

# Technical guidelines for Mapping Threats to Wilderness Character in the National Wilderness Preservation System

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## Summary

This document provides the methodology and technical processes for mapping threats to wilderness character for any designated (or proposed) wilderness area in the National Wilderness Preservation System. This document allows any of the wilderness managing agencies to independently produce a wilderness character map using a generic approach that can be adapted to any wilderness area.

Please note that this technical report references a number of supporting documents, which can be found in the [Supporting Documents](#) folder in the wilderness character mapping toolbox:

- **Overview of mapping wilderness character** – a general presentation describing the approach to mapping wilderness character.
- **Measures and datasources** – a list of commonly used measures and data sources collated from previous projects.
- **Measures BLANK** – a blank spreadsheet used for selecting measures to include in the wilderness character map.
- **Strategic questions** – a set of strategic questions (with potential answers) for driving the entire process of building a wilderness character map.
- **WCM\_database** – a hierarchical folder system for storing measure datasets.
- **Rasterize/Normalize tool** – a customized ArcGIS tool for converting vectors to rasters and normalizing values.
- **WCM report template** – a generic template that can be used by any wilderness-managing agency to generate a site-specific wilderness character mapping report.

Additionally, this document can be used in conjunction with previously completed wilderness character mapping reports (located in the [Reports & Papers](#) folder), which provide detailed processing notes for measures used to create the respective wilderness character maps.

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## **Basic requirements**

This section outlines the main requirements for undertaking a wilderness character mapping project.

### **Identify a need for developing a wilderness character map**

The decision to develop a wilderness character map should stem from a clear need at a wilderness area, which is identified and outlined by agency staff at the beginning of the project. In order to make this decision, agency staff need to become familiar with the purpose of wilderness character maps and the benefits they can provide to a wilderness area.

The primary purpose of a wilderness character map is to spatially depict threats to wilderness character and how they vary across a wilderness area. This mapping approach:

- Shows the current extent and magnitude of threats to wilderness character and how they vary across a wilderness.
- Provides a measurement baseline from which future monitoring can show how threats to wilderness character change spatially over time.
- Allows wilderness staff to analyze the potential impacts of different management actions on wilderness character.
- Identifies areas within a wilderness where resource managers should make an effort to control or mitigate impacts. These efforts may include monitoring conditions, establishing thresholds, or taking direct action.
- Identifies specific activities or impacts outside a wilderness that may pose a substantial risk of degrading wilderness character inside the wilderness.
- Improves internal staff communication about wilderness and wilderness character and improves external communication between the wilderness managing agencies and the public on related issues.
- Identifies and fills data gaps by collecting information from local staff and digitizing new spatial data.

Wilderness character maps have typically been used to support wilderness managing agencies in the process of revising or developing a wilderness/backcountry management plan. The Wilderness Act, and pursuant agency policies, state that wildernesses shall be administered for the protection of the area and preservation of its wilderness character. Wilderness character maps enable planning staff to deepen their understanding of wilderness character by depicting the influence of accumulative impacts on a wilderness area. This is particularly useful for evaluating planning alternatives, and their ability to mitigate where threats to wilderness character accumulate.

This approach has also proven beneficial to agencies assessing the impacts to wilderness character from proposed impacts adjacent to wilderness, such as new energy developments. The ability to spatially quantify where the impacts will occur, and how they will accumulate to degrade wilderness character is an important tool that can supplement environmental impact statements or inform decision making.

### **Understand the major cautions**

There are a number of potential concerns about producing a wilderness character map. Despite these concerns, wilderness staff have recognized these maps as the best available tool for spatially representing combined impacts to wilderness character. Major cautions about the maps include:

- *Creating sacrifice zones* – Wilderness character maps may facilitate the inappropriate creation of “sacrifice zones” or internal buffers within a wilderness, directly contravening congressional and agency mandates to preserve wilderness character across an entire wilderness. For example, if a map shows that some areas are “better” or of “higher quality” than others, the tendency may be to focus efforts on preserving wilderness character only in these specific areas while allowing wilderness character to degrade in “lower quality” areas. By showing the current extent and magnitude of threats to wilderness character and how they vary across the entire wilderness, the intent of these maps is to help staff maintain high quality areas while improving lower quality areas.
- *Comparing wilderness character among wildernesses* – Since this approach has been used for other wilderness areas, subsequent maps may facilitate inappropriate comparisons of wilderness character among different wildernesses. These maps show the current extent and magnitude of threats to wilderness character in different colors (representing pixel values), and it would be easy for users to compare the quantity of a given color from one wilderness to another. Comparing these maps among different wildernesses, however, is neither valid nor appropriate because each map is built with data from the unique context of a particular wilderness.
- *Assuming that the resulting maps completely describe wilderness character* – The maps may be misconstrued as an accurate and precise description of wilderness character. The maps are instead only an estimate of selected threats to wilderness character for which spatial data were available for a particular wilderness. As an approximate representation of threats to wilderness character, the maps should not be considered an absolute and complete description. In addition, the maps do not portray the threats to the symbolic, intangible, spiritual, or experiential values of wilderness character. In short, while these maps are useful for the purposes outlined above, they do not describe the complexity, richness, or depth of wilderness character.
- *Updating datasets in the future such that maps are not directly comparable* – As datasets are updated over time, future iterations of the maps may not be comparable with the original maps. Each map is a product of both the best available spatial data and the locally defined methods for processing those data. As with all long-term monitoring efforts, changes in the type and quality of data or in the data processing techniques can make comparisons between original and subsequent data invalid. Therefore, proposals to use new or altered data, or to change data processing methods, need to be assessed carefully to ensure the comparability of map products over time.

### **Obtain leadership support**

Developing a wilderness character map is a complex and lengthy process. It also requires a significant time commitment from the project coordinator and GIS specialist (3-4 months of dedicated work time each), and involvement from the project team members (up to 3-4 weeks of dedicated work time each). Therefore, it is essential that agency staff are briefed on the need for undertaking such a project, and they understand the time commitments required for the various team members. Using the NPS as an example, the superintendent’s support for the project is critical to ensuring that division chiefs can provide the flexibility for their staff to fully engage in the project. Finally, it is important that the project coordinator provides regular progress updates to the management team to ensure expectations are being met and the project is running on schedule.

### **Select a project coordinator**

Developing a wilderness character map will require a coordinator to run and manage the project. This person should have a strong grounding in wilderness character, knowledge of current and historical issues at the wilderness, and excellent communication skills. Initially, the coordinator will be responsible for ensuring buy-in from supervisors and leadership, planning the project, and selecting the project team. The coordinator will then oversee running the project from beginning to end. This will primarily involve planning and coordinating workshops with the project team, working closely with the GIS specialist, and taking the lead in the report writing. Typical candidates for this position are the wilderness specialist or lead planner for the wilderness area.

### **Ensure GIS capacity/capability**

A fundamental part of this project involves the production of GIS layers that represent threats to wilderness character. This requires compiling and creating an array of spatial datasets, processing them into map layers using a variety of GIS techniques, and finally combining these layers together to create the map products. Ideally, each wilderness should have an inventory of readily available spatial data, held either locally or regionally by the wilderness managing agency. The “Measures and Data Sources” spreadsheet lists commonly used measures for mapping wilderness character and their associated data sources. If required data does not exist, additional time should be factored into the project timeline for generating these data. The aforementioned tasks require specialist GIS skills, and would ideally be performed by a dedicated GIS professional working for the wilderness area. If there is no GIS specialist at the wilderness area, this task could potentially be outsourced to another agency office such as a regional office, or this work could be done by an independent GIS contractor or performed by University student or volunteer with strong GIS experience.

### **Assemble an interdisciplinary team**

To develop a wilderness character map, decision-making and knowledge input is required by staff that are familiar with all aspects of the wilderness area. Forming an interdisciplinary team is highly recommended for this purpose. The team will be responsible for the following tasks:

- Agree on the underlying strategy for the project.
- Identify measures and data sources for including in the map.
- Define weights for the measures.
- Provide data to the GIS specialist as required.
- Review the draft maps.
- Provide input for report writing.

The team does not need to include all staff with wilderness knowledge – selecting a smaller team will increase the ability to work through tasks more efficiently and effectively. An additional group of staff can then serve as consultants to the project, and be called upon to impart knowledge for specific issues. Potential team members may include (but not limited to) resource management staff (wildlife biologists, botanists, hydrologists, glaciologists, geologists, fire specialists), maintenance staff, backcountry rangers, law enforcement officers, interpretation staff, planners, and archeologists.

## **Approach**

A wilderness character mapping project uses GIS to spatially describe and assess impacts to wilderness character in a wilderness area. With this approach, it is essential to understand the variety of activities and influences that “threaten” wilderness character, as well as the role of wilderness managers in mitigating or responding to such threats. For example, in the Boundary Waters Canoe Area Wilderness (BWCAW) there has been, and continues to be, a substantial amount of human influence—ranging from a long history of human use and resource extraction, to current high visitation levels, to reasonably foreseeable future impacts from climate change. Although the BWCAW is far from being considered a “pristine” or “pure” wilderness, managers are nevertheless tasked with protecting and preserving its wilderness character from further degradation. Wilderness policies from each of the four wilderness managing agencies directly address the need for preserving wilderness character (Table 1). Only by understanding the myriad human influences that affect—or “threaten”—wilderness character can managers meet wilderness stewardship goals.

## **The Wilderness Character Framework**

Wilderness character maps adhere to the interagency strategy for monitoring wilderness character, as described in *Keeping It Wild 2: An Interagency Strategy for Monitoring Wilderness Character Across the National Wilderness Preservation System* (Landres et al. 2015). This interagency strategy was formally endorsed in the fall 2015 by the Interagency Wilderness Policy Council (which is composed of the highest policy-level personnel responsible for wilderness in each of the four wilderness managing agencies). Therefore, by adhering to the interagency strategy, wilderness character maps are consistent with interagency guidelines, terminology<sup>1</sup>, and monitoring protocols for wilderness character.

*Keeping It Wild 2* provides a tangible definition of wilderness character and identifies five qualities of wilderness character that apply uniquely to every wilderness: untrammeled, natural, undeveloped, solitude or primitive and unconfined recreation, and other features of value. These qualities apply to all designated wilderness areas because they are based on the legal definition of wilderness from the Wilderness Act (Section 2(c)). The five qualities of wilderness character form the foundation of the interagency monitoring strategy, and are the first level of the hierarchical monitoring framework. As described in *Keeping It Wild 2*, this framework divides wilderness character into successively finer components: the qualities of wilderness character are divided into a standard set of indicators<sup>2</sup>, which are monitored in turn through a set of locally relevant measures<sup>3</sup>. It is important that the project team understands the concept of wilderness character, and how the framework it provides is used to develop wilderness character maps (Figure 1).

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<sup>1</sup> Terminology used in this document to describe threats to wilderness character—including “degraded,” “negative impact,” “significant,” etc.—reflects common vocabulary used in laws, policies, and interagency wilderness character monitoring documents. These terms do not imply an analysis of impacts or determination of significant effects, such as required by the National Environmental Policy Act or other agency decision-making processes.

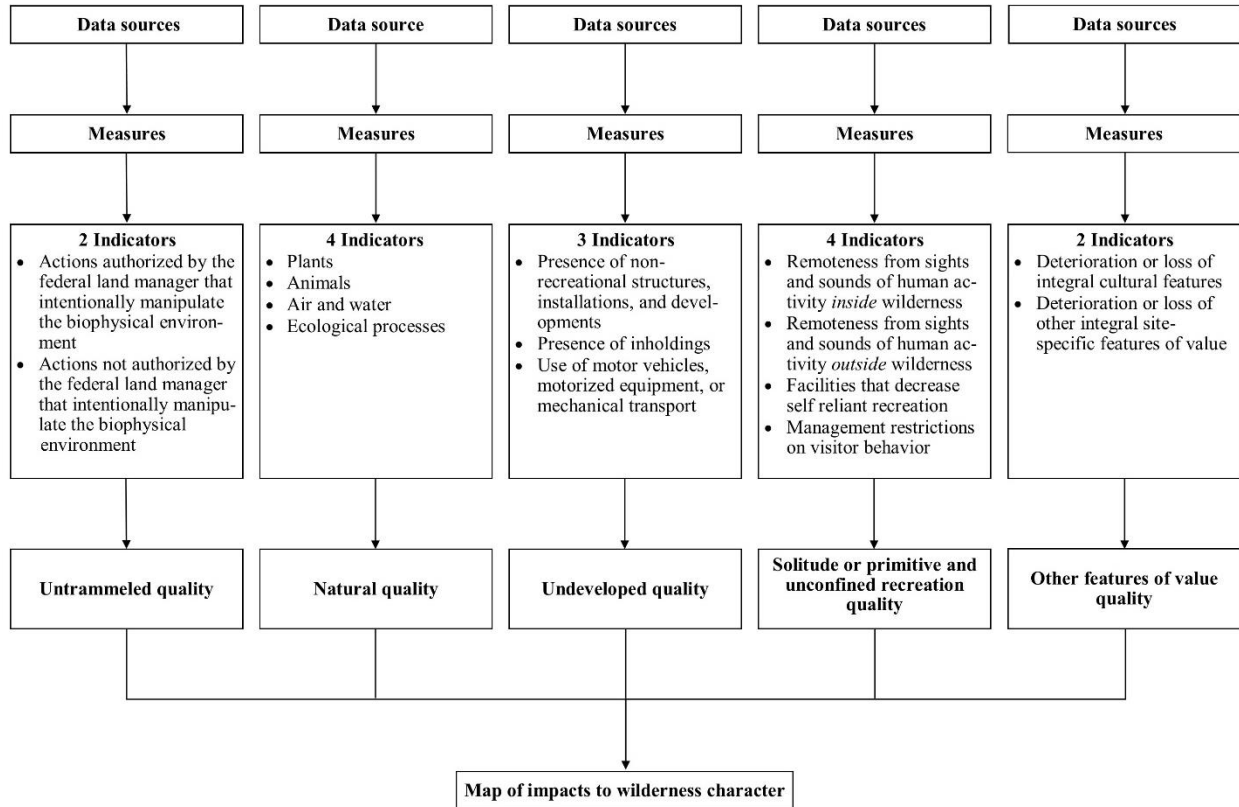
<sup>2</sup> Indicators are distinct and important elements within each quality of wilderness character. They have measurable attributes that can be the focus of wilderness character monitoring efforts.

<sup>3</sup> Measures are specific and tangible aspects of an indicator that can be measured to gain insight into the status of the indicator and to assess trends over time.



**Table 1.** Agency policy statements about the need to preserve wilderness character.

Agency	Policy reference	Policy statement
Bureau of Land Management (Department of the Interior)	43 CFR Part 6300 (Federal Register, Vol. 65, No. 241, page 78358, December 14, 2000)	I. Background. "Unless Congress specifies otherwise, BLM must ensure the preservation of <i>wilderness character</i> in managing all activities conducted within wilderness areas."
	Manual 6340—Management of Designated Wilderness Areas, Release 6-135, July 13, 2012	1.2 (A). Objectives. "Manage and protect BLM wilderness areas in such a manner as to preserve <i>wilderness character</i> ." 1.2 (B). "Manage wilderness for the public purposes of recreational, scenic, scientific, education, conservation, and historic use while preserving <i>wilderness character</i> ." 1.2 (C). "Effectively manage uses permitted under Section 4(c) and 4(d) of the Wilderness Act of 1964 while preserving <i>wilderness character</i> ."
		1.6 (A). Monitoring Wilderness Character. "Monitoring wilderness character, as outlined in Appendix C of this manual, is an ongoing responsibility of the agency."
Fish and Wildlife Service (Department of the Interior)	50 CFR 35.2 (a)	"[E]ach wilderness shall be administered for such other purposes for which the national wildlife refuge was established and shall be also administered to preserve its wilderness character."
	U.S. Fish and Wildlife Service Manual, Part 610 Wilderness Stewardship, Chapters 1–5, November 7, 2008	1.12. "As we carry out individual refuge establishing purpose(s) ... in areas designated as wilderness, we do so in a way that preserves <i>wilderness character</i> ."
		1.17 A. "Refuge System laws, regulations, and policies apply to refuge wilderness, but we carry them out in ways that preserve wilderness character and comply with the Wilderness Act's prohibitions."
		1.17 B. "We adhere to a much stricter standard than usual for approving actions in wilderness so that we maintain the <i>natural and untrammelled</i> condition of the wilderness."
		2.4 A. "We administer refuge wilderness to conform with the Wilderness Act's purposes of securing 'an enduring resource of wilderness,' preserving <i>wilderness character</i> , and providing opportunities for public use and enjoyment ... in ways that will leave the wilderness unimpaired for future use and enjoyment as wilderness."
		5.3 B. "We administer wilderness areas in Alaska in accordance with the policy in 610 FW 1-5."
National Park Service (Department of the Interior)	2006 Management Policies, Chapter 6: Wilderness Preservation and Management	6.1 General Statement. "The purpose of wilderness in the national parks includes the preservation of <i>wilderness character</i> and wilderness resources in an unimpaired condition ..."
		6.3 Wilderness Resource Management, 6.3.1 General Policy. "In addition to managing these areas for the preservation of the physical wilderness resources, planning for these areas must ensure that the <i>wilderness character</i> is likewise preserved."
	2013 Director's Order 41	6.2 Wilderness Character. "[E]ach wilderness park will integrate the concept of <i>wilderness character</i> into park planning, management, and monitoring in order to preserve the enduring benefits and values of wilderness for future generations." "Whenever a park planning process that has the potential to affect <i>wilderness character</i> occurs, the park should determine how <i>wilderness character</i> can be both integrated into the planning effort and presented in the planning document." " <i>Wilderness character</i> should be considered in the management and operations conducted by all divisions/work units."
Forest Service (U.S. Department of Agriculture)	Chapter 2320—Wilderness Management, June 21, 1990	2320.2 – Objectives, 4. "Protect and perpetuate <i>wilderness character</i> and public values including, but not limited to, opportunities for scientific study, education, solitude, physical and mental challenge and stimulation, inspiration, and primitive recreation experiences..."
		2323.14 – Visitor Management. "Plan and manage public use of wilderness in such a manner that preserves the <i>wilderness character</i> of the area."



**Figure 1.** Flow chart of the framework used for mapping threats to wilderness character.

## Timeline

Listed below is a generalized, month by month timeline for developing a wilderness character map.

### Month 1

Identify a coordinator to lead the project and assemble the project team. All project team members should be familiar with *Keeping It Wild 2*, Tricker and Landres, *In press*, and the commonly used measures and data sources spreadsheet (see the **Measures and datasources** spreadsheet in the toolbox). The coordinator will schedule a two-day meeting with the project team to achieve the following objectives:

- Explain the purpose of the project and present the wilderness character mapping presentation (See **Overview of mapping wilderness character** presentation in the toolbox). After this presentation, all team members should share a common understanding of what wilderness character is and how the mapping project will unfold.
- The project team will complete the strategic questions (see the **Strategic questions** document in the toolbox).
- The project team will identify measures for the 5 qualities of wilderness character (see the **Measures BLANK** spreadsheet in the toolbox) using the following steps:
  1. Compile a draft list of all measures threatening wilderness character, adding notes as necessary.
  2. Refine the list by completing the criteria for inclusion for each measure using relevance, work required, accuracy and completeness. Note existing or potential data sources for these measures. If data does not already exist on the agency network, identify a lead

person within the project team who will be responsible for acquiring data for each measure. This is an important step in the early stages of the project, as it reduces the workload on the GIS specialist (allowing him/her to focus on other project tasks) and allows staff familiar with the subject matter to quality control the data.

3. With the final list of measures, select weights for each measure.

After the meeting, the project coordinator will edit and complete the strategic questions document and measures spreadsheet as necessary, create a new sheet collating the data collecting tasks for each team member, and establish a workplan for completing the project. The coordinator will distribute these documents to the project team for review comments. After receiving all feedback, the coordinator will finalize the documents and agree on dates for the project team to deliver data to the GIS specialist. Note that a number of measure datasets may already exist in the agency database, negating the need for staff to track down these data. Finally, the GIS specialist will adapt the **WCM\_database** hierarchical folder system (available in the toolbox) to include new folders for the selected measures under each indicator.

### *Month 2*

The project team members will gather the datasets they are responsible for (working with the GIS specialist as required), and deliver them to the GIS specialist. Concurrently, the GIS specialist will begin assembling readily available datasets (i.e. wilderness boundaries, Digital Elevation Models, landcover, hydrography, infrastructure) and start developing map layers as data sets are received from the project team.

### *Month 3*

Towards the middle of the third month, all measure datasets should be delivered to the GIS specialist. The GIS specialist will spend a large proportion of this month processing the datasets into map layers, and begin compiling a set of draft wilderness character maps. Note that staff in the project team should be available to answer questions about the datasets they are responsible for as necessary.

### *Month 4*

The project coordinator will schedule a second two-day meeting with the project team to review the draft map layers. The team will assess each measure produced by the GIS specialist to ensure it captures the threat it represents to wilderness character. The GIS specialist will take notes for all edits required. The team will also review (and adjust as necessary) the weights for each measure. Following the meeting, the GIS specialist will make the final edits to the map layers and produce the final maps. During this time, the coordinator will begin writing the report (see the Wilderness Character Mapping report template in the toolbox).

### *Month 5*

The project coordinator and GIS specialist will prepare a first draft of the wilderness character mapping report. The coordinator will focus on the wilderness overview, description of measures, and rationales for weights. The GIS specialist will focus on the processing notes for each measure and producing figures for the indicator, quality and wilderness character maps and a histogram. Both will contribute to describing the overall map trends. At the end of the month, the coordinator will distribute the draft report to the project team for review.

### *Month 6*

The project team will complete their review of the draft report and return their edits to the coordinator. The coordinator will incorporate all edits and comments as required to produce a final draft of the report. If the report is to be published as an official agency document, the coordinator should consider sending the report out for external review before submitting it to agency editors. As required, the project coordinator and GIS specialist will be responsible for presenting the map products to the agency leadership team at the conclusion of the project.

## **Project team tasks**

This section constitutes three important tasks that the project team are required to complete before work can begin on developing layers for the wilderness character map.

### **Answer strategic questions**

There are several strategic questions that drive the entire process of building a wilderness character map. Answering these questions at the beginning of the process will allow a wilderness area to move forward in a more efficient way without having to go back and revisit these issues as they develop the map. These questions are listed approximately from general to specific order. Potential answers, in italics, synthesized from previous wilderness character mapping projects are offered as examples below the explanation of each strategic question. These questions are also available as a stand-alone document (titled **Strategic questions**) in the toolbox.

#### **1. Why is the wilderness area building a wilderness character map and how will it be used?**

There are many different reasons and each will drive the selection of measures and data sources that strongly affects the map.

*Potential reasons from previous wilderness areas include:*

- *Assess the effects of different plan alternatives on wilderness character.*
- *Establish a baseline to assess future trend in wilderness character.*
- *Evaluate cumulative impacts across all the qualities of wilderness character.*
- *Improve internal staff communication about wilderness and wilderness character.*
- *Improve external communication between the park and the public.*
- *Identify different zones within the wilderness to aid allocating resources and establishing thresholds for impacts.*

#### **2. Should the wilderness area strictly follow the qualities and indicators from Keeping It Wild 2?**

The wilderness area could add other indicators if those from *Keeping It Wild2* do not adequately capture something important.

*All the wilderness areas that developed a wilderness character map have used the indicators from Keeping It Wild 2 and so far no wilderness areas have added additional indicators (although they all reserved the right to do so if deemed necessary to capture an important element of the wilderness that wasn't adequately accounted for in Keeping It Wild 2.)*

#### **3. Should the wilderness area include the "other features of value" quality of wilderness character?**

The wilderness area could include measures for the other features of value quality of wilderness character, such as the condition of cultural and paleontological resources, or other measures as appropriate.

*Four out of the eight wilderness areas chose to include this quality. These wildernesses developed their own unique set of indicators and measures for this quality, based on the type of resources. Four of the wildernesses expressed interest in including this quality but did not develop specific measures. All wildernesses expressed concerns about making such data available in a map that could be seen by the public. Olympic National Park made the decision to only use this quality internally, and chose not to include this quality in any public documents.*

4. Should the wilderness area try to incorporate intangible measures (such as spiritual or symbolic values, or visitor experiences)?

Wilderness character could include intangible and experiential aspects, so wilderness areas could try to incorporate these into the map, although the wilderness would most likely need to develop new protocols to do this.

*None of the wilderness areas that developed a wilderness character map have tried to develop and incorporate intangible measures. There are several reasons for this, including the lack of an ability to adequately quantify any intangible measures in a way that could be mapped, and the desire to not map spiritual values of indigenous people. All wilderness areas acknowledged that intangible values were important but such information would only be used internally by staff for planning purposes to ensure that management activities didn't compromise these values.*

5. Should the map show only degradation to wilderness character?

This is primarily a technical issue of distilling many different types of data into a single spatial product. All wildernesses want to show the positive effects of management actions on wilderness character but showing these on the same map that depicts degradation of wilderness character masks what is happening. For example, if herbicides are used to treat exotic, invasive plants, the natural quality would improve and the untrammeled quality would degrade—the positive and degrading effects cancel each other out on the map.

*Most wilderness areas that developed a wilderness character map expressed interest in depicting positive management actions and attributes of wilderness. The best approach considered for attempting this was to develop separate products: one map depicting where wilderness is degraded and another map depicting where wilderness is improved or enhanced. To date, only Gates of the Arctic National Park and Preserve has produced a positive features map, which involved identifying three indicators (Natural features, Cultural features, and Management actions) with a set of measures for each quality.*

6. Should the wilderness area use the same measure in more than one quality?

Most measures could be included in more than one quality. For example, the data point for the presence of a management-created barrier in a stream to prevent exotic fish from moving upstream could be included in any of four qualities (the barrier disrupts water flow so degrades the natural quality; the decision to build the barrier degrades the untrammeled quality; the presence of the structure degrades the undeveloped quality; seeing the structure degrades the solitude quality).

*In general, all wilderness areas chose to use a measure under what staff felt was the single most appropriate quality because of concerns about over-emphasizing a particular measure if it was included in more than one quality. However, all wilderness areas decided that different types of data for a single measure were appropriate to use in different qualities. For example, the physical structure of artificial water sources (guzzlers) in Death Valley were shown as degrading the undeveloped quality, and the area around the guzzlers was shown as degrading the natural quality because of the multiple effects on flora and fauna caused by the increased ungulate presence. All wilderness areas reserved the right to include a measure in more than one quality and then weight the measure differently in the different qualities.*

7. Should the wilderness area weight the qualities or just weight the measures within each indicator?

The Wilderness Act does not state that any one aspect of wilderness is more important than any other, even though the on-the-ground reality is that some things cause greater impacts than others, and the

establishing legislation for some wildernesses may place greater emphasis on one aspect of a wilderness.

*All the wilderness areas that developed a wilderness character map chose to weight the qualities equally, the indicators under each quality equally, and only identify weights for the measures under an indicator.*

8. Should the wilderness area include measures that they do not have data for?

No wilderness area will have data for all the things that degrade wilderness character, even for some of the most important things such as climate change or loss of connectivity with the surrounding landscape, so how should these situations be treated?

*All the wilderness areas that developed a wilderness character map chose to include measures that were deemed crucial or of such importance that they wouldn't pass the red-face test if they weren't included, even when data for such measures did not exist or were not sufficiently reliable to be used. These measures were included under their appropriate indicator, weighted along with the other measures under that indicator, but not included in the mapping process. By including them and weighting them, such measures could be easily incorporated into the map when the data become available, and they have been identified as of high priority for future data collection efforts when resources become available.*

9. Should the wilderness area create separate wilderness character maps for different units, or for designated, recommended, and eligible wilderness?

There are many different configurations of wilderness across the National Wilderness Preservation System and each area will need to decide if they want to create one map or separate maps.

*Both Olympic and Saguaro wildernesses comprise of two spatially separated wilderness units – they decided to use a single protocol and weighting scheme for both compartments. Denali National Park and Preserve and Gates of the Arctic National Park and Preserve decided to create one map for designated and eligible wilderness, and include both park and preserve lands in this map.*

10. Should the wilderness area create different wilderness character maps to reflect different seasonal patterns?

This strongly depends on the wilderness area and the seasonality in use and impacts.

*Denali National Park and Preserve decided to create different maps to reflect summer and winter patterns because use and impacts are so different between these two seasons (these differences were only depicted in the Solitude quality). Death Valley National Park considered seasonal maps but there were not enough measures that would change seasonally to make this worthwhile.*

11. What is the spatial resolution for the map?

Spatial data come in a variety of different resolutions, from 1-square meter up to many square kilometers.

*Wilderness areas have used either 30-meter or 100-meter resolution, depending on the data availability and the size of the park. Some wildernesses used 30-meter resolution even though they had 10-meter data because 30-meter resolution was considered adequate for the purposes of the wilderness character map.*

## 12. How far back in time will data be used in creating the map?

Ideally, data are available back to the date when the wilderness was established, but rarely will an agency have such data. Instead, the first time the wilderness character map is created will become the de facto baseline, and agencies will need to decide how far back in time to use data if it is available.

*All wilderness areas decided that the year the wilderness character map is created will define its baseline for evaluating future change. Denali National Park and Preserve decided to go back up to five years for the untrammeled quality, depending on data availability, and go back as far as possible for the other qualities, as data availability allows. Most wilderness areas typically followed this approach, with some variation in the timescale for the untrammeled quality (some wilderness areas went as far back as 10 years). Denali also decided to create a “retrospective” wilderness character map using professional judgment back to the time of wilderness designation to use in estimating change to wilderness character since it was designated wilderness.*

### **Select measures and spatial data**

Each wilderness is unique in its combination of geographic setting, biophysical properties, enabling legislation, and administrative direction (Landres et al., 2015). As a consequence, measures that represent features, conditions, and actions that threaten wilderness character vary from one wilderness to the next.

Selecting measures under each of the five qualities is an iterative and collaborative decision making process. Possible measures are first identified by the project team, and then evaluated for their relevance to the indicator and the availability and quality of the required data. The quality of the required data for each measure is assessed using two metrics: accuracy (how well the dataset represents the measure) and completeness (how complete the dataset is across the entire wilderness). In general, only measures that are relevant, and that have readily available data of sufficient quality, are used for developing the wilderness character map. For certain measures this may involve developing new datasets based on institutional knowledge (i.e. drawing known locations of impacts onto paper maps, which can then be digitized by the local GIS specialist). In some cases, potential measures may have insufficient or non-existent data but can still be acknowledged for their significance to their respective indicators. As data improve or become available, these “data gap measures” should be reevaluated for inclusion in future iterations of the wilderness character map.

Both vector and raster datasets are used to generate measures that depict the distribution of threats across a wilderness area. The majority of vector data, comprising of points, lines and polygons, is agency produced or commissioned, including datasets depicting infrastructure (buildings, roads, trails, campsites, and toilets), wildfire perimeters, non-native invasive species, science installations, and administrative motorized use. Certain datasets can be developed specifically for the mapping projects, such as joining tabular records with relevant spatial data to depict trail encounters, travel zone occupancy and poaching incidents or newly digitized spatial data based on institutional knowledge (such as rangers drawing specific features onto paper maps). Lastly, certain vector data can be obtained from national, regional or state sources, such as the hydrology, fish and wildlife, and glaciology. Raster-based data consist of a matrix of cells (organized into rows and columns) where each cell contains a value representing information.

Raster data were either obtained from nationally produced datasets such as departure from historic fire regime (LANDFIRE, 2012), air quality (CASTNET, 2016) and soundscape (Mennitt et al, 2013); or from



more localized, project specific output such as night sky (Duriscoe et al, 2007), overflight noise pollution (Betchkal, 2013), or customized vegetation maps (Volter et al, 1995).

See the **MeasuresDatasources** spreadsheet for a list of commonly used measures (and their potential data sources) for developing a wilderness character map, and the **Measures BLANK** spreadsheet for selecting measures. Both documents are available in the toolbox.

### **Choose weights**

Once measures are selected, each need to be evaluated independently to determine the magnitude of its effect on wilderness character. Some measures have a greater impact to wilderness character than others; for example, at the Boundary Waters Canoe Area Wilderness, the departure from natural fire regimes measure has a relatively greater impact (because fire suppression is widespread and causes blowdowns, tree species changes, and fuel build up), whereas the shoreline erosion measure has a relatively smaller impact (because it only occurs at one location). To accurately portray the variable magnitudes of the measures' effects, each measure is assigned a "weight"—a value from 1 (low impact) to 10 (high impact)—by the project team. The project team can then review the draft maps and modify the weighting scheme to reflect their knowledge and experience of the condition of wilderness character on the ground. While this interactive process runs the risk of allowing staff to "game the system" to produce a desired outcome, staff experience has been shown to be highly accurate in judging resource conditions (Cook et al., 2014). The project team must employ caution and consensus-driven oversight to ensure accuracy in the maps produced.

Specific rationales for weights assigned to each measure should be recorded in the wilderness character mapping report under their respective qualities. The following questions are used to help determine weights for all measures:

- Is the measure spread throughout the wilderness (higher weight) or specific to a particular area (lower weight)?
- Does the measure represent a major management issue, e.g. suppressed fires (higher weight), or is it something relatively benign, e.g. boundary markers (lower weight)?
- Does the measure depict an emerging threat that requires intensive management, e.g. the spread of non-native invasive species (higher weight), or does it depict an issue that has largely been solved and is no longer of high concern to management, e.g. sulfur deposition (lower weight)?
- Is the measure an issue year-round (higher weight) or relevant to a particular time of year or season (lower weight)?
- Are the data representing the measure accurate and complete (higher weight) or are they of poorer quality (lower weight)?
- Are the data quantitative (higher weight) or qualitative (lower weight)?

The initial set of weights should be recorded in the measures spreadsheet under the "weights" column.

## **GIS tasks**

Individual measures are mapped by applying GIS processing techniques to their respective datasets using ArcGIS. For vector-based data, features representing threats to wilderness character are assigned values to represent their spatial impact on the landscape. This task can utilize either a simple binary approach for features such as exotic plants (i.e. presence = 1; absence = 0) or a range of values for datasets representing different types of features such as research installations (where the footprint or visibility of the feature dictates the assigned value). All vector data are then converted to rasters at a pre-specified resolution. Note that the process of converting vector data to a raster will often exaggerate the footprint of the respective features (known as “pessimistic resampling”). For example, when converting the point locations of invasive species to a raster, the location of the individual plants will now be represented by a cell at the specified resolution (i.e. 30m). This exaggeration may skew the reality on the ground, but given the scale and purposes of the map, this approach provides a standardized method for representing features across the wilderness. Certain types of vector data may require additional processing techniques, such as density analysis, to provide for more intuitive interpretation of the raw data. See previously completed wilderness character mapping reports (in the toolbox) for further examples of data that were created and processed into map layers.

### **Create new data**

Depicting certain measures may require the creation of new datasets. Outlined below are four instances where this may be necessary, with associated examples:

- Creating new spatial information from institutional knowledge – this can either occur by a subject expert drawing information onto printed maps, which can then be digitized by the GIS specialist; or the subject expert working directly with the GIS specialist to create new digital datasets.
- Amending existing spatial data with new attribute information – for example, joining visitor encounter statistics data to backcountry management zone polygons.
- Creating new data layers from existing spatial information – for example, interpolating point data from collared animal locations to create a “heat map” depicting collar location density across the wilderness.
- Combining multiple datasets together for one measure – for example, combining datasets together depicting different types of research installations.

### **Process vector data**

For pre-existing datasets, there are typically three main tasks for processing these data into map layers:

#### *Project data*

All data should be projected to the local coordinate system as necessary. Use the ArcToolbox **Project** tool to reproject datasets.

#### *Query or edit existing data*

A number of datasets may require additional querying or editing, and may necessitate input from subject experts. For example, an agency dataset for non-native invasive species might include both sites where invasive species are present and where they have been treated. Therefore, this dataset would need to be queried to show the correct data under each quality (i.e. the presence of invasive species in the Natural Quality, and the treated sites in the Untrammeled Quality). Querying data can be performed by simply sorting information in the

attribute table or running more complex queries using the Selection tools (i.e. Select By Attributes or Select By Location).

Editing data may be required to capture specific impacts to wilderness character. For example, suppressed fire data are often represented by the entire surface area (polygons) where the fire burned. However, the actual trammeling action to put out the fire may have only occurred on one or two fronts of the fire (i.e. the creation of firelines or the use of retardants). The GIS specialist should work with the subject expert to amend these data as necessary using the editing tools to accurately capture the actions that occurred. Another commonly performed task is buffering features (see Geoprocessing tools) to capture the full extent of their impact. For example, a road corridor may be buffered to a distance agreed by the project team to capture its associated noise impacts. Finally, certain polygon data (typically for non-native invasive species locations) may be too small to convert to raster. The GIS specialist can address this by converting polygons (under a particular size threshold) to points using the ArcToolbox **Feature To Point** tool.

### *Assign values*

Once data are collected for each measure, the next step is to assign values to the spatial information that reflect the impact of the measure on the ground. Typically, in a presence/absence scenario (i.e. non-native invasive species), the location of the impacted site is assigned a value of 1 (and in theory the rest of the wilderness becomes a value of zero for that particular measure).

To assign values, open the attribute table for the appropriate shapefile and under Table Options select "Add Field". Choose a name for the new field (e.g. WC\_value) and populate it with values for each feature associated with the shapefile. If all features in the shapefile require the same value, right click the value field and select "Field Calculator" and enter the required value for all the features.

Certain measures may require a range of values or a simple metric to represent the different levels of impact depicted by the measure. For example, installations may range in size from small boundary markers to large radio repeaters, or inholdings may have different levels of development potential (depending on the landowner). The project team should use their professional judgement when determining the scale of values, which can be as simple as a range of 1-5 or 1-10.

## **Analyze viewshed and travel time**

Two GIS-based models have been used in previous wilderness character mapping projects to generate measures that represent threats to the solitude quality:

### *Viewshed*

Line of sight impacts of modern human features both inside and outside wilderness can significantly detract from a sense of solitude. A viewshed analysis can depict these line of sight impacts of modern features, as determined by their size and visibility. Performing this analysis has a significant time cost, with the respect to collating and prepping the model inputs and running the model (which can take months depending on the size of the wilderness, resolution of the inputs, and the processing speeds of available PCs). However, understanding the effect of

viewshed impacts on a wilderness area in a spatial context serves as a powerful tool for managers, and this approach is also particularly useful for evaluating the viewshed impacts inside a wilderness from proposed developments adjacent to wilderness areas (i.e. see the Mapping Wilderness Character in Gates of the Arctic National Park and Preserve report, which analyzed the impacts of a proposed road construction project adjacent to existing wilderness).

A Digital Surface Model (DSM) would typically be the preferred dataset for developing inputs for a viewshed analysis – these data contain elevations of natural terrain features in addition to vegetation and human features such as buildings and other types of infrastructure. Because DSMs are usually fine scale (increasing computational time costs), expensive to produce, and have limited coverage, no wilderness character mapping projects to date have used this product to perform a viewshed analysis.

In lieu of DSMs, a Digital Elevation Model (DEM)<sup>4</sup>, which are bare earth raster grids (available for the entire country at multiple resolutions), can be used to provide the basic elevation data for the viewshed environment. This layer can then be augmented with vegetation<sup>5</sup> and feature height data to produce a basic terrain model. The feature height data will need to be rasterized and clipped into the vegetation layer, so the features do not “sit” on top of the vegetation data. This can be done utilizing the Mosaic Operator option in the ArcToolbox **Mosaic To New Raster** tool. This new layer can then be added to the DEM (using the raster calculator) to create the terrain model. Care should be taken to ensure all layers share the same projection and grid resolution, and are snapped to same extent. To account for edge effects<sup>6</sup> from visible human features immediately outside the wilderness boundary, the viewshed analysis area should include a buffer zone around the wilderness (usually between 15-30km).

Numerous software programs exist for running viewshed analysis. ArcGIS offers a viewshed tool that determines the raster surface locations visible to a set of observer features. However, the output for this tool is binary and does not consider factors such as distance from a viewshed feature. The viewshed measures for all wilderness character mapping projects to date have utilized custom-made software called Viewshed Explorer<sup>7</sup>, which uses an inverse square distance function to calculate the significance of visible cells. Put simply, this tool determines the relative viewshed value for each cell by calculating the proportion of the features that can be seen and the distance between the cell and the particular features. Thus, the smaller the proportion of the feature in view and the further away it is, the lower the viewshed value for the particular cell. The greater the proportion of the feature in view and the closer it is, the higher the viewshed value of the particular cell.

To use the viewshed explorer, two input grids are required. The first grid is the viewshed environment (the DEM augmented with vegetation and feature height data), and the second grid is the feature information for analyzing inside the viewshed environment. Both inputs need to be converted to floating point grids – see the ArcToolbox **Raster to Float** tool. Depending on what distance the viewshed analysis is set to (i.e. the distance after which a feature is no longer

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<sup>4</sup> Available at the USGS National Map website: <https://nationalmap.gov/elevation.html>

<sup>5</sup> For example, the LANDFIRE existing vegetation height dataset: <https://www.landfire.gov/NationalProductDescriptions22.php>

<sup>6</sup> A problem created during spatial analysis when patterns of interaction or interdependency across borders of the bounded region are ignored or distorted (ESRI 2015).

<sup>7</sup> Available from <http://www.wildlandresearch.org/media/uploads/Voxel-Viewshed-Explorer.pdf>

visible to the human eye), it may be necessary to run the analysis in batches by breaking up the two input grids into a set tiles. This will also enable the analysis to be run on multiple PCs. Once the analysis is completed, the tiles can be stitched back together again using the ArcToolbox **Mosaic To New Raster** tool.

Examples of viewshed analyses, including further details on types of features analyzed and data processing tasks, can be found in the Solitude quality section of previous wilderness character mapping reports.

### *Travel time*

A travel time model can be used to identify areas of a wilderness that are more remote than others due to the time 'cost' of travelling across the landscape. The model is based on a GIS implementation of Naismith's Rule (with Langmuir's correction<sup>8</sup>), which provides a simple formula that helps to plan a hiking expedition by calculating how long it will take to walk a route, including ascents. The model allows wilderness managers and planners to better understand how access to wilderness areas can impact these remote areas, and help facilitate the determination of different management zones within the wilderness area.

Terrain and landcover information are used to calculate the relative time necessary to walk into a roadless area from the nearest point of legal motorized access, taking into account the effects of distance, relative slope, ground cover, and barrier features such as very steep ground and water bodies. DEMs are used for adjusting walking speeds based on slope angle (for both ascent and descent) and landcover data can be used to determine impedance to walking speeds based on different vegetation types. These layers can be augmented with trails (which will generally provide the easiest walking options through a landscape) and rivers (which can be programmed to add a time cost for crossing depending on the size of the river).

Travel time analyses can be performed in ArcGIS using the ArcToolbox **Path Distance** tool. Inputs required are a source grid (i.e. trailheads and/or roads), elevation data (DEM), and a cost surface. The cost surface input can be configured by providing impedance values for the different types of vegetation found in a land cover layer. For example, dense forests and alder/willow should have high impedance values, whereas more open terrain such as grasslands and sagebrush should have lower impedance values. The cost surface input should also include impedance values for the time it takes to cross rivers. Impassable (steep) terrain and rivers, along with lakes, should be coded as "null" to force the "hiker" to walk around these features. A simple lookup table (Table 2) can be used to account for vertical and horizontal factors when moving from one cell to another. As with the viewshed analyses, care should be taken to ensure all travel time inputs share the same projection and grid resolution, and are snapped to same extent. To account for edge effects from access points outside the wilderness boundary, the travel time analysis area should include a buffer zone around the wilderness (15km is typically the maximum distance used).

Examples of travel time analyses, including further details on calculating travel speeds for the cost surface grid and additional data processing tasks, can be found in the Solitude quality section of previous wilderness character mapping reports.

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<sup>8</sup> Langmuir's correction acknowledges the need to descend slowly in steep terrain as it is necessary to take shorter steps, or reduce slope angle and extend path length by zig-zagging.

**Table 2.** Vertical relative moving angle (WRMA) field.

VRMA (Degrees)	Vertical factor
-40	2.4
-30	1.87
-20	1.45
-12	0.29
-11	0.33
-10	0.37
-9	0.44
-8	0.47
-6	0.51
-5	0.72
0	0.72
10	1.78
20	2.9
30	4.19
40	5.75

### **Process raster data**

Raster datasets consist of a matrix of cells (organized into rows and columns) where each cell contains a value representing information. The main task for prepping these data is re-projecting the raster to the relevant coordinate system and clipping the raster to the study area boundary (taking care that they are all snapped to the same extent). This includes output from the viewshed and travel time models.

### **Documentation**

A variety of data processing techniques are used for developing the measures for the wilderness character map. For the purposes of transparency and repeatability, the GIS specialist will need to produce notes for all major processing tasks utilized for each measure. These notes can be added to the project report, in order to facilitate deeper understanding of how the overall wilderness character was developed. For each measure, the notes should cover:

*Sources:* list relevant information pertaining to the data source, including data type, date range, and person responsible for creating/maintaining the dataset.

*Processing notes:* describe the major processing tasks for converting the raw data into map layers.

*Cautions:* describe any major caveats associated with the raw data and/or the processing tasks.

## Convert vector data to rasters and normalize values

Once all datasets representing measures are assigned values, the next steps are to rasterize the vector data and then normalize the values for all measures by slicing (linear rescaling) them onto a standardized scale of 0-255 on an equal interval basis. This normalized range of values allow datasets, and therefore measures, to be evaluated together on a common relative scale (Carver et al. 2008) whereby the 'polarity' of these individual map layers are maintained such that lower values represent optimal conditions and higher values represent degraded conditions (Carver et al. 2012). For example, soundscape and nitrogen deposition measures use different units (decibels vs. parts per billion) and cannot be analyzed together without normalization.

### *Convert a vector dataset to a raster and normalize values*

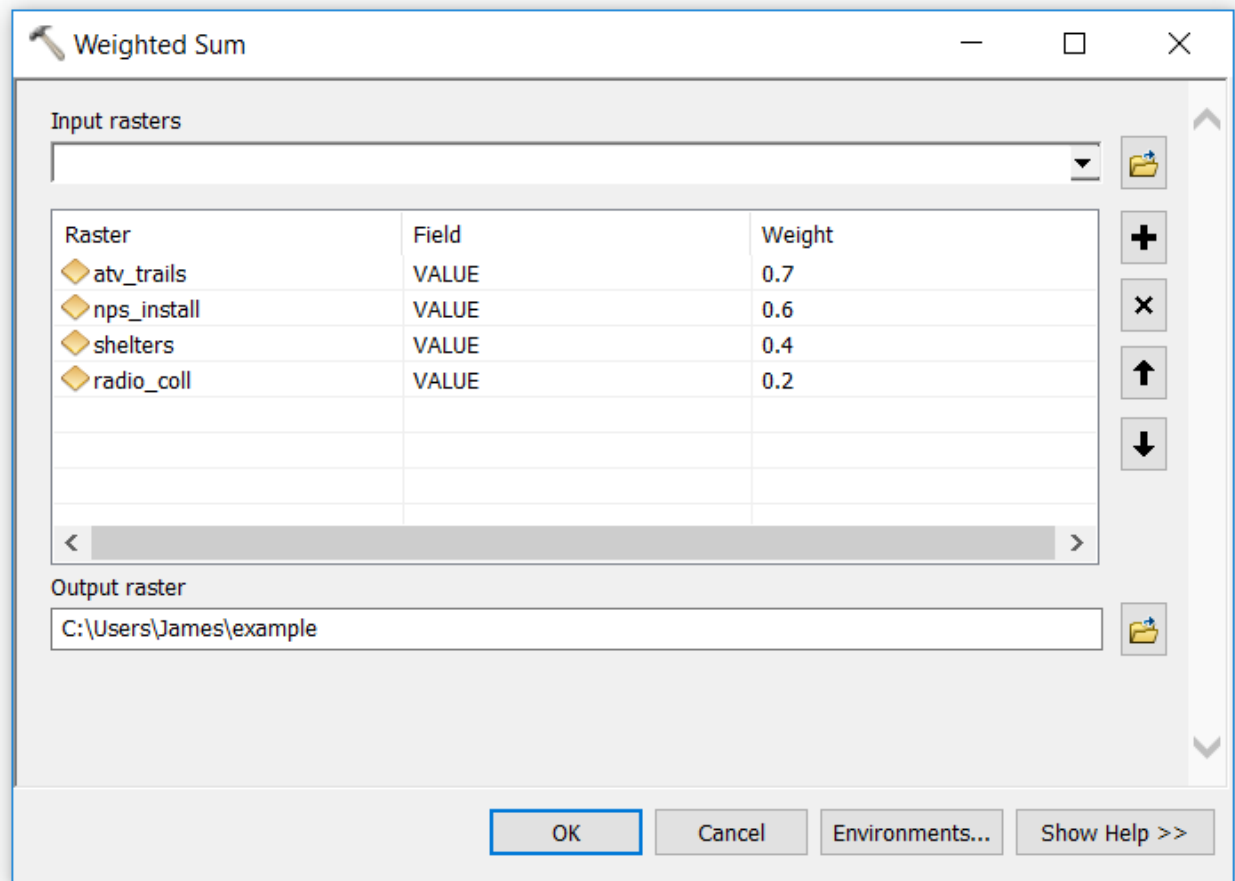
All measures represented in vector format need to be converted to raster and have their values normalized. A tool can be created in ArcGIS model builder to automate this process. Instructions for creating this tool are described in Appendix A, and a generic version of the tool is available in a zip folder in the toolbox (instructions are provided for adapting the tool for a particular wilderness, including setting the local coordinate system and creating the study area mask).

### *Normalize raster values*

1. If necessary, change the primary value field for the non-normalized raster (if a raster has more than one field of values in the attribute table, only the primary field will be used for raster calculations). Open the ArcToolbox and select the ArcToolbox **Lookup** tool. Select the input raster and the new primary field, and save to a new raster.
2. To normalize the raster values, open the ArcToolbox and select the ArcToolbox **Slice** tool.
  - 2.1 Select the raster for normalizing, choose a name for the output.
  - 2.2 Set number of output zones to 256
  - 2.3 Set the Base zone for output to 0
  - 2.4 From the environments tab, click Processing Extent and set Snap Raster to the study area mask.
  - 2.5 From the environments tab, click Raster Analysis and set Cell Size and Mask to the study area mask.

## Combine measures

Once all the measures have been normalized, the next step is to combine them together using their respective weights (that were recorded in the measure spreadsheet when the project team met in the first meeting) to create the indicator maps. This can be done using the ArcToolbox **Weighted Sum** tool (Figure 2). Repeat this process for all the other indicators.



**Figure 2.** Weighted sum tool for combining measures together using weights.

The indicator maps are then added together in the ArcGIS raster calculator (i.e., Indicator1 + Indicator2 + Indicator3) to produce maps for their respective quality, and finally the quality maps are combined together to produce the map of threats to wilderness character.

This map, along with the individual measure layers, should be reviewed by the project team to assess how accurately they portray the on-the-ground impacts in the local wilderness area. This process will also enable the project team to review and adjust the measure weights as necessary. The GIS professional will make any required edits to the map layers (and adjust the measure weights as necessary) before finalizing the map products.

### **Reclass output**

For the purpose of interpreting the wilderness character map, the final GIS task involves reclassing the map (using equal intervals<sup>9</sup> in the ArcToolbox **Reclassify** tool) to transform the range of values for all map pixels onto a scale of 0 (most degraded condition, highest cumulative threat level from all measures) to 100 (optimal condition, no threats to wilderness character). These values can then be split into ten equal categories (i.e. 0-10, 11-20, 21-30, etc.) to clearly emphasize the variation in the magnitude of threats to wilderness character. A histogram of this reclassified map can then depict the distribution of pixel values per category.

<sup>9</sup> This reclassification scheme divides the range of attribute values into equal-sized sub-ranges, allowing the user to specify the number of intervals while ArcMap determines where the breaks should occur (ESRI 2015).



### **Create final maps for the report**

Create vicinity maps and final indicator maps to be used as figures in the final report. The final indicator maps should be created using an appropriate color ramp – the majority of wilderness character maps have used a green (optimal condition) – brown (degraded condition) color ramp, but some wilderness areas have requested a blue-red option which is easier to discern for people that are color blind. The maps should also be displayed using the “minimum-maximum” stretch method<sup>10</sup> to accurately reflect the range of values of the final map products.

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<sup>10</sup> The stretch method defines the type of histogram stretching that was applied to raster datasets to enhance their appearance. The minimum-maximum stretch applies a linear stretch on the output minimum and output maximum pixel values, which were used as endpoints for the histogram (ESRI 2015).

## **Reporting tasks**

### **Assess trends**

The map products are used to describe the overall trends in wilderness character for the wilderness area. The ten reclassified categories can be used to reference specific areas within the wilderness that exhibit optimal or degraded condition. Emphasis should be placed on explaining the accumulative influence of measures across the landscape, particularly for the heavily degraded areas. The task of describing these trends will typically be undertaken by the project lead, with input from the GIS specialist as necessary. Below is an example of a well written discussion for the Boundary Waters Canoe Area Wilderness, which referenced a number of lakes in describing the overall trends in wilderness character (see the full report for map figures and histogram):

*The histogram of the distribution of pixel values shows that most pixels fall within the 71-80 or 81-90 categories, indicating that the majority of the wilderness has high quality wilderness character that has not been substantially impacted by threats. Overlaying the map of threats to wilderness character with a map of BWCAW waterbodies reveals that patterns and variations in the magnitude of threats are strongly linked to lakes for both high quality and degraded areas. The lowest quality categories are highly correlated with lakes that allow motorized use, especially those that are wilderness entry points. The lowest four categories (0-40) are primarily clustered around the end of the Gunflint Trail (Saganaga and Seagull lakes) and the Fernberg Road (Snowbank, Parent, Moose, Newfound, Found, Basswood—especially Pipestone Bay, Newton, Fall, and South Farm lakes). Additional areas within these categories include lakes in the Trout Lake and Vento units (Trout, Clearwater, Duncan, and East Bearskin lakes), Paulson Lake (south of Seagull Lake), and a small portion of Knife Lake (near Thunder Point). Of the 17 lakes within the lowest four categories, twelve allow motorized use (encompassing more than half of all motorized lakes in the wilderness), eight are motorized entry point lakes, and an additional six are easily accessible via a short portage from an entry point.*

*In contrast, the highest quality categories are primarily found away from entry points and travel routes, especially in areas with fewer and smaller lakes and within pristine management areas. The three largest areas within the highest category (91-100) are found in the La Croix and western Kawishiwi districts (from west to east, these are: the area between Finger and Hustler lakes, the area east of Stuart Lake, and the area south of Crooked Lake's Thursday Bay). In addition to these larger areas, hundreds of individual lakes spread across the wilderness are also within the highest category. These lakes tend to be smaller in size and more difficult to access: many lack designated sites or maintained portages, and dozens are so small as to be unnamed. While some of these high quality individual lakes are on the western side of the BWCAW, the majority are concentrated in the center of the wilderness around the northern portion of the Tofte District. Other areas with high quality lakes include the southeastern Kawishiwi District and the northwestern Gunflint District. In general, smaller lakes and areas that are more difficult to access have fewer threats to wilderness character than larger lakes and areas near popular entry points.*

### **Report writing**

The project coordinator will usually serve as the lead author for the wilderness character mapping report. To aid report writing, **WCM report template** is available in the toolbox. This template provides a generic report outline, with instructions for completing the various sections. The author should be

mindful to adapt this report to the specific agency that administers the wilderness. The main report writing tasks are as follows:

### General

- Insert administrating agency, unit and wilderness names as necessary.
- Provide locally relevant examples for wilderness character mapping concepts in the project overview and methods sections.

### Introduction

- Provide a history and description of the wilderness area.
- Insert agency/wilderness maps.
- Outline the purposes of the mapping project.
- Edit the concerns and cautions section as necessary.
- Insert the total number of years the project team has worked at the wilderness in the report outline.

### Overview of the Process for Developing the Map of Threats to Wilderness Character

- Edit this section to reflect relevant agency wilderness policy.
- Update the flow chart to reflect numbers of measures and data sources using the editable publisher document available in the toolbox.

### Methods

- Edit the data sources section as necessary
- Provide details on local projections and the agreed mapping resolution.
- Provide descriptions for each measure under the respective quality sections. If necessary, also provide descriptions for datagap measures, along with a rationale for not including the measure in the map.
- Populate the dataset tables under each quality with data source information for all measures.
- For each measure, provide relevant information for the data sources, processing notes, and any associated cautions. Enlist help from the GIS specialist as necessary.
- Populate the weights tables under each quality with rationales for the measure weights.
- Insert indicator and quality maps.

### Map of Threats to Wilderness Character

- Generate a histogram for the reclassified wilderness character map.
- Provide a description of the trends in the wilderness character map.
- Edit the improvements section to reflect agency/unit policy on data collection.

Each project team member should have the opportunity to review the report before it is finalized. External reviewers may be required if the wilderness managers want to publish the report as an official agency document.

## **Lessons learned**

This section consolidates lessons learned from developing the first wilderness character map for the Death Valley Wilderness, and refining this approach at 6 additional wilderness areas.

### **Capacity**

The decision to undertake the development of a wilderness character map should not be taken lightly. The process requires a significant time commitment from the staff involved and requires the availability of a wide array of spatial data. Therefore, it is important to fully understand the requirements outlined at the beginning of this document before greenlighting such a project.

### **Keeping it Wild 2 and wilderness character**

It is extremely beneficial to the process of developing a wilderness character map that everyone on the project team is familiar with the concept of wilderness character. Team members should be well versed in the framework – how wilderness character is broken down into finer sets of qualities, indicators and measures. Team members should also attempt to integrate existing assessments, inventories and monitoring projects into the mapping project where possible.

### **Strategic questions**

This is an important part of the process, and is worth spending the time to make sure every question is fully understood and answered appropriately. Essentially, the answers to these questions lay the foundation for developing the map. With shaky foundations, the map may need to be rebuilt before it is finished.

### **Data availability**

At the beginning of project, the project team will identify a set of measures for the wilderness that represent the many impacts that threaten wilderness character. To develop the wilderness character map, these measures will need to be depicted using spatial information. Unfortunately, a number of these measures will likely need to be omitted from the map due to either a lack of suitable data, or data that can't be processed into a useable map layer. This can be frustrating, particularly if a measure has a significant influence on wilderness character. However, every wilderness character map produced to date has encountered this problem. It is important to recognize these issues when identifying measures, and acknowledge them when writing the report. This can be done by listing these measures as having "data gaps", and fully describing the associated issues. This ensures transparency and may enable the measure to be used in the future as new information becomes available or existing information improves.

### **Data sharing protocols**

Once the project team has identified measures for depicting in the wilderness character map, the GIS specialist should adapt the **WCM\_database** hierarchical folder system (available in the toolbox) to include new folders for the selected measures under each indicator. This database will enable all data to be well organized and easy to locate. Ideally, the database should be located on a local agency network so that administrative rights can be extended to the project team and subject experts so they can submit requested information to this database independently. The GIS specialists should ensure that all data submitted to the database meets with required metadata protocols, such as the date and resolution of the dataset, who created the data and any associated caveats. Finally, the database should be accompanied with a measure spreadsheet that tracks progress on data delivery and processing. This

can be customized as necessary, i.e. color coding measures according to their current status (i.e. no data available yet, or measure completed).

### **Viewshed and travel time models**

These two models produce output that can be used to measure remoteness from the sights and sounds of human activity both inside and outside the wilderness (under the solitude quality). However, both models require a significant amount of time to pull together datasets, configure these data into model inputs (requiring advanced GIS skills), run the models, and process the results. Additionally, the viewshed model software requires a license (typically \$1500 for a single license), the output can take months to run depending on the size of the wilderness, and there is a steep learning curve for the user to master. Therefore, the project team should give careful consideration to these factors before deciding to include these measures in the wilderness character map.

### **Report writing**

Writing the wilderness character mapping report can be a time-consuming process. The report template, available in the toolbox, is designed to streamline this process. The project team can review the template at the onset of the project and assign staff to edit particular sections. For example, an interpretive ranger may be best placed to speak to the history of the wilderness area and the GIS specialist will be the most appropriate person to describe the processing notes. For the latter example, it has proven useful to record these notes as the measure layers are produced (whilst they are still fresh in the memory of the GIS specialist). There are also a number of tasks that can be initiated before the wilderness character maps are produced, such as providing descriptions and weight rationales for the different measures under each quality, which will decrease the writing workload at the end of the project.

### **Terminology**

The purpose of a wilderness character map is to depict where wilderness character is degraded within a wilderness area. To make this purpose more explicit, recent projects have described this approach as mapping “threats” to wilderness character. Threats can be defined as a combination of:

- Historical activities that continue to degrade wilderness character (e.g. historical logging activity, departure from natural fire regimes).
- Current actions or influences that degrade wilderness character (e.g. non-native invasive species, administrative motorized/mechanized use).
- Impending issues that are likely to degrade wilderness character into the future (e.g. change in winter temperature, night sky obfuscation).

By identifying and depicting threats to wilderness character, the maps provide managers a tool to better understand the extent and magnitude of impacts to wilderness character, and thereby improve wilderness stewardship. However, each wilderness is at liberty to use their own terminology to describe this approach, such as using the word “impacts” to describe degradations to wilderness character. The key take-home message here is that the project team should be in agreement with the terminology used to describe the mapping approach, which should then be reflected consistently through the report.

### **Positive features**

The aforementioned approach describes the use of measures to represent features, conditions, and actions that threaten wilderness character. While some actions, conditions, or features in wilderness may have a positive influence on wilderness character (such as the preservation of an endangered keystone species), such “value added” features are not encompassed by these measures. Similarly,

when actions or features have a mix of both positive and negative effects (such as management regulations that confine visitors in order to protect natural resources), the selected measures only quantify the negative impacts. Therefore, the majority of projects adopt this “negative mapping” approach because it allows for the full magnitude of threats to be depicted. In contrast, simultaneously displaying positive and negative impacts on a single map would result in these opposing influences being mutually offset or cancelled out, thereby obscuring the true extent of their individual effects on wilderness character.

A number of wilderness areas that have developed a wilderness character map also expressed an interest in creating a separate map that captured the positive aspects of the wilderness, such as management activities that benefit or improve wilderness character. However, the intent to produce this map has typically been overridden by the main obligation for producing the wilderness character map. If a wilderness is indeed interested in developing a positive features map, this part of the project needs to be discussed and outlined in the first meeting and ample time should be allocated for developing this product. Whilst no formalized approach exists for creating a positive features map, the Gates of the Arctic National Park and Preserve (see report in the toolbox) developed the first positive features map for a wilderness area using three locally defined indicators with associated measures.

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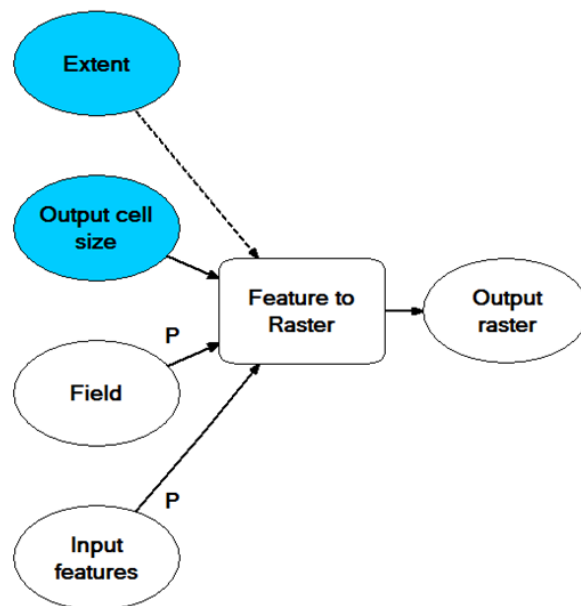
## **Appendix A** – Creating the rasterize and normalization tool.

*Note: a generic version of the tool is available in a zip folder in the toolbox, along with instructions for adapting the tool for a particular wilderness.*

Before configuring the tool, a mask for the wilderness area needs to be created. This can be done by converting the wilderness boundary polygon to a raster at the resolution agreed in the strategic questions (typically 30m or 100m) using the ArcToolbox **Polygon to Raster** tool. Ensure the value for the study area mask is 1 and the rest of the extent is 'null' (use the ArcToolbox **Reclass** tool to set these values if necessary). Note that the project team may elect to create the wilderness character map for the entire administrative area and not just the wilderness (i.e. National Park Service could feasibly include wilderness, eligible wilderness, park and preserve lands). The benefit of extending the study area beyond the wilderness boundary is to enable comparison against other areas within the administrative boundary that may have wilderness designation potential.

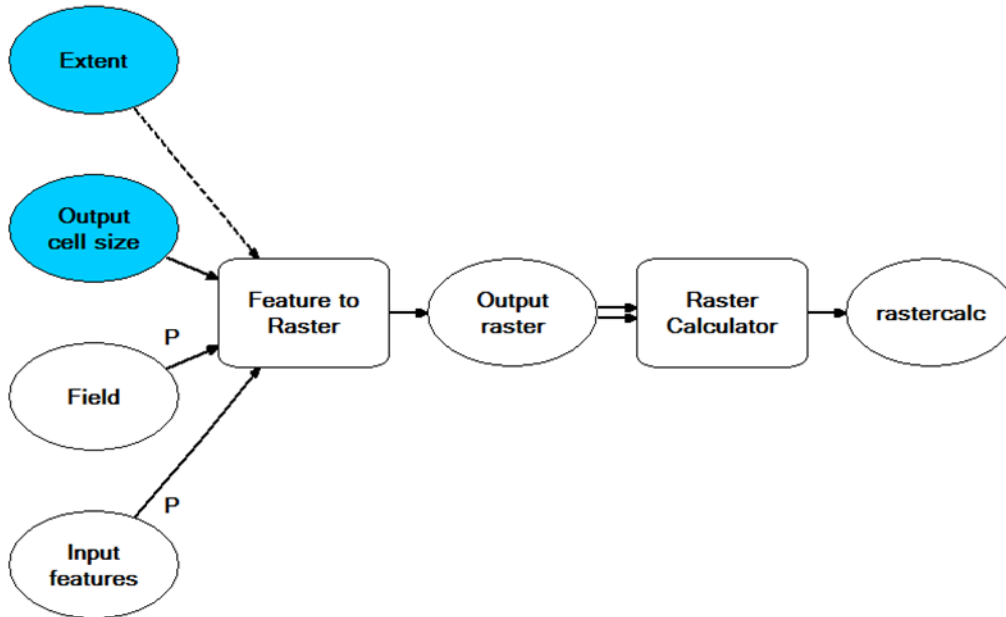
*Process steps for rasterize and normalization model:*

1. Open Arc Catalog, create a new folder and right click to select a New Toolbox.
2. Right click the Toolbox, and select a New Model.
3. Right click the Model, and select Edit – this will open the editing window.
4. Open ArcToolbox, select and drag the ArcToolbox **Features to Raster** tool into the editing window.
  - 4.1. Right click the Features to Raster tool and select Make Variable/From Parameter/Input Features. Repeat process to select Field and Output cell size.
  - 4.2. Right click the Features to Raster tool and select Make Variable/From Environment/Processing Extent/Extent.
  - 4.3. Double click Output cell size and enter the agreed cell size resolution.
  - 4.4. Double click Extent and navigate to study area mask and select it.
  - 4.5. Right click Input Features and select Model Parameter.
  - 4.6. Right click Field and select Model Parameter.

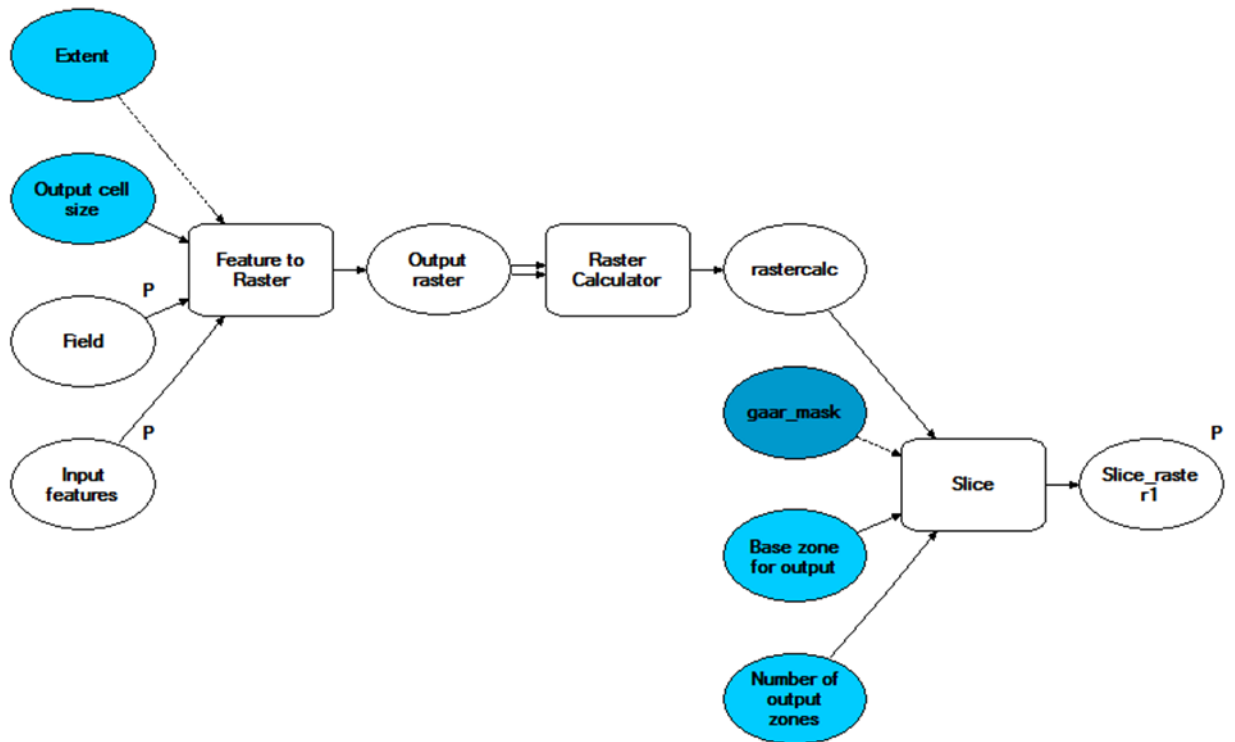




5. Open ArcToolbox, select and drag the ArcToolbox **Raster Calculator** tool into the editing window.
- 5.1. Double click Raster Calculator and enter the following expression:  
`Con(IsNull("%Output raster%"), 0, "%Output raster%")`



6. Open ArcToolbox, select and drag the ArcToolbox **Slice** tool into the editing window.
- 6.1. Right click the Slice tool and select Make Variable/From Parameter/Number of output zones.  
 Repeat process to select Base zone for output.
- 6.2. Right click the Slice tool and select Make Variable/From Environment/Raster Analysis/Mask.
- 6.3. Double click Number of output zones and enter 256.
- 6.4. Double click Base zone for output and enter 0.
- 6.5. Double click Mask and navigate to study area mask and select it.
- 6.6. Right click Raster Output (2) and select Model Parameter.
- 6.7. Finally, select Connect from the toolbar and join the Raster Calculator output to the Slice tool, and select Input Raster.



7. Save the tool and close it.
8. To use the tool, double click it and select the input dataset for converting to raster. Then select the field with values for normalizing, and finally select the folder and output name for the results and click ok.