Wilderness Character Background

Wilderness Character

Wilderness character is a fundamental component of the Wilderness Act (1964), appearing in Sections 2(a) and 4(b) that establishes the preservation of wilderness character as the primary goal of the Act. Yet despite the inclusion of this term in the Act itself, a robust understanding and integration

of wilderness character into wilderness management has been slow to manifest. A long-standing challenge faced by agencies charged with managing wilderness areas and thus preserving wilderness character was the lack of an explicit definition for wilderness character in the act. Despite this omission, Section 2(c), entitled Definition of Wilderness, provides a foundation from which a definition of wilderness character can be derived. In the definition provided below, several key words or phrases have been italicized that have been recognized as critical components to translating requirements of wilderness into a definition of wilderness character.

“A wilderness, in contrast with those areas where man and his own works dominate the landscape, is hereby recognized as an area where the *earth and its community of life are untrammelled by man*, where man himself is a visitor who does not remain. An area of wilderness is further defined to mean in this Act an area of *undeveloped Federal land* retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its *natural conditions* and which (1) generally appears to have been *affected primarily by the forces of nature*, with the imprint of man's work substantially unnoticeable; (2) has outstanding opportunities for *solitude or a primitive and unconfined type of recreation*; (3) has at least five thousand acres of land or is of sufficient size as to make practicable its preservation and use in an unimpaired condition; and (4) may also contain *ecological, geological, or other features of scientific, educational, scenic, or historical value*.” (Wilderness Act, 1964)

Translating these ideas from a set of provisional requirements for an area to be designated as wilderness into a working definition of wilderness character requires an understanding of the term “character.” The term “character” can be defined as *the aggregate of features and traits that form the individual nature of some person or thing* (Dictionary.com, 2014). There are two key aspects of this definition as it applies to wilderness character. The first is that character is an *aggregate* of features and traits. This means that the character of an area cannot be represented by any one particular feature or trait but instead is a function of the collection and relationship of many features. The second part of the definition is that character is the *nature* or manifestation of the aggregation of features or traits.

This interpretation of the usage of the word “character” appears consistent with that of the Interagency Wilderness Character Monitoring Team (Landres et al., 2008). Therefore, to maintain continuity with national WCM efforts the definition derived by the Interagency Wilderness Character Monitoring Team has been chosen as the working definition for this study:

“Wilderness character may be described as the combination of biophysical, experiential, and symbolic ideals that distinguishes wilderness from other lands.” (Landres et al., 2008)

While this definition expresses a succinct theoretical overview of wilderness character, applying these concepts in a wilderness setting requires the identification of tangible qualities of wilderness (Landres et al., 2008; National Park Service, 2014). Five distinct qualities have been identified from Section 2(c) of the Wilderness Act, Definition of Wilderness: untrammelled, natural, undeveloped, solitude or a primitive and unconfined type of recreation, and other features of value. Collectively these five qualities form the foundation for assessing wilderness character. Quantifying

each quality, however, requires identifying specific measures and data that appropriately represent the functional components of each quality.

The Monitoring Hierarchy

WCM is based on a hierarchical approach in which wilderness character is broken down sequentially into levels or elements of increasing specificity and detail. This structure establishes a one-to-many relationship where each level or element is generally comprised of one or more elements below it (**Figure 1**). A brief description of each of these levels is provided below but are explained in detail in the Forest Service *Technical Guide for Monitoring Selected Conditions Related to Wilderness Character* (Landres et al., 2009)

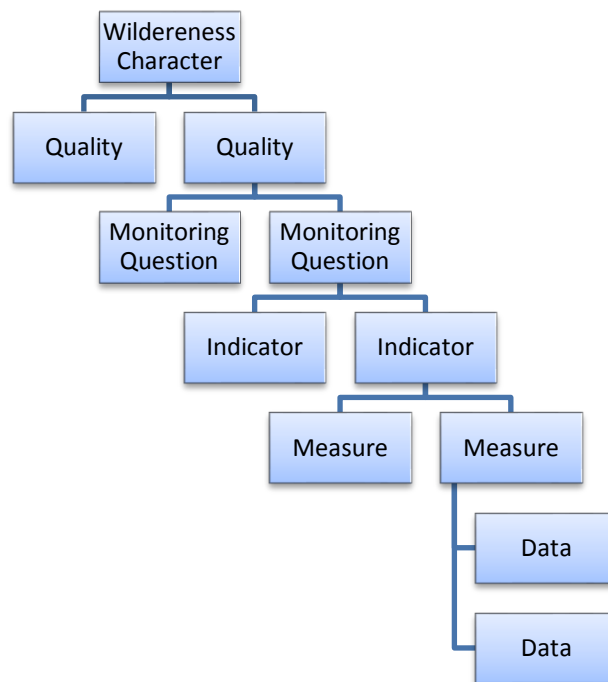


Figure 1. Monitoring elements form a hierarchy where each level represents a one-to-many relationship with the elements below it.

Qualities.

These are the fundamental components of wilderness that relate directly to concepts expressed in Section 2(c) of the Wilderness Act. They include: untrammeled; natural; undeveloped; opportunities for solitude or primitive and unconfined recreation; and other features of value. The first four qualities are required and present in every wilderness while the fifth, other features of value, may or may not be present. However, when the fifth quality is present it should be considered of equal standing with the first four. Considerations for determining if this quality is present are discussed in further detail in the findings section for evaluating this quality in the context of the Rocky Mountain National Park Wilderness case study.

Monitoring Questions

These can be thought of as topical groupings under each quality that help guide the selection of subsequent indicators and measures. Examples for the undeveloped quality might be: “What are the trends in non-recreational development inside wilderness?” and “What are the trends in mechanization inside wilderness?” These questions help refine undeveloped into topical groups focused on development and mechanization, respectively.

Indicators

These represent specific topics or elements that can inform each monitoring question. Examples for the monitoring question “What are the trends in non-recreational development inside wilderness?” for undeveloped might be: non-recreational structures, installations and developments and inholdings. While these are both types of developments, the source or initiating entity for each is likely different. Non-recreational structures, installations and developments will be largely under the purview of the managing agency, while inholdings are a result of historic land agreements. Both *Keeping it Wild* (Landres et al., 2009) and *Keeping it Wild in the National Park Service* (National Park Service, 2014) strongly recommend the inclusion of at least 13 pre-identified indicators.

Measures

These are discrete elements that represent one aspect or specific quantity of an indicator. Following with the previous example for undeveloped, non-recreational structures, installations and developments could be represented by the following measures: number of monitoring or research installations; distance from monitoring or research installations; number of patrol cabins; and miles of non-wilderness trails. Each measure represents one specific quantity of the selected indicator. Most measures can be represented by a single numeric representation, i.e. number of installations, miles of trail, number of cabins etc.

Most indicators require multiple measures in order to fully quantify the various dimensions of the indicator. The WCM framework strongly encourages selecting at least one measure for each indicator and only selecting measures that utilize existing data (Landres et al., 2008). Measures may be directly computed from a dataset such as the “number of monitoring or research installations” or may require intermediate analysis using a specialized platform such as a Geographic Information System in order to compute “distance from monitoring or research installations”.

Data Sources

Data can come from a variety of sources including existing agency data systems, internal and external reports, national data collection efforts, and any other data related to the wilderness area. Within the WCM framework the widest degree of agency discretion is given to the selection of measures and data to inform indicators. A primary concern when identifying data is assessing the ability of the data to adequately and reliably inform trends in the measure being evaluated (Landres et al., 2009).

Baseline Conditions, Monitoring Frequency and trends.

Ultimately, the purpose of monitoring is to establish a scientifically rigorous base for assessing the trends of selected conditions over time (Fancy, Gross, & Carter, 2009). In order to assess trends over

time it is necessary to establish a baseline or reference condition to which subsequent condition assessments conducted at a given frequency will be compared. Both Keeping it Wild (Landres et al., 2008) and NPS Management Policies 2006 specify that a wilderness should be evaluated against its own reference condition. Baseline conditions within the WCM framework are considered to be the first time data are collected for all measures in a wilderness character assessment (National Park Service, 2014). Once the initial assessment has been conducted, all measures should be reassessed every five years to establish trends.

Methods

In order to evaluate the ability of existing data to describe qualities of wilderness character in Rocky Mountain National Park (RMNP), it was determined the best approach was to apply WCM using current guidelines. RMNP Wilderness is an ideal test case as it provides both a recently designated wilderness area and is known to have a comparatively robust history of biophysical and recreational research that could support a WCM effort.

Study Site

RMNP is situated along the continental divide in the Rocky Mountains of northern Colorado. Established January 26, 1915 under the Rocky Mountain National Park Act, the park set aside 229,062 acres of mountainous landscape to protect it from destructive uses and provide for its enjoyment by the public (Rocky Mountain National Park, 1984). In particular, the park is recognized for its exceptional accessibility to wild landscapes including one of the largest expanses of alpine tundra ecosystems managed by the National Park Service within the lower 48 states (Rocky Mountain National Park, 2012). Since the time of designation, numerous boundary adjustments and land acquisitions have increased park acreage to its current total of 265,770 acres (nps.gov/romo).

As early as the 1960's much of the park was managed as wilderness. In 1974, President Richard Nixon recommended 239,835 acres of the park to be formally designated as wilderness (Suzanne Jones & Jeff Widen, 2006). Eventually, 35 years after the first formal proposal, the Omnibus Public Land Management Act of 2009 officially designated 249,339 acres as the Rocky Mountain National Park Wilderness. The creation of this new wilderness, in addition to 2,917 acres of the Indian Peaks Wilderness already within the park boundary, set aside almost 95% of the park as designated wilderness (**Figure 2**).

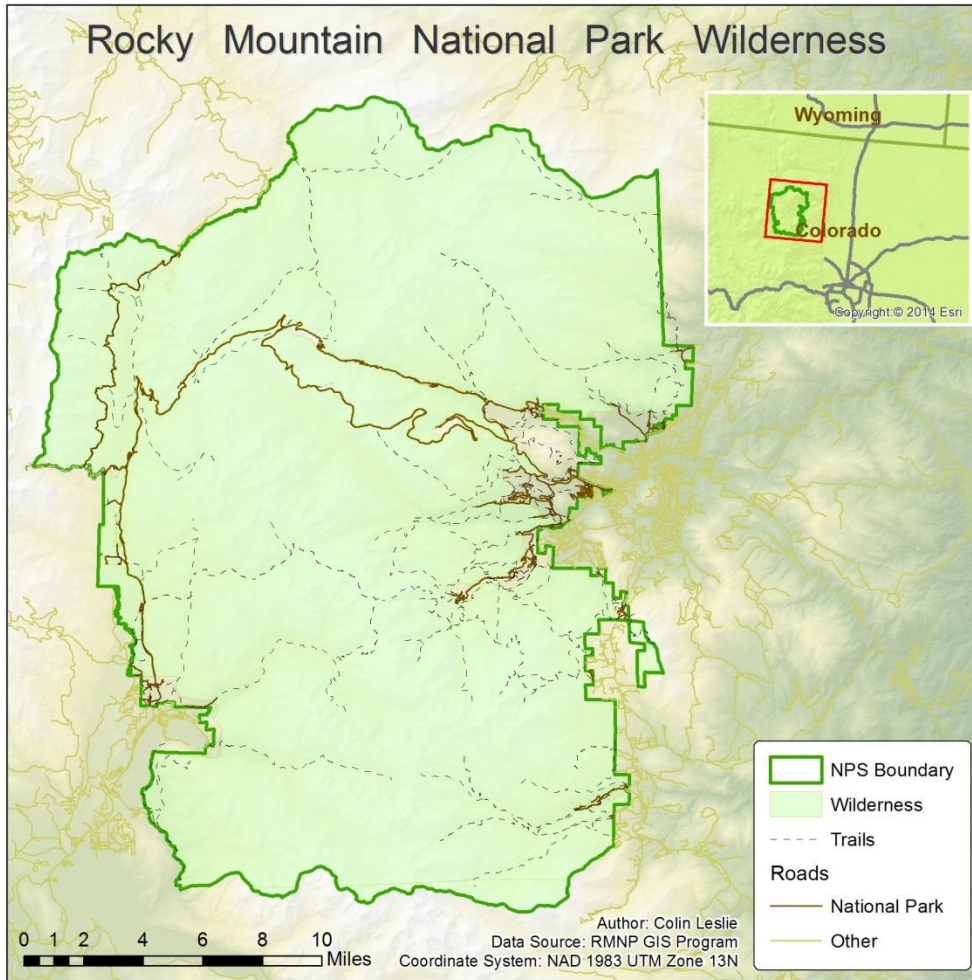


Figure 2. The Rocky Mountain National Park Wilderness is 249,339 acres in area. Combined with a small section of the Indian Peaks Wilderness, this sets aside almost 95% of Rocky Mountain National Park as wilderness.

The process of conducting the initial assessment for a WCM effort in RMNP Wilderness was carried out in three phases: identification of potential data sources, refinement and selection of measures, and finally recording the status of selected measures as baseline conditions. Since the WCM framework by design allows for a degree of flexibility in its implementation, additional methods specific to this study are outlined below.

Identification of Sources

In 2012, RMNP initiated a two-year cooperative agreement with Colorado State University to conduct a wilderness character assessment for the park. In preparation of the cooperative agreement, RMNP conducted an initial internal review identifying a “laundry list” of potential measures and data sources. This document also identified primary contact information for park managers across divisions, responsible for maintaining a variety of programs and data repositories. RMNP has a long history of natural resource and recreation management and as such, many potential data sources were initially identified. After the agreement was initiated, a series of additional meetings were conducted

in order to prioritize and refine measures deemed most salient by park managers. These meetings resulted in the identification of additional agency and non-agency data sources from programs, reports and studies pertaining park resources. For a full list of potential measures and data sources that were identified, see Appendix A.

Additionally, *Keeping it Wild in the National Park Service* (2014) includes 40 potential (example) measures, each with a number of known data sources. While this document was not released until half way through the two year study, it still provided a number of previously unidentified data sources that were selected for inclusion. Next, it was necessary to develop methods for the evaluation and refinement of potential measures and data.

Refinement and Selection of Sources

A large number of data sources were initially identified that related to one or more qualities of wilderness character. *Keeping it Wild in the National Park Service* (2014) provides several general recommendations to help guide managers in refinement and selection of final measures to include.

- Relevant to wilderness: The potential measure and data should pertain directly to known issues within wilderness
- Use existing data when possible: Preferable data should already exist and be recent enough to representative of current conditions
- Start with smallest number of measures possible: Use data that are most indicative of overall conditions within wilderness

While these recommendations provided valuable context, a more systematic process for refining measures was desired. The method selected was developed by the USFWS and utilizes a four parameter system and is designed to aid in the prioritization of potential measures. The four parameters presented below have been taken directly from the USFWS Wilderness Fellow Final Report template, which was developed as a standardized template for wilderness character assessments of U.S. National Wildlife Refuges.

A. Level of significance (the measure is highly relevant to the quality and indicator of wilderness character, and is highly useful for managing the wilderness): High = 3 points, Medium = 2 points, Low = 1 point

B. Level of vulnerability (measures an attribute of wilderness character that currently is at risk, or might likely be at risk over 10-15 years): High = 3 points, Medium = 2 points, Low = 1 point

C. Degree of reliability (the measure can be monitored accurately with a high degree of confidence, and would yield the same result if measured by different people at different times): High = 3 points, Medium = 2 points, Low = 1 point

D. Degree of feasibility (the measure is related to an existing effort or could be monitored without significant additional effort): High = 1 point, Low = 0 point (if 0 is given, do not use)

Using the individual parameters above, scores were added together to give a composite prioritization score. For example, the measure “number of monitoring or research installations” was high significance (3), high vulnerability (3), medium reliability (2), and high feasibility (1), for a final prioritization score of 9. Stated in a more qualitative manner; the number of monitoring or scientific installations is important to wilderness character, likely to change significantly over the next 10-15 years and while current efforts are not yet as reliable as they could be, it is still a feasible measure to track without much additional effort.

In addition to prioritizing measures based on relevance to wilderness character, it was also desired to address the issue of spatial coverage. The goal of monitoring is to be systematic and comprehensive, yet work and research is often focused on addressing specific problem areas rather than gathering baseline data as a whole for wilderness (Hendee & Dawson, 2002). The result is that wilderness areas may have high quality data but only for specific areas. In addition, it was identified early on that many data were either available or relatable in a geographic information system. This is of particular interest from the standpoint of wilderness character mapping, a separate yet potentially highly informative and complementary approach to assessing wilderness character (National Park Service, 2014).

Figure 3 shows the systematic process developed for this study to evaluate the spatial coverage of a data source, which involves assigning data a score (level) from 5 (best) to 1 (poor). This process provides a method for identifying the better of two similar data sources that could inform a measure and also assists in identifying a general level of coverage for all potential measures. For example, the trails GIS layer maintained by RMNP is Level 5 data. It is already spatial, provides complete coverage, and is precise in both location and attribute data. In contrast, annual number of visitors is Level 2 data. It is not spatial, not relatable, but does provide an estimate of the annual number of visitors to RMNP and thus can serve as a proxy for the number of visitors to RMNP Wilderness. If the number of visitors or at least the distribution of use levels could be measures and allocated throughout the park, then annual number of visitors can likely move from Level 3 to Level 4 data. Under this scenario, annual number of visitors is now spatial and provides complete coverage, even if the exact number of visitors per trail, road or other discrete area is still unknown.

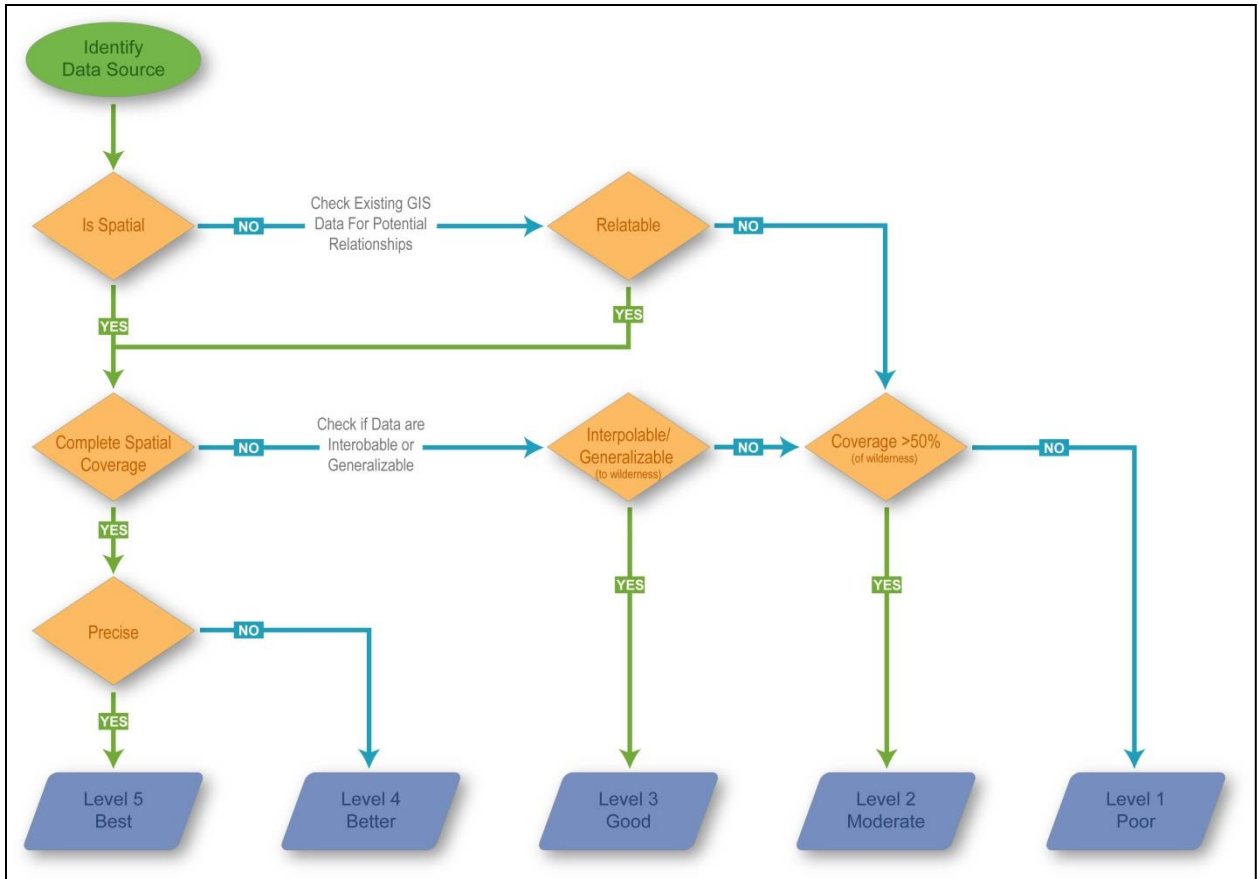


Figure 3. The flowchart above provides a systematic approach to evaluating the spatial coverage of data.

Compiling Baseline Conditions

The final step when conducting an initial WCM assessment is the compilation of baseline conditions for final selected measures. While many of the data and measures selected for final inclusion in this study have compiled and summarized data, the high diversity of sources made the final compilation of baseline conditions beyond the scope of this study. Undertaking this final step is best suited following formal vetting of measures by RMNP staff. Even so, a number of maps, figures and charts have been provided throughout the findings section for select sources where summarized data were available as examples of what the final assessment may look like.

Results

Untrammelled

Measures for the untrammelled quality focus primarily on actions related to plant or animal management and fire management. A number of plant and animal measures of interest were identified including: number of native fish removed per day, acres of plant removal projects (generally invasive species), number of re-introductions, number of animals tagged, number of elk culled per year and number of elk exclosures.

Two of these measures, native fish removed per day and number of animals tagged or banded were deemed not feasible. Most native fish are taken by recreational anglers which does not require reporting and the migratory nature of most banded animals does not allow for the estimate of the number of banded animals within wilderness at any given point in time. Acres of plant removal projects is target primarily at the removal of invasive species. While the removal of invasive species provides a beneficial outcome for natural quality, it is non-the-less dependent upon human action, thus warranting its inclusion under untrammeled. Number of reintroductions for both plant and animal species was determined to be both a reliable and feasible measure for inclusion, although its occurrence is not predicted to happen frequently.

The final two measures, number of elk culled per year and number of elk exclosures relate directly to RMNP's Elk and Vegetation Management plan. After extensive research, the park determined that high concentrations of elk were beyond the range of historic natural variability and as a result vegetation communities supporting a diversity of bird, butterfly and other plant species were being negatively impacted (Rocky Mountain National Park, 2008). Under this plan, the park established a number of additional elk exclosures to protect vegetation (many were already in place) and initiated a 20 year timeline to gradually reduce the elk population through culling to the upper limit of estimated historic population sizes. While clearly examples of agency actions that manipulate the biophysical environment, these two measures are not necessarily indicative of overall wilderness conditions. However, the plan specifically specifies intent to restore, to the extent possible, the natural range of variability in elk and vegetation communities over a 20 year period. Therefore, these measures have the potential benefit of examining the interaction between temporary degradation in one quality (untrammeled) for the long term gain in another quality (natural).

Fire is now widely recognized as a critical component of ecosystem management. As the ecological community has come to embrace a more dynamic, non-equilibrium view of ecosystems, so too have we developed an understanding that fire can occur both in varying frequency and severity (Thrower, 2006). However, the historic suppression of natural fire coupled with the need to protect private property continues to necessitate the use of both prescribed fire and the suppression or control of naturally started wildfires. As such, the measures for number of prescribed burns and number of natural fire starts that received a suppression response have been identified for inclusion. Additionally, number of visitor-ignited fires has been included for *actions not authorized by the federal land managers* as these fires are neither naturally ignited, nor started for the potential ecological benefits of prescribed burning.

Finally, number of Minimum Requirements Decision Guide (MRDG) forms have been identified for potential inclusion. The Minimum Requirements concept charges agencies with evaluating any proposed action in wilderness based on how appropriate or necessary that action is for the administration of the wilderness area (National Park Service, 2006). If the action is deemed necessary, additional considerations should be made in order to select the minimum methods and equipment necessary to carry out the action. At present, the reporting of both number of MRDGs that have been submitted as well as number that have been approved have been identified as measures. Reporting both number submitted as well as number approved can provide additional insight into

how MRDGs are trending over time. A third potential measure that has not been included at this time is MRDGs that have been modified after submission to reduce impacts. Inclusion of this measure may be useful, but will require additional criteria in order to establish what constitutes a significant enough modification for inclusion. The final list of identified measures along with priority and spatial scores can be found in Table 1.

Table 1. Identified measures for the untrammelled quality in RMNP including prioritization and spatial scores.

Indicator	RMNP Measure	Prioritization Score	Spatial Score
Authorized actions that manipulate the biophysical environment	Acres of plant removal projects	10	4
	Number of Elk culled per year	8	5
	Number of elk exclosures	8	5
	Number of reintroductions	7	4
	Number of prescribed burns	10	5
	Percent of natural fire starts that received a suppression response	10	5
	Number of submitted MRDGs involving actions that manage plants animals, pathogens, soil, water, or fire	10	2
	Number of approved MRDGs involving actions that manage plants animals, pathogens, soil, water, or fire	10	2
Unauthorized actions that manipulate the biophysical environment	Number of visitor-ignited fires	7	5

Natural

Among the five qualities of wilderness, natural quality yielded the greatest number of identified potential measures. The National Park Service and numerous other federal land management and regulatory agencies have a long history of natural resource management in general, as well as specifically related to Rocky Mountain National Park. Specifically, the NPS Inventory and Monitoring Program (I&M), US Geological Survey, LANDFIRE, and the Environmental Protection Agency all manage data collection efforts that include monitoring of conditions in RMNP. In addition to collecting a diverse array of data, all of these agencies and programs are funded separately from RMNP and thus place no additional burden on park financial or staff resources for their collection and dissemination.

The NPS I&M program monitors a range of natural resource conditions across the National Park Service and provides monitoring information through the NPS Integrated Resource Management Applications (IRMA) data portal. I&M data were particularly informative of measures involving abundance of both native and non-native plant and animal species.

Based on recommendations from Keeping it Wild in the National Park Service (2014), a number of data sources for measures under the physical resources indicator were identified. Measures primarily focused on visibility, atmospheric deposition and water quality. Visibility is

based on average deciview and is monitored through the Interagency Monitoring of Protected Visual Environments (IMPROVE). The IMPROVE data portal hosted at Colorado State University provides a number of data management and summary tools allowing for the reporting and visualization of visibility metrics (Figure 4).

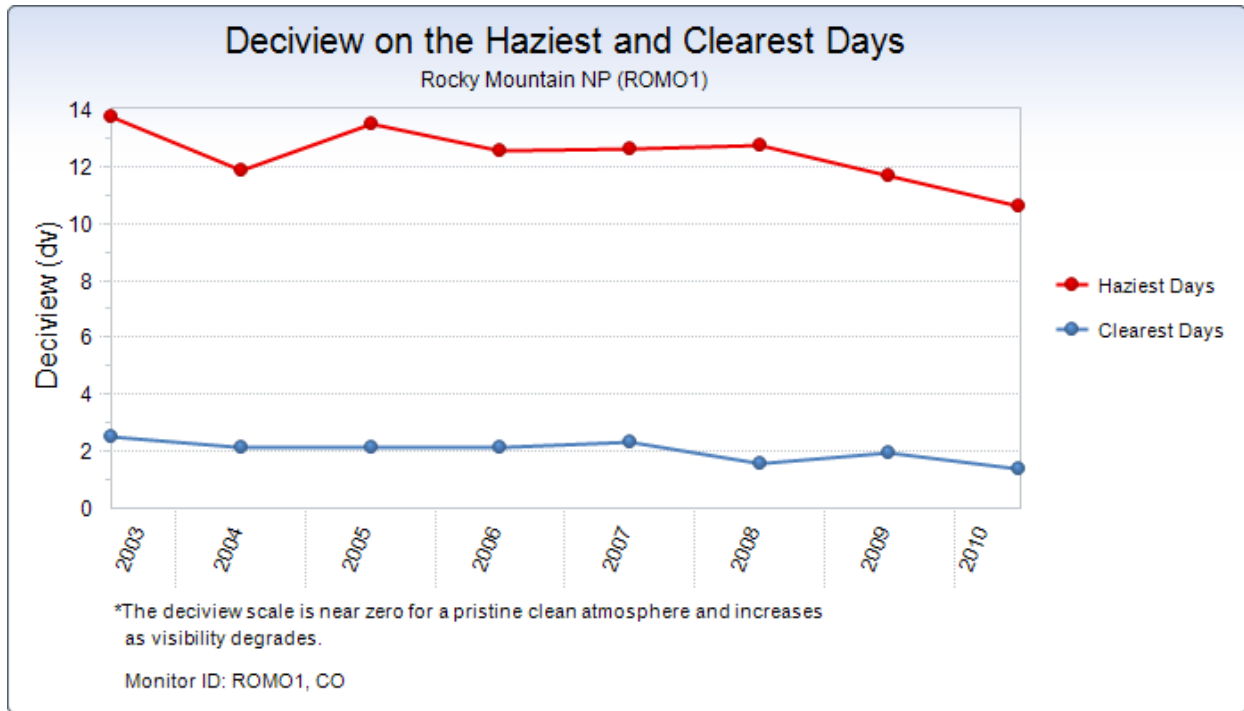


Figure 4. Deciview of the haziest and clearest day for each year between 2003 and 2010 in Rocky Mountain National Park (IMPROVE, 2014)

Atmospheric deposition data are collected by the National Atmospheric Deposition Program (NADP). The NADP monitors eight dissolved chemicals along with pH and provides annual weighted mean concentrations from 1980 to present. Chemical related to acid deposition are of primary interest including sulfate (SO₄), nitrate (NO₃) and ammonium (NH₄). These data are available publically through the NADP data portal which provides tools for the visualization and download of raw and summarized data including automatic calculation of a trend line representing a smoothed three year average for each year (Figure 5).

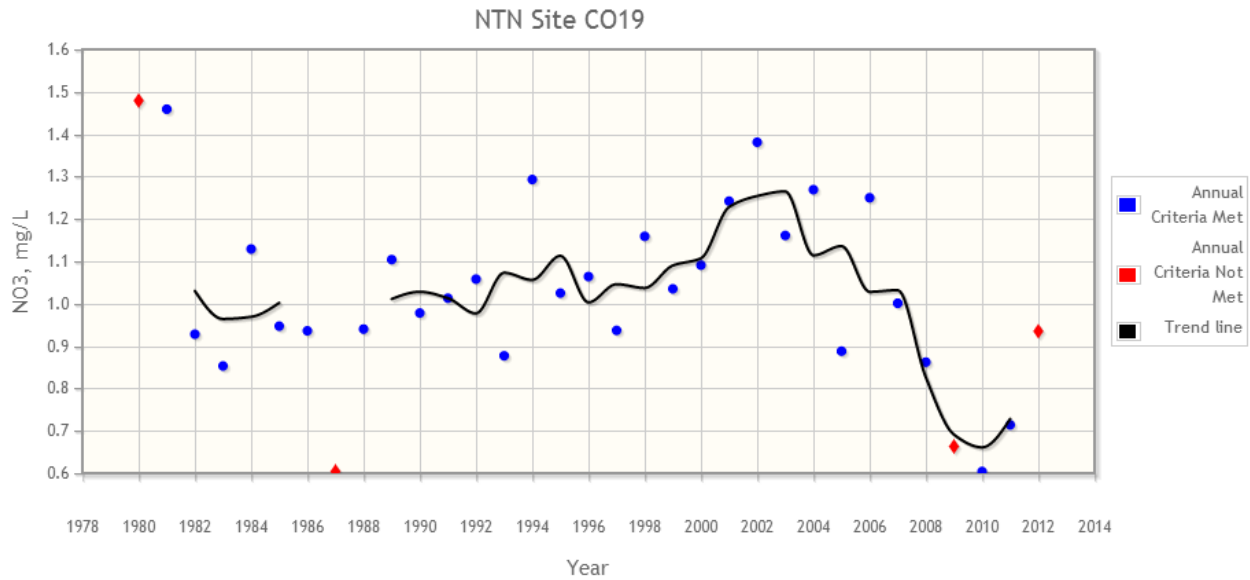


Figure 5. Nitrate (NO₃) deposition at Rocky Mountain National Park-Beaver Meadows (CO19) NTN site from 1980 to 2013 (NADP, 2014).

Water quality is monitored primarily through a distributed network of stations for which data are available for download through the EPA STorage and RETrieval Data Warehouse (STORET). The EPA periodically compiles these data into a Watershed Quality Assessment Report which provides a qualitative description of watershed health as well as a list of stressors that are causing impairment. For example, the St. Vrain Watershed which comprises the majority of the south eastern portion of RMNP wilderness was last rated as “Impaired Water” in 2010 with stressors causing the impairment listed in (Table 2).

Table 2. The sources or “causes” of impairment leading to the classification of the St. Vrain watershed as impaired for 2010 (EPA/STORET, 2014).

Cause of Impairment	Rivers and Streams (Miles) and Ponds (Acres)
Cadmium	3.7
pH	31.2
Zinc	131.1
Arsenic	21.1
Cause Unknown	27.3
Lead	6.0
Copper	84.2
Ammonia, Un-ionized	45.6
Manganese	6.0
Selenium	87.0
Temperature, Water	31.9
Escherichia Coli (E. Coli)	32.4

In addition to ongoing data collection and monitoring efforts from supporting agencies, a Natural Resource Condition Assessment (NRCA), completed for RMNP in 2010, was also identified. The purpose of an NRCA is specifically to help answer the question “What are current conditions for

important park natural resources?” (Theobald et al., 2010). This report greatly expedited the identification of the *most* salient measures for the natural quality of RMNP Wilderness as well as providing a summary of natural resource conditions across the park.

- Condition assessments fell into four main classes:
- Air and Climate: Condition of alpine lakes and atmospheric deposition
- Water: Extent and connectivity of wetland and riparian areas
- Biotic Integrity: Extent of exotic terrestrial plant species, extent of fish distributions, and extent of suitable beaver habitat
- Landscapes: Extent and pattern of major ecological systems and natural landscapes connectivity

The NRCA provided data for eight out of twelve identified measures for natural quality in RMNP Wilderness. While an NRCA is intended to provide a synthesis of the best existing scientific data and knowledge (Theobald et al., 2010), it is only as robust as the best available data and therefore includes a number of additional criteria in order to establish context for each condition assessment.

Each condition assessment is comprised of several parts including: what is being measured; why analysis of the condition is important; potential stressors that can alter the state of the resource being assessed; confidence of the data in terms of concern, evidence and agreement; current conditions; and where possible reference or historic conditions. Specific details including data sources, statistical methods, and models can be referenced directly in the RMNP NRCA report. The final list of identified measures along with priority and spatial scores can be found in **Table 3**.

Table 3. Identified measures for the natural quality in RMNP including prioritization and spatial scores.

Indicator	RMNP Measure	Prioritization Score	Spatial Score
Plant and animal species and communities	Abundance, distribution, or number of indigenous species that are listed as threatened and endangered, sensitive, or of concern	8	2
	Abundance, distribution, or number of invasive non-indigenous species	9	4
	Change in demography or composition of communities	8	5
	Change in demography or composition of communities	8	5
Physical resources	Visibility based on average deciview and sum of anthropogenic fine nitrate and sulfate	10	4
	Ozone air pollution based on concentration of N100 episodic and W126 chronic ozone exposure affecting sensitive plants	8	3

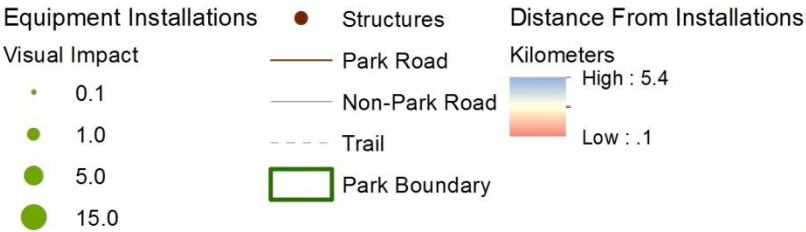
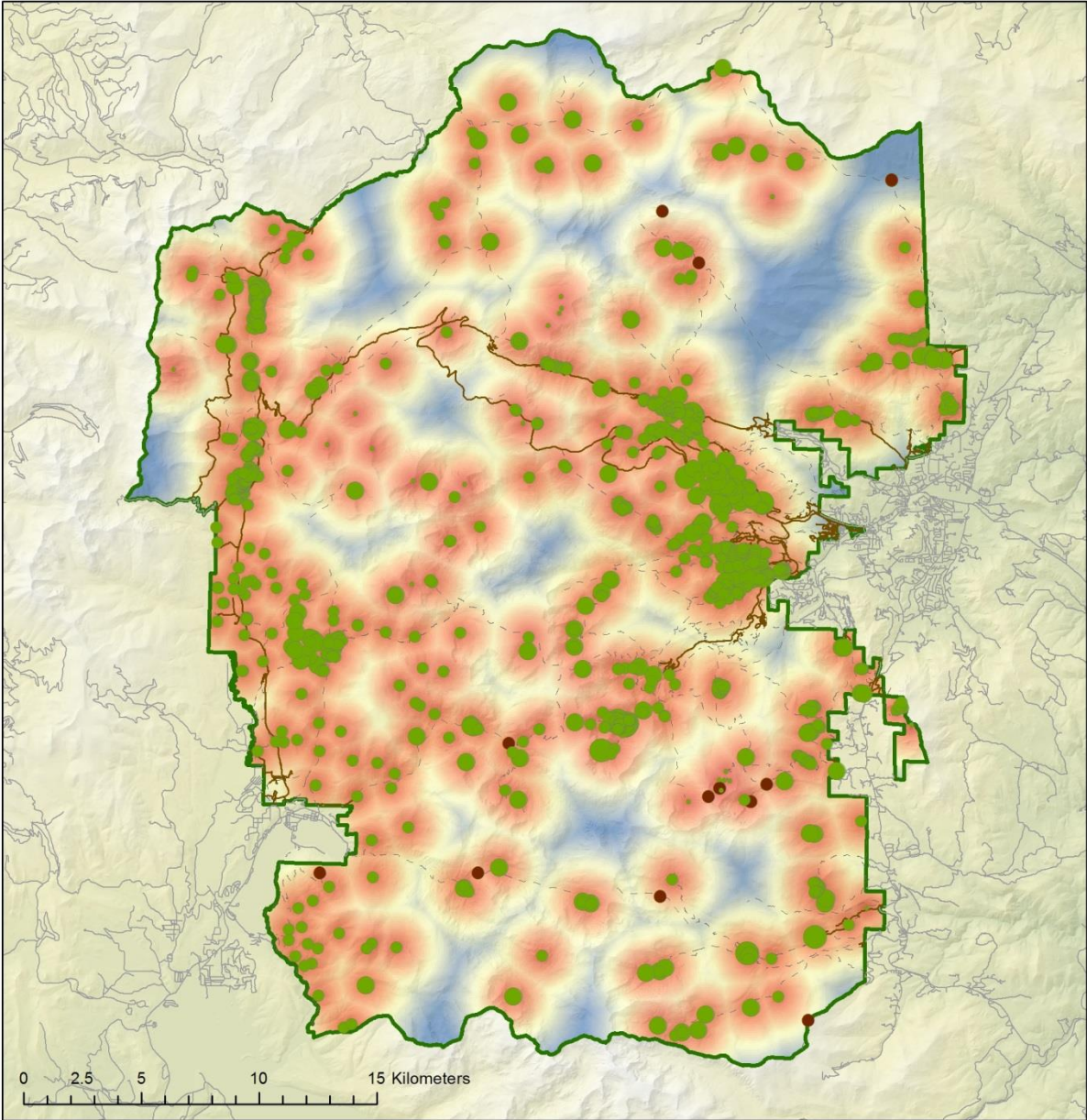
	Acid deposition based on concentration of sulfur and nitrogen in wet deposition	8	3
	Extent and magnitude of change in water quality	9	3
Biophysical processes	Area and magnitude of loss of connectivity with the surrounding landscape	9	5
	Area and magnitude of loss of connectivity with the surrounding landscape	9	5
	Area and magnitude for pathways of nonindigenous species into the wilderness	9	5
	Area and magnitude of loss of connectivity with the surrounding landscape	8	5

Undeveloped

The undeveloped quality primarily focused on the number of non-recreational installations, inholdings, and amount of mechanized activity in wilderness. Rocky Mountain National Park maintains a robust geographic information system of park infrastructure including structures, trails, roads and other permanent installations. In addition to infrastructure, RMNP Resources Management developed and maintained a database of research installations throughout the park including information on: installation date, proposed removal date, actual removal date, relative visual impact based on size, description of the installation, and geographic coordinates.

A review of park GIS data for infrastructure and research installations revealed missing as well as incorrect attribution of whether those data were located in wilderness. In order to accurately determine number of installations in wilderness, a new attribute was created for each feature class/dataset indicating if the installation was within wilderness based on the official RMNP wilderness GIS dataset. Using ESRI ArcGIS Spatial Analyst Tools, these data could be summarized for a variety of spatial extents including by the entire wilderness, watershed, management zone, or any other delineated area. Additionally, a number of alternative analysis could be performed to yield additional information regarding the distribution or density of structures in wilderness. Figure 6 below shows one potential analysis in which the distance to the closest equipment installation has been calculated on a 30x30 meter grid covering the entire wilderness. This type of analysis allows managers to view not just the number of developments, but how potential impacts from those developments vary spatially across the wilderness.

Equipment and Structures in Wilderness



Author: Colin Leslie
 Data Source: RMNP GIS Program
 Coordinate System: NAD 1983 UTM Zone 13N

Figure 6. Along with point locations of equipment installations and structures within wilderness, this map shows the relative impact of installations as a function of Euclidean distance calculated for a 30x30 meter

grid across the landscape. The maximum calculated distance for any installation within RMNP Wilderness is roughly 5.4 kilometers.

Inholdings either completely within or adjacent to wilderness have a high potential for impact do to a generally greater degree of freedom regarding development. While there are no identified inholdings currently within RMNP Wilderness, a number of areas designated as potential wilderness are adjacent to or surround private inholdings. If these areas are considered further in the future this measure can provide a course estimation of how this indicator has changed.

The level of mechanized equipment use in the wilderness was also identified as a relevant measure. Two measures that were specifically identified were hours of helicopter use and hours of motorized equipment or mechanized transport. Data to quantify and track these measures is most likely available from park dispatch, Law Enforcement, fire management, and MRDG forms from the wilderness management office. At this time, only one measure has been identified for hours of helicopter use as the distribution of the type of use is unknown. However, splitting this measure into two measures, emergency and non-emergency use, could be considered. The final list of identified measures along with priority and spatial scores can be found in Table 4.

Table 4. Identified measures for the undeveloped quality in RMNP including prioritization and spatial scores.

Indicator	RMNP Measure	Prioritization Score	Spatial Score
Non-recreational structures, installations, or developments	Number of monitoring or research structures	9	3
	Number of patrol cabins	8	5
	Miles of non-wilderness class trail	8	5
Inholdings	Number of properties in or adjacent to wilderness	6	5
Biophysical processes	Hours of helicopter use	9	1
	Hours of motorized equipment or mechanical transport	9	1

Solitude

Opportunity for solitude or a primitive and unconfined recreation establishes a definite intent for the type of recreation that wilderness should provide. Solitude is a complex multi-dimensional phenomena. However, the concept of remoteness reflected both in the literature as well as the WCM framework allowed for the identification of a number of potential measures for RMNP Wilderness.

Three measures were identified for the *remoteness from sights and sounds of people inside the wilderness* indicator including: number of visitors, number of encounters on wilderness trails and length-of-stay for overnight trips. These measures were all determined to be significant to wilderness vulnerable to change over the next ten years, or both. RMNP is roughly 95% wilderness with an annual visitation of roughly three million people. As such, it is likely that the majority of visitors step

foot within wilderness at some point during their visit. The NPS Visitor Use Statistics office provides annual as well as monthly reports on the number of park visitors through the NPS IRMA data portal. This measure is recognized as a very coarse measure of visitation with minimal information on spatial distribution, however no alternative measures were identified.

Number of encounters on wilderness trails provides a more directly applicable measure to opportunity for solitude in wilderness. At present, data for this measure are only available on a select number of trails within the park. Despite limited data, this measure has been selected for a number of reasons including: a high degree of significance to wilderness, high degree of vulnerability to change over the next ten years, well established collection protocols, and high feasibility for expansion under existing wilderness management.

Finally length-of-stay is has been shown to be an important attribute in obtaining solitude in wilderness under certain conditions (Cole & Hall, 2012). RMNP requires overnight users to obtain a permit and to camp at designated backcountry campsites. As a result, RMNP maintains a database of all wilderness permits issued, the number of nights the permit was issued for, and selected campsites for each night. This database can be queried to obtain descriptive statistics for length-of-stay directly or can be related to the park campsite GIS dataset in order to determine length-of-stay by area such as management zone, trail system or other area of interest.

While the indicator described above addresses sights and sounds of people in wilderness, two related measure were identified that did fit directly into this indicator or others. Therefore, the indicator *remoteness from no-natural sights and sounds* was created for the measures visibility of non-recreational infrastructure and audibility of non-natural sounds within wilderness. Visibility of non-recreational infrastructure focuses on measuring the visibility of non-recreation structures or installations in wilderness such as those identified under the *non-recreational structures, installations, or developments* indicator for undeveloped quality. Basic models for visibility can be generated using viewshed analysis techniques in a GIS or more advanced models such as visual magnitude (Chamberlain & Meitner, 2013) or improved line of site algorithms can provide a more refined measure of the visual impact of an object on the surrounding landscape (Liu, Zhang, Chen, & Chen, 2008).

The management of soundscapes in order to preserve natural sound environments is of particular interest for park managers. While humans can directly produce sounds in wilderness (talking, walking, other activities) this measure focuses more on the presence of non-natural sounds from sources such as aircraft and road vehicles. Monitoring aircraft and roadway noise can be accomplished using a number of different metrics and measurement techniques. Currently, the most extensive monitoring in RMNP has been conducted by the NPS Natural Sounds and Night Skies office using acoustical recording equipment in the field and then post processing of data in order to compute a range of metrics.

A number of discrete studies have also examined the issue of anthropogenic noise in RMNP. A study on hiker's exposure to transportation noise examined relationships between transportation noise and visitor's experience around the Bear Lake Road corridor within the park (Park, Lawson,

Kaliski, Newman, & Gibson, 2010). While techniques in acoustical modeling of outdoor environments such as the one conducted by Park, Lawson, Kaliski, Newman, & Gibson (2010) continue to improve, it is also recognized that direct measurement of the acoustical environment remains an important aspect of quantifying soundscapes (Miller, 2008). Through consultation with the NPS Natural Sounds and Night Skies office, a method for Observer Based Source Identification Logging (OBSIL) was identified and piloted during the summer of 2013. This pilot study examined the potential for OBSIL as a simple, low cost method for measuring two metrics related to soundscapes, percent time audible (PTA) and noise free interval (NFI). Full results from this study have been presented in an accompanying paper to this document, but in general reveal OBSIL to be a complimentary measurement technique to longer term deployment of acoustical monitoring equipment for evaluating how soundscapes vary across the wilderness.

The potential impact of surrounding outside development on a wilderness area is also an important consideration. The indicator *remoteness from occupied and modified areas outside the wilderness* is intended to address these impact. Two measures were selected for this indicator, night sky visibility averaged over the wilderness and distance from roads outside of wilderness. The NPS Natural Sounds and Night Skies office officially defines night skies under the term natural lightscapes. Natural lightscapes can be impacted by a number of factors including the amount of light being generated by nearby sources such as cities, as well as atmospheric scattering which can be directly impacted by air quality.

Distance from roads outside wilderness was selected as a measure as roads have the potential to impact both the visual and auditory environment. The precise visual and auditory impact of roads requires complex modeling and is dependent upon a number of factors including terrain, distance, vegetation, and atmospheric conditions to name a few. However, distance from roads provides an easy to model measure that utilizes readily available GIS data. Measuring distance or remoteness from roads can be conducted either equally for all road types or roads could be weighted based on attributes such as road type, level of use, highway class etc.

The final two indicators, *facilities that decrease self-reliance* and *management restrictions on visitor behavior* are intended to address the concept of primitive and unconfined recreation. RMNP's Backcountry and Wilderness Management Plan established four management classes, each intended to satisfy varying combinations of desired social, resource and management conditions. One measure was identified for each of these indicators. Management class 3 includes around 27,474 acres and allows camping only in designated campsites. Management classes 2 and 4 also include some designated camping but also provide for dispersed camping, whereas management class 1 is designated as day use only. From these management classes, two potential measures were identified, number of designated backcountry campsites and acres subject to restricted activities. The first measure, number of designated backcountry campsites, informs the indicator *facilities that decrease self-reliance*. The second measure, acres subject to restricted activities, informs the indicator *management restrictions on visitor behavior*.

It is important to note that while both of the measures potentially degrade the opportunity for solitude or a primitive and unconfined type of recreation quality, they also potentially enhance

measures under the natural quality. This study does not seek to establish the degree to which this purpose has been realized but simply to draw attention to potential interactions among qualities such as this. The final list of identified measures along with priority and spatial scores can be found in Table 5.

Table 5. Identified measures for the solitude quality in RMNP including prioritization and spatial scores.

Indicator	RMNP Measure	Prioritization Score	Spatial Score
Remoteness from sights and sounds of people inside the wilderness	Number of visitors	8	2
	Number of encounters on wilderness trails	10	2
	Length-of-stay for overnight trips	8	4
Remoteness from non-natural sights and sounds	Visibility of non-recreational infrastructure	8	4
	Audibility of non-natural sounds within wilderness	8	2
Remoteness from occupied and modified areas outside the wilderness	Night sky visibility averaged over the wilderness	7	1
	Distance from roads outside of wilderness	8	4
Facilities that decrease self-reliant recreation	Number of designate backcountry campsites	7	4
Management restrictions on visitor behavior	Acres subject to restricted activities	8	4

Other Features of Value

Only one potential measure has been identified at this time for the other features of value quality. The indicator *loss of cultural resources* and the associated measure, number of disturbances to cultural resource, was identified in *Keeping it Wild in the National Park Service* (National Park Service, 2014) and found to be present in RMNP. However, it should be noted that no specific features pertaining to wilderness were identified in the 2009 Omnibus Public Lands Act which designated RMNP wilderness. While this does not necessarily preclude features such a research natural areas (which are present in RMNP wilderness) from inclusion in this quality, these features must be evaluated carefully to determine if and how their existence as a specific feature maintains the wilderness resource. The selected measure for this quality are listed in Table 6.

Table 6. Identified measure for the other features of value quality in RMNP including prioritization and spatial scores.

Indicator	RMNP Measure	Prioritization Score	Spatial Score
Loss of cultural resources	Number of disturbances to cultural resources	8	3

Discussion

The purpose of this study was to determine if WCM as established by in *Keeping it Wild* (Landers et al, 2008) and subsequent guidance documents could in fact adequately capture the required number and diversity of measures to support a WCM effort in RMNP Wilderness. While there are numerous factors that can ultimately affect the success or failure of WCM, the primary goal of this study was to attempt to utilize existing data to construct a wilderness character assessment. In discussing the success of this effort for RMNP Wilderness, it is helpful to consider two separate but related questions. First, is utilizing only existing data robust enough to adequately capture and evaluate qualities of wilderness character? Second, what insights can be gained when considering the criteria (USFWS and spatial coverage) used to identify the best existing data for capturing and evaluating qualities of wilderness character? After reviewing the final list of potential measures as well as the process used in their identification and refinement for this study, a number of answers to these questions became apparent.

Utilizing Existing Data

A key recommendation for WCM is to try and utilize existing data to the greatest extent possible in order to identify and select measures to represent qualities of wilderness character. While no formal hypothesis was developed on the success or failure of this recommendation, the general consensus at the onset of this study was that utilizing only existing data would be inadequate to represent all thirteen indicators established in *Keeping it Wild* (Landres et al., 2008) and later in *Keeping it Wild in the National Park Service* (National Park Service, 2014). However, after extended consultation with park staff, multiple reviews of independent research, and identification of numerous data sources recommended in *Keeping it Wild in the National Park Service* (National Park Service, 2014), at least one measure was identified for each indicator. To the extent that data were identified for each indicator, the recommendation of using existing data was a success. The question of how adequately those data capture and evaluate the overall status of wilderness character though, is less clear.

Assuming the five qualities of wilderness character do in fact capture the multi-dimension aspect of wilderness character, then the adequacy of an assessment is primarily determined by the degree to which measures and data can comprehensively describe the quality to which they are attributed. Although this effort did not focus on an explicit evaluation of minimum inputs (measures and data) necessary to comprehensively describe each quality, many questions related to this topic were raised during the selection process.

For example, RMNP has an extensive history of scientific research, particularly in the area of natural resource management. The result is that for the natural quality, the number of identified data sources and measures far exceeded the recommended number. Early discussions with park managers focused primarily on what data (and at what scale) would be most representative of wildlife species status throughout the wilderness. Potential data included known ranges for an individual species such as elk, a species index representing the statistical relationship between numbers of native and non-native species, or the status of potential habitat for a known indicator species such as beaver. While

discussions with staff proved extremely helpful in identifying the range of potential natural resource data, selecting the most salient data to represent measures for the natural quality would have proved extremely difficult if not for the inclusion of the RMNP NRCA.

The primary purpose of an NRCA is to identify the most relevant natural resource condition assessments for an area as determined through the extensive effort of numerous subject matter experts. For this wilderness character assessment, selecting the most salient measures required little more than correlating findings in the NRCA with recommended indicators for the natural quality. By successfully matching up most natural resource conditions examined in the NRCA with indicators for the natural quality, confidence was fairly high that the natural quality was being comprehensively represented.

The same confidence held true for the undeveloped quality, where most infrastructure is accounted for through existing park inventories. Conversely, opportunities for solitude or primitive and unconfined type of recreation offered lower confidence, as several important values identified in the literature, such as length of stay or number of wilderness encounters (Cole and Hall, 2012), were either unrepresented or underrepresented in identified data and measures. Other features of value is also fairly tenuous as research for linking the importance of a specific feature to the overall preservation of wilderness is at this time largely lacking.

Finally the comprehensiveness of data and measures selected for the untrammeled quality represents the lowest confidence of all the qualities. While measures selected for the undeveloped quality are capable of tracking actions, they do not currently evaluate the degree to which those actions influence the biophysical environment, or influence other qualities of wilderness character. Although the untrammeled quality is evaluated on equal footing with other qualities in WCM, the use of the term in the Wilderness Act of 1964 itself is intended to represent the ideal state of wilderness rather than a specific quality (Scott, 2002). While the existence of a truly untrammeled system may no longer be possible due to human modification of the global environment, minimizing human manipulation of the wilderness environment is still a worthy goal. Therefore, the inclusion of a quality tracking human action in wilderness is important, but at present the measures selected for the untrammeled quality offer limited operational insight as both the individual and cumulative impact of actions remains unknown. Understanding the degree to which management actions are manipulating the wilderness environment will require not just an inventory of actions, but an integrated understanding of the positive or negative effects of those actions on the other qualities of wilderness character.

Selecting Best Data

Two methods for determining the *best* or most relevant measures among a set of potential data were utilized in this study. Developing these methods up front allowed for a more systematic approach throughout the selection and reporting process.

First, by utilizing an evaluative framework such as the one developed by the USFWS while doing an initial inventory of data sources, high priority measures were identified and then recorded for follow-up consideration. This proved especially useful considering the multidisciplinary nature of

wilderness, as often the evaluation of data required follow-up consultation with subject matter experts. In addition to the organizational benefits, an unforeseen but potentially more important benefit is that of transparency. Since WCM is intended to track trends over time, it is likely that relevant data and measures will change. For example, a measure that was deemed not feasible (ability to consistently monitor it) during this assessment may be feasible in the future due to technological advancements. Conversely, a measure that was deemed as highly vulnerable to change now, may stabilize in the future, thus decreasing its overall priority. Evaluating and recording changes in specific attributes can provide managers with additional insights over the long term.

Second, developing a systematic spatial data evaluation method increased understanding of data coverage. Discrepancies among data quality, coverage, and availability can result in data gaps regarding key components of qualities of wilderness character. Data gaps are likely to be common when attempting to only utilize existing data as historically most agencies have focused on addressing individual resource management issues and not necessarily measuring baseline condition in wilderness (Hendee & Dawson, 2002). This was observed in several circumstances where data were ranked as a high priority under the USFWS framework, but received a low spatial score due to insufficient coverage, such as “number of encounters on wilderness trails,” for the opportunities for solitude or a primitive and unconfined type of recreation quality (**Table 5**). In this instance, the measure received a prioritization score of 10, indicating both a high significance and vulnerability, but a spatial score of 2 indicating that data were available for less than 50% of applicable areas in the wilderness.

Both the prioritization and spatial coverage evaluations provided key insights into each of the selected measures. A couple of additional questions were raised though while evaluating measures, including what metrics to track and what scale to summarize data at. For example, the undeveloped quality assesses the level of non-recreational development and generally relies on tracking the *number* of structures or installations in wilderness. Under this measure, trends are tracked by changes in the number of structures at the scale of the wilderness as a whole. As shown in **Figure 6**, other possible methods for quantification could involve either distance or density functions calculated using a GIS. These methods can provide managers greater insight into how a measure varies across the wilderness. Literature pertaining directly to assessing low levels of development such as that found in wilderness is sparse.

Finally, it should be recognized that data also varied greatly in their level of synthesis and, thus, representation of wilderness resources as a whole. By far, the Natural Resource Condition Assessment for RMNP provided one of the most highly synthesized data sets for this study including a scientifically robust assessment of the confidence in the data, current and reference or baseline conditions, and, finally, any important stressors for the conditions such as visitor use, climate change, land use change, or pollution, to name a few. While these data provide a robust assessment of wilderness conditions, they also represent a significant investment of time and research by a range of professional scientists across multiple agencies. For some data synthesized in the Natural Resource Condition Assessment, such as atmospheric deposition in alpine lakes, the National Atmospheric Deposition Program (NADP) track most of the same pollutants, but at a much coarser scale. While

obviously related efforts, the tradeoffs between these two collection efforts should be more thoroughly evaluated before choosing one over the other. These represent just a few of tradeoffs that must be considered when selecting data for a monitoring effort.

Literature Cited

- Cole, D. N., & Hall, T. E. (2012). The effect of use density and length of stay on visitor experience in wilderness. Retrieved from <http://www.leopold.wilderness.net/pubs/769.pdf>
- Chamberlain, B. C., & Meitner, M. J. (2013). A route-based visibility analysis for landscape management. *Landscape and Urban Planning*, *111*, 13–24.
doi:10.1016/j.landurbplan.2012.12.004
- Dictionary.com. (2014). character. Retrieved from <http://dictionary.reference.com/browse/character>
- Fancy, S. G., Gross, J. E., & Carter, S. L. (2009). Monitoring the condition of natural resources in US national parks. *Environmental Monitoring and Assessment*, *151*(1-4), 161-174.
- Hendee, J. C., & Dawson, C. P. (2002). *Wilderness Management* (3rd ed.). Fulcrum Publishing. Retrieved from <http://books.google.com/books?hl=en&lr=&id=CcljwJXpi54C&oi=fnd&pg=PA2&dq=endangered+american+wilderness+act&ots=RyL7wsE816&sig=jDxyIM87sRDKnViJOyNEhFsTD44>
- Landres, P., Barns, C., Dennis, J. G., Devine, T., Geissler, P., McCasland, C. S., ... Swain, R. (2008). *Keeping It Wild*. Retrieved from https://eng.ucmerced.edu/czo/files/private/research_in_wilderness_policies/rmrs_gtr212.pdf
- Landres, P., Boutcher, S., Liese, D., Hall, T., Tamara Blett, Terry Carlson, ... Deb Bumpus. (2009). *Technical guide for monitoring selected conditions related to wilderness character* (General Technical No. WO-80). US Department of Agriculture, Forest Service.
- Liu, L., Zhang, L., Chen, C., & Chen, H. (2008). An Improved LOS Method for Implementing Visibility Analysis of 3D Complex Landscapes (pp. 874–877). IEEE.
doi:10.1109/CSSE.2008.1157
- National Park Service. (2006). *NPS Management Policies 2006.pdf*.
- National Park Service. (2014). *Keeping It Wild in the National Park Service - A User Guide to Integrating Wilderness Character into Park Planning, Management, and Monitoring* (Planning Guide No. WASO 909 121797). U.S. Department of the Interior.
- Park, L., Lawson, S., Kaliski, K., Newman, P., & Gibson, A. (2010). Modeling and mapping hikers' exposure to transportation noise in Rocky Mountain National Park. *Park Science*, *26*(3), 59–64.
- Rocky Mountain National Park. (1984). ROMO Land Protection Plan.

Rocky Mountain National Park. (2008). Final Environmental Impact Statement - Elk and Vegetation Management Plan.

Wilderness Act, 16 U.S.C. § 1131-1136 (1964).

Scott, D. W. (2002). " Untrammelled," Wilderness Character," and the Challenges of Wilderness Preservation. *Wild Earth*, 11(3/4), 72-79.

Suzanne Jones, & Jeff Widen. (2006). Rocky Mountain National Park Wilderness Act - Fact Sheet.pdf.

Theobald, D. M., Baron, J. S., Newman, P., Noon, B., Norman, J. B., Leinwand, I., ... Hartman, M. (2010). *ROMO Natural Resources Condition Assessment Theobald 2009* (Natural Resource Report No. NPS/NRPC/WRD/NRR—2010/228) (pp. 1–206). Fort Collins, CO: U.S. Department of the Interior, National Park Service, Natural Resource Program Center.

Thrower, J. (2006). Adaptive Management and NEPA - How a Nonequilibrium View of Ecosystem Mandates Flexible Regulation. *Ecology LQ*, 33, 871.

Appendix A – Evaluation of potential measures considered

USFWS Prioritization Framework

Directions: In each row, write the potential measure in the left column under the appropriate indicator. Add or delete rows as needed. Use the criteria and ranking guide below to create an overall score for each measure. If the combined score for criteria A and B is ≤ 2 , STOP and do not score criteria C and D. Those measures with the highest overall scores should be the highest priority for assessing trends in wilderness character.

A. Level of significance (the measure is highly relevant to the quality and indicator of wilderness character, and is highly useful for managing the wilderness): High = 3 points, Medium = 2 points, Low = 1 point

B. Level of vulnerability (measures an attribute of wilderness character that currently is at risk, or might likely be at risk over 10-15 years): High = 3 points, Medium = 2 points, Low = 1 point

C. Degree of reliability (the measure can be monitored accurately with a high degree of confidence, and would yield the same result if measured by different people at different times): High = 3 points, Medium = 2 points, Low = 1 point

D. Degree of feasibility (the measure is related to an existing effort or could be monitored without significant additional effort): High = 1 point, Low = 0 point (if 0 is given, do not use)

Table 7. The USFWS criteria can be used to create a composite score for every potential measure to assist with selection of the most relevant measures.

POTENTIAL MEASURE	Criteria for Prioritizing Potential Measures				OVERALL SCORE	Comments
	A. Significance	B. Vulnerability	C. Reliability	D. Feasibility		
Untrammeled Quality						
Indicator: Authorized actions that manipulate the biophysical environment Measure:						
Indicator: Unauthorized actions that manipulate the biophysical environment Measure:						
Natural Quality						
Indicator: Plant and animal species and communities Measure:						
Indicator: Physical resources Measure:						
Indicator: Biophysical processes Measure:						
Undeveloped Quality						
Indicator: Non-recreational structures, installations, or developments Measure:						
Indicator: Inholdings Measure:						
Indicator: Use of motor vehicles, motorized equipment, or mechanical transport Measure:						
Solitude or Primitive and Unconfined Recreation Quality						
Indicator: Remoteness from sights and sounds of people inside the wilderness Measure:						
Indicator: Remoteness from occupied and modified areas outside the wilderness Measure:						
Indicator: Facilities that decrease self-reliant recreation Measure:						
Indicator: Management restrictions on visitor behavior Measure:						
Other Features Quality (if applicable)						
Indicator: Loss of cultural resources Measure:						

Spatial Score Analysis

Directions: For each measure and corresponding data source, begin in the top left “Identify Data Source”. Use the criteria provided below to determine an overall Spatial Score for the data source using the flowchart.

- **Is Spatial:** Are the data in a spatial/GIS format?
- **Complete Spatial Coverage:** Do the data cover or apply to the entire wilderness area?
- **Precise:** Does the resolution of the data provide a relatively precise measure relative to expect variability in the wilderness area?
- **Relatable:** If the data are not natively spatial, can they be related to an existing spatial dataset based on a common attribute?
- **Interpolable/Generalizable:** If the data do not completely cover the wilderness area, can they be interpolated using statistical techniques to give an estimate of conditions across wilderness?
- **Coverage >50%:** If the data cannot be interpolated, does existing data cover 50% or more of the wilderness?

Once a score has been obtained, record it in the table below along with the data source and summary method.

- **Spatial Score:** Indicates the level of spatial coverage for the data relative to the wilderness area.
- **Data Source:** The program, report, or archive from which the data were or can be obtained
- **Summary Method:** How are the data reported. Represented as metric/area unit. For example, total acres per wilderness area would be represented by “Acres/Wilderness”

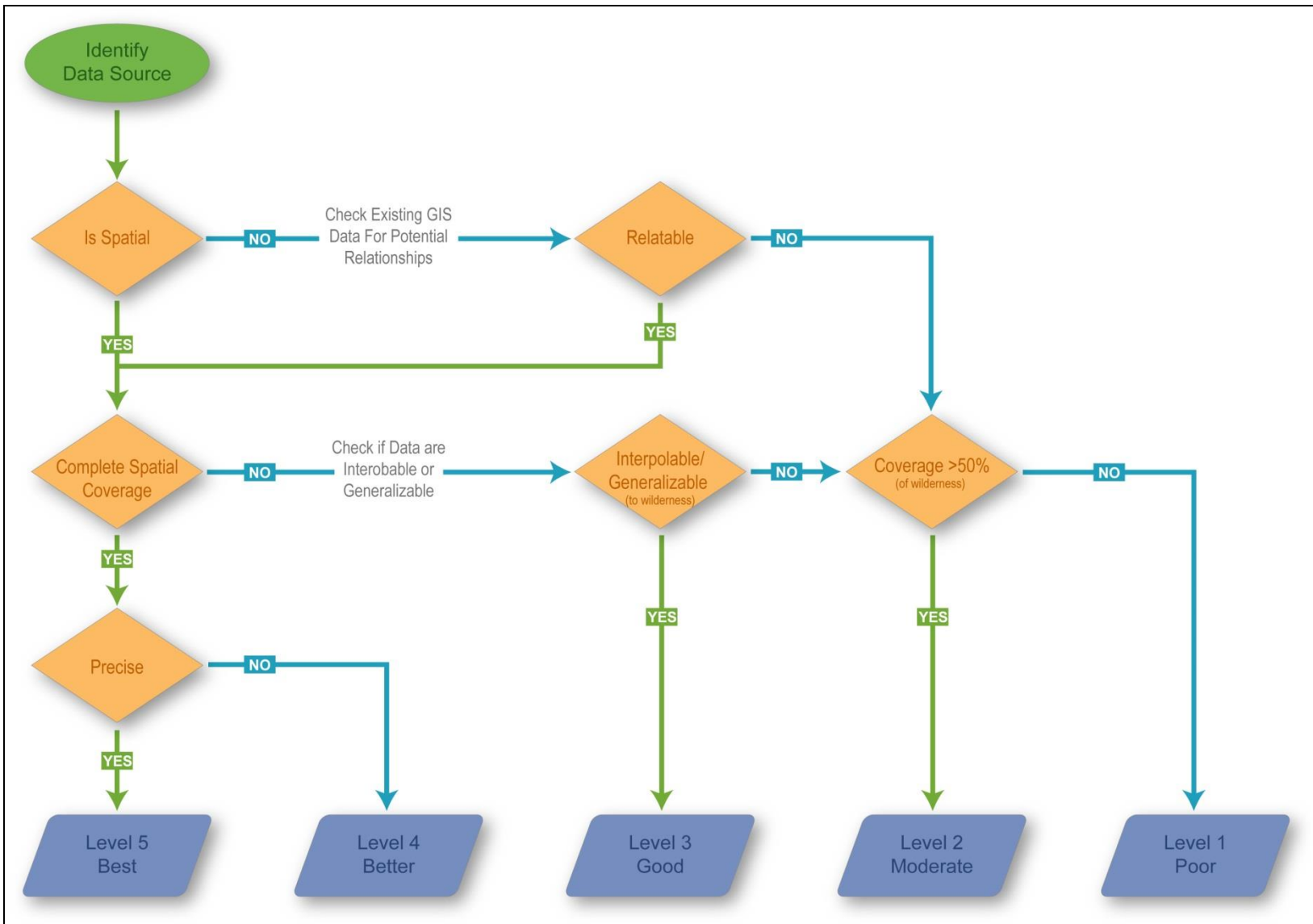


Figure 7. Framework for assigning a spatial score for identified data sources.

Measures and Scores

Table 8. Identified potential sources for measures and data along with USFWS prioritization score and spatial score

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent	Recommended Measure	USFWS Criteria				Prioritization Score	Metric	Summary Area	Spatial Score
							A. Significance	B. Vulnerability	C. Reliability	D. Feasibility				
Untrammeled	Authorized actions that manipulate the biophysical environment	Number of actions to manage plants animals, pathogens, soil, water, or fire	Acres of plant removal projects	RMNP Resource Management - Botanist		Y	3	3	3	1	10	Acres	Wilderness/ Watershed/ Other Unit	4
		Number of actions to manage plants animals, pathogens, soil, water, or fire	Number of Elk culled per year	RMNP EVMP	2012	Y	2	2	3	1	8	Count	Wilderness	5
		Number of actions to manage plants animals, pathogens, soil, water, or fire	Number of elk exclosures	RMNP EVMP, GIS or Scientific Installations DB		Y	2	2	3	1	8	Count	Wilderness/ Watershed/ Other Unit	5
		Number of actions to manage plants animals, pathogens, soil, water, or fire	Native fish removed per day	RMNP Resource Management – Wildlife Biologist		N	1	2	1	0	4	Count	Wilderness	2

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent	Recommended Measure	USFWS Criteria					Metric	Summary Area	Spatial Score
							A. Significance	B. Vulnerability	C. Reliability	D. Feasibility	Prioritization Score			
		Number of actions to manage plants animals, pathogens, soil, water, or fire	Number of reintroductions	RMNP Resource Management – Wildlife Biologist		Y	2	1	3	1	7	Count	Wilderness	4
		Number of actions to manage plants animals, pathogens, soil, water, or fire	Number of prescribed burns	FMO	2013	Y	3	3	3	1	10	Count	Wilderness	5
		Percent of natural fire starts that received a suppression response	Percent of natural fire starts that received a suppression response	FMO	2013	Y	3	3	3	1	10	Percent	Wilderness	5
		Number of actions to manage plants animals, pathogens, soil, water, or fire	Number of animals tagged or banded	RMNP Resource Management – Wildlife Biologist		N	2	1	1	0	4	Count	Wilderness	1
		Number of actions to manage plants animals, pathogens, soil, water, or	Number of submitted MRDGs involving actions that manageplants	RMNP Wilderness Office	2013	Y	3	3	3	1	10	Count	Wilderness/ Watershed/ Other Unit	2

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent	Recommended Measure	USFWS Criteria					Metric	Summary Area	Spatial Score
							A. Significance	B. Vulnerability	C. Reliability	D. Feasibility	Prioritization Score			
		fire	animals, pathogens, soil, water, or fire											
		Number of actions to manage plants animals, pathogens, soil, water, or fire	Number of approved MRDGs involving actions that manage plants animals, pathogens, soil, water, or fire	RMNP Wilderness Office	2013	Y	3	3	3	1	10	Count	Wilderness/ Watershed/ Other Unit	2
	Unauthorized actions that manipulate the biophysical environment	Number of unauthorized actions by agencies, citizen groups, or individuals that manipulate plants, animals, pathogens, soil, water, or fire	Number of visitor-ignited fires	FMO	2013	Y	3	1	2	1	7	Count	Wilderness/ Watershed/ Other Unit	5
Natural	Plant and animal species and communities	Abundance, distribution, or number of indigenous species that are listed as	Number of indigenous species that are listed as threatened and endangered,	RMNP ESA Listing/ NPS IRMA	2013	Y	2	2	3	1	8	Count	Wilderness	2

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent	Recommended Measure	USFWS Criteria					Metric	Summary Area	Spatial Score
							A. Significance	B. Vulnerability	C. Reliability	D. Feasibility	Prioritization Score			
		threatened and endangered, sensitive, or of concern	sensitive, or of concern											
		Number of extirpated indigenous species	Number of extirpated indigenous species	RMNP Resource Management/ NPS IRMA	2013	N	2	1	2	1	6	Count	Wilderness	2
		Number of non-indigenous species	Number of non-indigenous speices	RMNP Resource Management/ NPS IRMA	2013	N	2	1	2	1	6	Count	Wilderness	2
		Number of non-indigenous species	Species Index (ratio of native to non-native species)	RMNP Resource Management/ NPS IRMA		N	2	1	1	1	5	Count	Wilderness	2
		Abundance, distribution, or number of invasive non-indigenous species	Proportion and abundance of non-native exotic plant species	NRCA Report	2010	Y	3	3	2	1	9	Percent	Watershed	4
		Change in demography or composition of communities	Extent and connectivity of fish distributions	NRCA Report	2010	Y	3	2	2	1	8	Extent	Wilderness/ Watershed/ Other Unit	5

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent	Recommended Measure	USFWS Criteria					Metric	Summary Area	Spatial Score
							A. Significance	B. Vulnerability	C. Reliability	D. Feasibility	Prioritization Score			
		Change in demography or composition of communities	Extent of suitable beaver habitat	NRCA Report	2010	Y	3	2	2	1	8	Extent	Wilderness/ Watershed/ Other Unit	5
		Change in demography or composition of communities	Number of elk, beaver or pika	RMNP Resource Management/ NPS IRMA		N	2	2	3	1	8	Count	Wilderness	2
		Change in demography or composition of communities	Acres of habitat restored	RMNP Resource Management	2013	N	1	2	3	1	7	Acres	Wilderness/ Watershed/ Other Unit	4
	Physical resources	Visibility based on average deciview and sum of anthropogenic fine nitrate and sulfate	Visibility based on average deciview	IMPROVE Data	2010	Y	3	3	3	1	10	Visibility	Wilderness	4
		Ozone air pollution based on concentration of N100 episodic and W126 chronic ozone exposure affecting sensitive		EPA AIRS Data	2013	Y	2	2	3	1	8	Concentration	Wilderness	3

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent	Recommended Measure	USFWS Criteria					Metric	Summary Area	Spatial Score
							A. Significance	B. Vulnerability	C. Reliability	D. Feasibility	Prioritization Score			
		plants												
		Acid deposition based on concentration of sulfur and nitrogen in wet deposition	Acid deposition based on concentration of sulfur and nitrogen in wet deposition	National NADP/NTN data (sites CO19, CO89, CO98)	2013	Y	2	2	3	1	8	Concentration	Wilderness	3
		Extent and magnitude of change in water quality	Extent and magnitude of change in water quality	I&M Monitoring Data	2001	N	2	1	3	1	7	Concentration	Wilderness	3
		Extent and magnitude of change in water quality	Atmospheric deposition of nutrients and pollutants in high elevation lakes	NRCA Report	2010	Y	3	3	2	1	9	Levels	Lake	3
		Extent and magnitude of human-caused stream bank erosion	Extent and magnitude of human-caused stream bank erosion	USGS/EPA Water Quality Portal		N	2	2	3	1	8	Extent	Wilderness	2
		Extent and magnitude of disturbance or loss of soil or	Extent and magnitude of disturbance or loss of soil or	I&M Monitoring Data	2013	N	2	1	3	1	7	Extent	Wilderness/ Watershed/ Other Unit	5

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent	Recommended Measure	USFWS Criteria					Metric	Summary Area	Spatial Score
							A. Significance	B. Vulnerability	C. Reliability	D. Feasibility	Prioritization Score			
		soil crusts	soil crusts											
	Biophysical processes	Area and magnitude of loss of connectivity with the surrounding landscape	Connectivity of natural landscapes	NRCA Report	2010	Y	3	3	2	1	9	Connectivity	Wilderness	5
		Area and magnitude of loss of connectivity with the surrounding landscape	Extent and proportion of major ecological systems	NRCA Report	2010	Y	3	3	2	1	9	Extent	Watershed	5
		Area and magnitude for pathways of nonindigenous species into the wilderness	Pathways for exotic species	NRCA Report	2010	Y	3	3	2	1	9	Extent	Wilderness/ Watershed/ Other Unit	5
		Area and magnitude of loss of connectivity with the surrounding landscape	Connectivity of riparian and wetlands	NRCA Report	2010	Y	3	2	2	1	8	Connectivity	Wilderness	5

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent	Recommended Measure	USFWS Criteria				Prioritization Score	Metric	Summary Area	Spatial Score
							A. Significance	B. Vulnerability	C. Reliability	D. Feasibility				
Undeveloped	Non-recreational structures, installations, or developments	Index of authorized physical development	Number of monitoring or research structures	RMNP Scientific Installations Database	2013	Y	3	3	2	1	9	Count	Wilderness/ Watershed/ Other Unit	3
			Number of animals tagged or banded	RMNP Resource Management – Wildlife Biologist		N	2	2	1	0	5	Count	Wilderness	1
		Index of authorized physical development	Number of patrol cabins	RMNP GIS		Y	3	1	3	1	8	Count	Wilderness/ Watershed/ Other Unit	5
		Index of authorized physical development	Miles of non-wilderness class trail	RMNP GIS		Y	3	1	3	1	8	Miles	Wilderness/ Watershed/ Other Unit	5
	Inholdings	Area of existing or potential impact of inholdings	Number of properties in or adjacent to wilderness	RMNP GIS		Y	3	1	1	1	6	Count	Wilderness	5
	Use of motor vehicles, motorized equipment, or mechanical transport	Type and amount of administrative and nonemergency use of motor vehicles,	Hours of helicopter use	RMNP Fire/Dispatch/Law Enforcement		Y	3	3	2	1	9	Hours	Wilderness	1

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent	Recommended Measure	USFWS Criteria					Metric	Summary Area	Spatial Score
							A. Significance	B. Vulnerability	C. Reliability	D. Feasibility	Prioritization Score			
		motorized equipment or mechanical transport												
		Type and amount of administrative and nonemergency use of motor vehicles, motorized equipment or mechanical transport	Hours of motorized equipment or mechanical transport	RMNP Wilderness Office – MRDG		Y	3	3	2	1	9	Hours	Wilderness	1
Solitude or Primitive and Unconfined Recreation	Remoteness from sights and sounds of people inside the wilderness	Amount of visitor use	Number of visitors	NPS Stats Office	2013	Y	2	3	2	1	8	Visitors	Wilderness	2
		Number of trail contacts	Number of encounters on wilderness trails	RMNP Wilderness Office	2013	Y	3	3	3	1	10	Encounters	Trail	2
			Number of camping nights per year (1 camping night = 1 visitor camping for 1	RMNP Backcountry Permit Database	2012	N	1	2	2	1	6	Nights	Wilderness	4

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent	Recommended Measure	USFWS Criteria					Metric	Summary Area	Spatial Score
							A. Significance	B. Vulnerability	C. Reliability	D. Feasibility	Prioritization Score			
			night)											
			Length-of-stay for overnight trips	RMNP Backcountry Permit Database	2012	Y	3	1	3	1	8	Nights	Wilderness	4
	Remoteness from non-natural sights and sounds		Visibility of non-recreational infrastructure	RMNP GIS		Y	2	2	3	1	8	Area	Wilderness	4
		Extent and magnitude of intrusions on the natural soundscape	Audibility of non-natural sounds within wilderness	NPS Natural Sounds and Night Sky office		Y	3	3	1	1	8	Audibility	Wilderness	2
	Remoteness from occupied and modified areas outside the wilderness	Night sky visibility averaged over the wilderness	Night sky visibility averaged over the wilderness	NPS Natural Sounds and Night Sky office		Y	3	2	1	1	7	Visibility	Wilderness	1
			Area from which outside development is visible	RMNP GIS		N	2	1	2	1	6	Area	Wilderness	4

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent	Recommended Measure	USFWS Criteria					Metric	Summary Area	Spatial Score
							A. Significance	B. Vulnerability	C. Reliability	D. Feasibility	Prioritization Score			
			Distance from roads outside of wilderness	RMNP GIS		Y	3	1	3	1	8	Area	Wilderness	4
	Facilities that decrease self-reliant recreation	Type and number of agency-provided recreation facilities	Number of designate backcountry campsites	RMNP GIS		Y	2	1	3	1	7	Count	Wilderness	4
	Management restrictions on visitor behavior	Type and extent of management restrictions	Acres subject to restricted activities	RMNP GIS		Y	3	1	3	1	8	Area	Wilderness	4
Other Features (if applicable)	Loss of cultural resources		Number of disturbances to cultural resources	RMNP ASMIS Database		Y	2	2	3	1	8	Count	Wilderness	3