

Vonarskarð 4x4 Hypothetical Access Route Review of impacts on wilderness

A report by the Wildland Research Institute for Náttúruverndarsamtök Íslands,
Samtök um náttúruvernd á Norðurlandi, Skrauti and Ungir umhverfissinnar
September 2021

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Executive summary

This report has been prepared on behalf of four NGOs in Iceland, namely Iceland Nature Conservation Association, (Náttúruverndarsamtök Íslands), The Icelandic Youth Environmentalist Association (Ungir umhverfissinnar), Skrauti - Nature Conservation Society, and SUNN - North Iceland Nature Conservation Association (Samtök um náttúruvernd á Norðurlandi), by the Wildland Research Institute, UK. The report assesses the potential impacts of the hypothetical changes to 4x4¹ access in the Vonarskarð area in terms of likely changes to the patterns of wilderness quality in the local area resulting from impact to remoteness and visibility of human artefacts. The Vonarskarð area is defined as the area of the central highlands about and above 950m between the Tungafellsjökull and Vatnajökull icecaps in the northwest of the Vatnajökull National Park. The area covers approximately 113 km² of mainly mountains, hills and sand dissected by rivers, as well as containing small, vegetated wetland areas and several areas of high geothermal activity².

The work presented here builds on previous mapping projects carried out for both the European Union and the Scottish Government together with similar analyses carried out for the proposed Hvalá hydro powerplant in the Drangar Peninsula, Northwest Iceland. The Wilderness register and indicator for Europe (Kuiters et al., 2013) provides both a compilation of existing designated wilderness areas across Europe, using databases such as the EEA and WDPA, and a map of wilderness and wild areas in Europe based on appropriate definitional and habitat criteria. This shows that the total area of the top 1% wildest land across the whole of EU/EEA is 56,810 km² of which 24,063 km² is found in Iceland which accounts, in other words, for a little over 42% of the top 1% wildest land in Europe. The mapping methods used involve the integration of digital spatial datasets on land cover, land use and remoteness from settlements and mechanised access. A similar and more detailed approach was used to map wilderness and wild land areas across Scotland and its national parks. This has allowed the Scottish Government to identify 42 Wild Land Areas for use in supporting policy on landscape protection and decision making about large scale developments such as renewable energy infrastructure.

Work at these regional and national levels allows the use of high-resolution spatial data and detailed analyses to accurately model and predict the geographical extent of impacts from existing and proposed development on changes to natural land cover, reductions in remoteness and increased visual impact, which together can be used to map wilderness quality in a rigorous, robust and repeatable manner. Similar methods and approaches to those used in Scotland are applied here. The methods and datasets applied mirror those used to successfully map wilderness quality in the Drangar Peninsula and predict likely impacts from the proposed Hvalá hydro powerplant. These are reapplied here to map wilderness quality in the Vonarskarð area of the central Highlands of Iceland and predict the impacts on wilderness from reverting the changes made in 2011 to the 4x4 access rules.

Reverting the changes to 4x4 access in Vonarskarð would involve re-opening the previous route, connecting existing gravel roads or tracks to the north and south. This would allow 4x4 vehicles to drive between the roadheads at Svarthöfði in the south and Gjóstkúlfir in the north. Analyses developed as part of this report show that re-opening this route would have a significant adverse impact on the wilderness qualities of this area, with the outcome that the area of core wilderness in the vicinity would be reduced by approximately **6515ha or 54% of the total area of study** (See Figure 1.1). This work refers only to impacts of summer/autumn 4x4 access and does not consider winter (on snow) driving. The relatively short season of motorized access possibilities (except on snow or ice) in the central highlands and Vonarskarð in particular being late summer and autumn (mid-late July to -September-October) each year.

This analysis is based on a mapping of four commonly used attributes of wilderness quality across the Vonarskarð and its surrounding area. These are: naturalness of land cover, remoteness from mechanised access, absence of modern human artefacts, and ruggedness of the terrain. Naturalness of land cover takes satellite-based maps of land cover into account and measures the degree of human modification through agriculture, grazing and construction where these occur. Remoteness measures the time taken to walk from any point of mechanised access including roads usable by 2WD (two-wheel drive) and 4WD (four-wheel drive) vehicles, taking terrain,

¹ Four-wheel drive or 4WD vehicles

² Baldursson, Trausti, and Magnússon, Borgþór. Umsögn um Vonarskarð. Náttúrufræðistofnun Íslands. (2019). https://www.ni.is/sites/default/files/atoms/files/uttekt_um_vonarskard.pdf

land cover, and barrier features such as lakes and large rivers into account. Absence of modern human artefacts measures the visual impact from built features in the landscapes such as buildings, roads, dams and other structures taking size, distance and intervening terrain into account. Ruggedness is measured directly from the topography and is a key aspect of wilderness quality that provides a measure of both scenic quality/interest and the challenging nature of the terrain. All four attributes are combined using multi-criteria evaluation (MCE) methods to provide an overall measure of wilderness quality and its spatial pattern and variability across the study region. By inserting the hypothetical 4x4 route and its associated effects and landscape modifications into the model, this approach can provide rigorous and robust estimates of the level of impact on patterns of wilderness quality in the locality of the route. The mapping work described in the report is confirmed and supported by local knowledge gained through communication with local park managers and rangers, and through site visits and ground truthing work carried out in August 2021.

Vonarskarð is an area which is at present largely free from visual impact and currently contains almost no modern human infrastructure except for old informal 4x4 routes³ and earth dams built between 1980-1981 by the National Power Company, Landsvirkjun, in the attempt to divert river flows to the southwest towards the catchment area of rivers Kaldakvísl (where Hágöngulón Reservoir is now), Tungnaá and Þjórsá, the largest hydropower area of Iceland. The analyses presented here show that reversing the changes made in 2011 and re-opening the 4x4 route (as lobbied for by 4x4 groups) would significantly impact this wilderness area by increasing vehicle damage to fragile soils and vegetation, increasing foot erosion in sensitive geothermal areas and considerably increasing the visual impact from vehicles, their tracks and associated reductions in remoteness.

The 2013 Nature Conservation Act No. 60/2103 which entered in to force in November 2015, introduces the management objectives for wilderness protected areas in Iceland as follows: *"The protection should aim to safeguard the characteristics of the areas e.g. to maintain diverse and unusual landscapes, panoramas and/or conserve complete large ecosystems, and ensure that present and future generations can enjoy therein solitude and nature without disturbance from man-made infrastructures or traffic from motor vehicles"*. This follows closely those objectives as stated in the IUCN standards and guidelines for Category 1b Wilderness Areas. Article 5 of the Nature Conservation Act 2013 provides some basic numeric criteria to help highlight potential wilderness areas in Iceland. These are: *"An area of uninhabited land that is in principle at least 25 km² in size or so that one can enjoy solitude and nature without disturbance from man-made structures or the traffic of motorized vehicles and in principle at least 5 km away from man-made structures and other evidence of technology, such as power lines, power stations, reservoirs and elevated roads"*. These numeric criteria are relative, thus giving rise to the need for more robust mapping approaches than those carried out hitherto.

It is important to note that wilderness protection is also mentioned within the new National Planning Strategy (Landsskipulagsstefna) that was adopted by a Parliament Resolution in March 2016. It states that: *"The Planning Agency and the Environment Agency are responsible for regularly updating maps of the extent and development of wilderness in the central highlands. This includes setting criteria for assessing the extent of the wilderness based on planning considerations and having regularly updated maps on the extent of the wilderness accessible to the planning work of local and other parties"*.

While the development of policy and legislation for the protection of wilderness qualities in the landscapes of Iceland is in its infancy and much of the existing focus has been on the central highlands region, the government has a duty of care to help preserve this important resource across the island. Work presented here will help inform further development of government policy on wilderness and associated planning and protection measures. The recent addition to the Nature Conservation Act (February 2021) makes wilderness mapping mandatory for the whole of Iceland by June 2023.

The Wildland Research Institute (WRI) is an independent academic institute with specialist knowledge in wilderness, policy advice, mapping and landscape assessment. WRI have detailed, in-depth knowledge of the wilderness mapping processes and are the originators of the original wilderness methodology developed for the two Scottish National Parks and have acted as technical advisors to the Scottish Government during their national wild land mapping process. In addition, WRI are co-authors of the EU Wilderness Register and mapping programme (2013) and are currently helping the IUCN map wilderness quality across France. They have also

³ Many tyre tracks are still visible ten years after the changes made to the 4x4 access in Vonarskarð.

worked on mapping wilderness character for the US National Park Service and wilderness quality and intactness in China. WRI have existing experience in applying these mapping approaches to modelling wilderness quality and impacts associated with planned developments in Iceland and are fully conversant with both the landscape and datasets available for Iceland. WRI are authors of the much-cited report on "The Status and Conservation of Wilderness in Europe" commissioned by the Scottish Government.

1. Introduction

1.1 This report has been prepared on behalf of four Icelandic NGOs, namely Iceland Nature Conservation Association, (Náttúruverndarsamtök Íslands), The Icelandic Youth Environmentalist Association (Ungir umhverfissinnar), Skrauti - Nature Conservation Society, and SUNN - North Iceland Nature Conservation Association (Samtök um náttúruvernd á Norðurlandi). The report provides an overview of the national policy and planning frameworks on wilderness in Iceland and the mapping methods used to define areas of wilderness. The report further reviews the status of wilderness in the vicinity of a hypothetical re-opening of a 4x4 route. The report assesses the potential impacts of this hypothetical 4x4 access in the Vonarskarð area in terms of wilderness as defined by the 2013 Nature Conservation Act No. 60/2013⁴ using internationally recognised mapping techniques together with local knowledge based on information provided by local park managers and field visits.

1.2 It is recognised here that 4x4 access, including the use of so-called “super jeeps”, to access remote off-road areas of the central highlands is a controversial aspect of Iceland’s domestic and international tourism industry. Construction of roads for energy development (hydro power and geothermal) have resulted in greater use of 4x4 vehicles to access remote wilderness areas for recreation and tourism. This has created conflict between recreational users and conservationists due to the environmental impacts associated with 4x4 usage including loss of opportunities for solitude and damage to fragile ecosystems from vehicle tracks⁵.

1.3 The report examines the hypothetical re-opening for 4x4 access in the context of its potential and likely impacts on wilderness within the Vonarskarð area. This is supported by mapping carried out by WRI using rigorous, robust and repeatable techniques to show how the proposed route would reduce the total area of wilderness in Vonarskarð and how the proposed route would significantly compromise the wilderness quality and values across the area. The study area and its location is shown in Figure 1.1. Evidence from fieldwork carried out in August 2021 shows that previous 4x4 tracks can still be seen in places and that new tracks from illegal 4x4 use are highly noticeable where they occur. This shows the soils and vegetation of the Vonarskarð area to be highly sensitive to disturbance and erosion by off-road vehicles with the tracks made visible for many years.

1.4 The details on the hypothetical re-opening of 4x4 route are drawn from Open Street Map based on existing routes as either GIS Shapefiles⁶ or from personal communication with local experts including Vatnajökull National Park officers⁷. The 4x4 route, as occasionally driven from the 1950s until the first Management Plan for Vatnajökull National Park entered into force in 2011, is shown in Figure 1.2.

1.5 This report has been prepared by the Wildland Research Institute (WRI), an independent academic institute with specialist knowledge in wilderness, geographical information systems (GIS) and landscape assessment⁸. WRI have detailed, in-depth knowledge of the wilderness mapping processes. WRI are the originators of the original wilderness mapping methodology developed for the two Scottish National Parks^{9,10} and have acted as technical advisors to Scottish Natural Heritage (SNH) and the Scottish Government during their original Phase I

⁴ See: <https://www.althingi.is/lagas/nuna/2013060.html>

⁵ Árnason, Þ., 2020. Exploring wilderness in Iceland: Charting meaningful encounters with uninhabited lands. In *Rethinking Wilderness and the Wild* (pp. 189-204). Routledge.

⁶ Shapefiles are machine-readable map data files for using GIS analyses and mapping.

⁷ Local knowledge was gained via a conference call with Fanney Ásgeirsdóttir, Park Manager (þjóðgarðsvörður) and Jóna Björk Jónsdóttir, Assistant Park Manager in early summer 2021. In addition, in-the-field information was provided through contact with Fanney Ásgeirsdóttir and Auður Lilja Arnþórsdóttir, Park Ranger (landvörður) during site visit and ground truthing in August 2021.

⁸ <http://www.wildlandresearch.org>

⁹ <http://www.geog.leeds.ac.uk/groups/wildland/Cairngorm2008.pdf>

¹⁰ https://www.lochlomond-trossachs.org/wp-content/uploads/2016/07/Research_WildnessStudy2011.pdf

mapping process¹¹. In addition, WRI have been contracted, together with partners Alterra and PAN Parks, by the European Union Environment Agency (EEA) to extend the methodology to the whole of the Europe^{12,13}. This approach has also been adopted in a modified form for use in mapping wilderness character by the US National Park Service within national park wilderness areas in the United States^{14,15} and has also been applied in China¹⁶. WRI have existing experience in applying these mapping approaches to modelling wilderness quality and impacts associated with planned developments in Iceland and are conversant with both the landscape and datasets for Iceland. WRI are also the authors of the much-cited report on "The Status and Conservation of Wilderness in Europe" commissioned by the Scottish Government¹⁷. WRI are currently working for IUCN France to develop a map of Haute Naturalité (High Naturalness)¹⁸, again based on modifications to the mapping approaches developed in Scotland.

¹¹ Carver, S., Comber, A., McMorran, R., & Nutter, S. (2012). A GIS model for mapping spatial patterns and distribution of wild land in Scotland. *Landscape and Urban Planning*, 104(3), 395-409.

¹² Europe's ecological backbone: recognising the true value of our mountains. EEA Report No 6/2010

¹³ Wilderness register and indicator for Europe Final report 2013 (draft) Contract N°: 07.0307/2011/610387/SER/B.3

¹⁴ Tricker, James; Landres, Peter; Dingman, Sandee; Callagan, Charlie; Stark, John; Bonstead, Leah; Fuhrman, Kelly; and Steve Carver. 2012. Mapping wilderness character in Death Valley National Park. Natural Resource Report NPS/DEVA/NRR-2012/503. National Park Service, Fort Collins, Colorado. 82p.

¹⁵ Carver, Steve; Tricker, James; and Peter Landres. 2013. Keeping it wild: mapping wilderness character in the United States. *Journal of Environmental Management*, 131 (2013) 239-255. doi:10.1016/j.jenvman.2013.08.046

¹⁶ Cao, Yue, Steve Carver, and Rui Yang. "Mapping wilderness in China: Comparing and integrating Boolean and WLC approaches." *Landscape and Urban Planning* 192 (2019): 103636.

¹⁷ Fisher, Mark; Carver, Steve; Kun, Zoltan; Arrell, Katherine and Mitchell, Gordon. A review of the status and conservation of wild land in Europe. Report prepared for the Scottish Government, November 2010. <http://www.scotland.gov.uk/Topics/Environment/Countryside/Heritage/wildland>

¹⁸ Projet CARTNAT Cartographie de la Naturalité Rapport intermédiaire phase II.

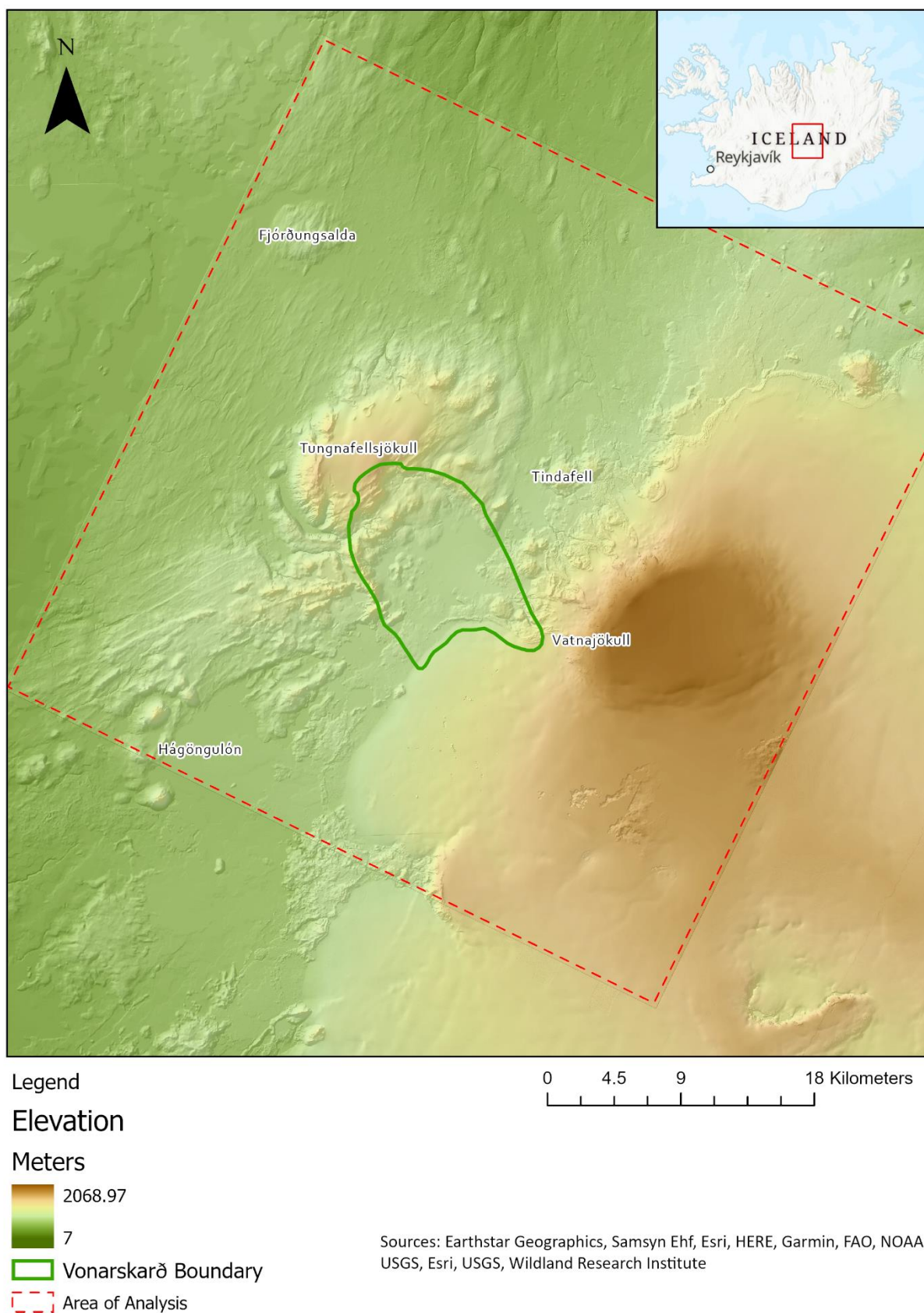


Figure 1.1 Study area location

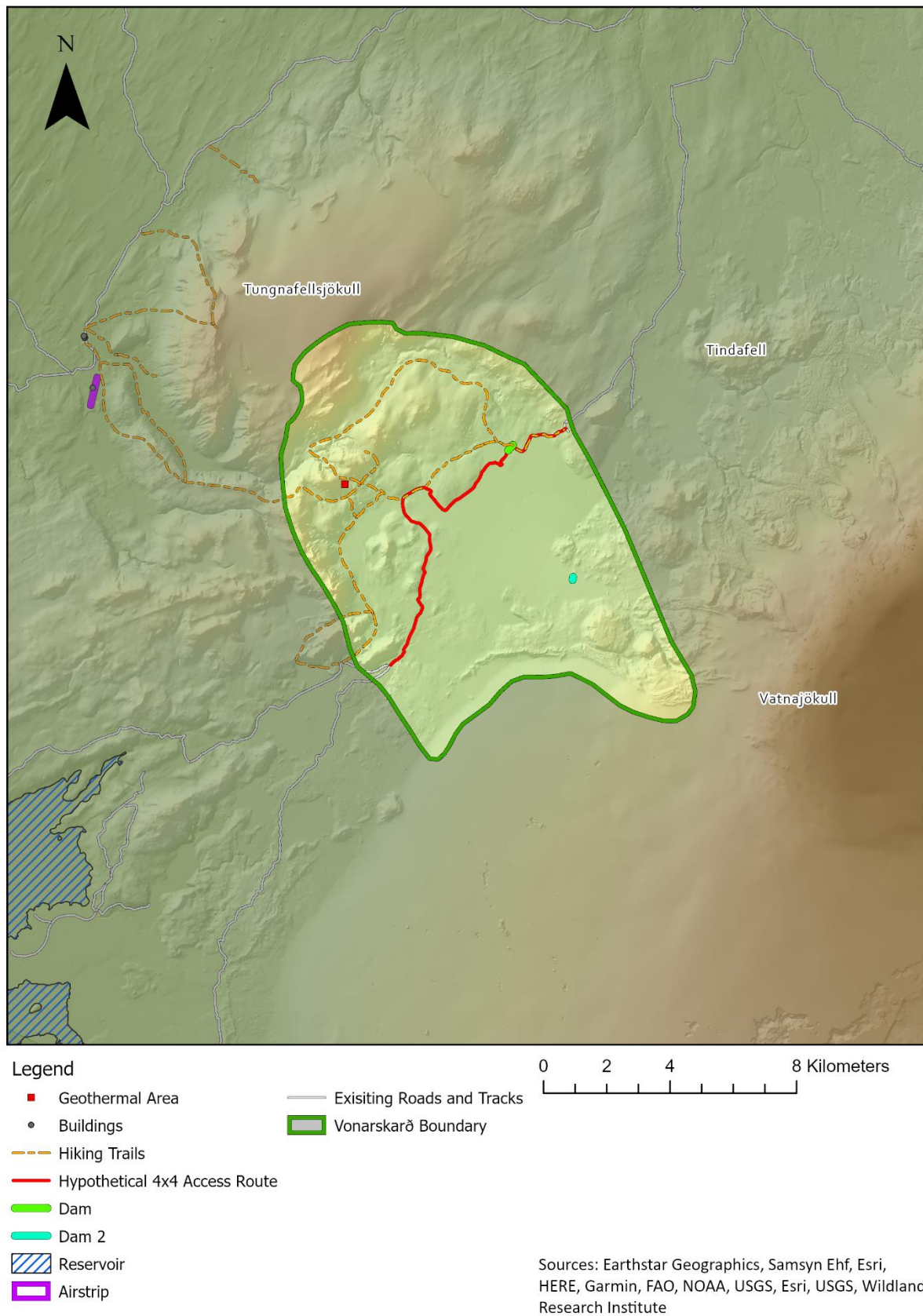


Figure 1.2 Route of the previously open 4x4 access route

2. Defining wilderness and approaches to mapping

2.1 The Wilderness Register and Indicator for Europe report¹⁹ and associated mapping shows that the total area of the top 1% wildest land across the whole of EU/EEA is 56,810km² of which 24,063km² is found in Iceland. Iceland accounts, in other words, for just over 42% of the top 1% wildest land in Europe. Although most of the areas highlighted are Iceland's numerous icecaps, this is a significant figure and includes significant areas of ice-free land in the interior and remote coastal areas. Figure 2.1 shows the pattern of wilderness quality across Iceland based on the indicator mapping in the 2013 EU Wilderness Register report.

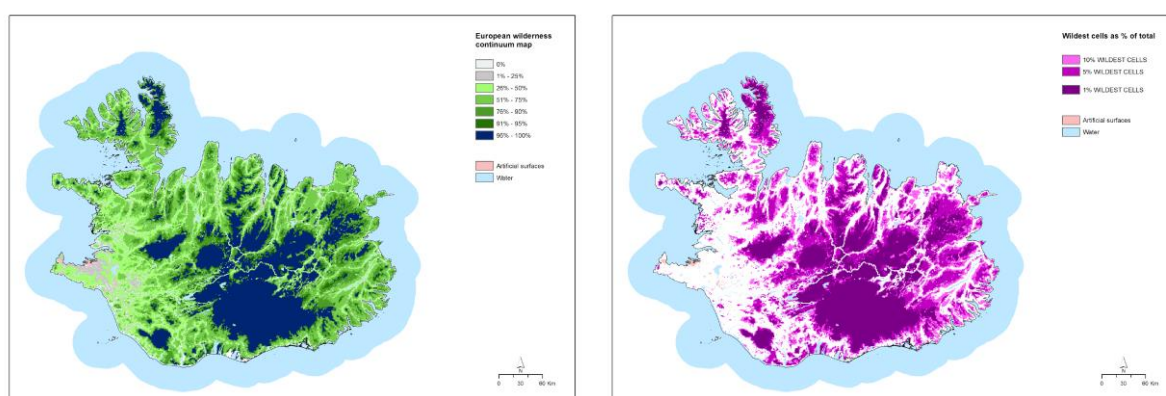


Figure 2.1 Wilderness quality in Iceland (After Kuiters et al., 2013)

2.2 One of the stated objectives of the 2013 Nature Conservation Act No. 60/2103²⁰ which entered in to force in November 2015, is to protect wilderness areas. The Act introduces the management objectives for wilderness protected areas in Iceland as follows: *"The protection should aim to safeguard the characteristics of the areas e.g. to maintain diverse and unusual landscapes, panoramas and/or conserve complete large ecosystems, and ensure that present and future generations can enjoy therein solitude and nature without disturbance from man-made infrastructures or traffic from motor vehicles"*²¹. This follows closely those objectives as stated in the IUCN standards and guidelines for Category 1b Wilderness Areas which itself defines wilderness areas as: *"Protected areas that are usually large, unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition"* (Dudley, 2013, p. 14). Article 5 of the Nature Conservation Act 2013 provides some basic numeric criteria to help highlight potential wilderness areas in Iceland. These are: *"An area of uninhabited land that is in principle at least 25 km² in size or so that one can enjoy solitude and nature without disturbance from man-made structures or the traffic of motorized vehicles and in principle at least 5 km away from man-made structures and other evidence of technology, such as power lines, power stations, reservoirs and*

¹⁹ Wilderness register and indicator for Europe Final report 2013 (draft) Contract N°:
07.0307/2011/610387/SER/B.3

https://ec.europa.eu/environment/nature/natura2000/wilderness/pdf/Wilderness_register_indicator.pdf

²⁰ <https://www.althingi.is/lagas/nuna/2013060.html>

²¹ Jóhannsdóttir, Aðalheiður (2016) "Wilderness Protection in Iceland" in Kees Bastmeijer (ed.) Wilderness Protection in Europe. The Role of International, European and National Law pp 370.

*elevated roads*²². These criteria are guidelines intended to highlight potential wilderness areas and not regarded as absolute thus giving rise to the need for more robust mapping approaches²³.

Wilderness protection is also mentioned within the new National Planning Strategy (Landsskipulagsstefna) that was adopted by a Parliament Resolution in March 2016²⁴. This states that: *“The Planning Agency and the Environment Agency are responsible for regularly updating maps of the extent and development of wilderness in the central highlands. This includes setting criteria for assessing the extent of the wilderness based on planning considerations and having regularly updated maps on the extent of the wilderness accessible to the planning work of local and other parties”*. This currently applies to the central highlands region²⁵, of which Vonarskarð is part, but will now be expanded to other wilderness areas of Iceland in the future, as per a mandate given by the Minister for the Environment and Natural Resources to the Planning Agency in 2018 and the proposal put forward to the Parliament in 2021 for a revised National Planning Strategy^{26,27}.

2.3 The connection between physical attributes such as terrain, size, distance and vegetation with how people perceive wilderness in the landscape is key to the successful mapping of wilderness. Most wilderness mapping programmes use combinations of perceived and biophysical (ecological) attributes of wilderness to describe the patterns and variations in wilderness quality across a target landscape. While there is no one single and universally accepted method, these mapping programmes tend to focus on measures of naturalness (e.g. how natural the landscape and its ecology is) and remoteness (e.g. how large an area is and how remote places are from human settlement, roads and other infrastructure). Different countries may modify and adjust the measures and attributes used to define wilderness in a manner that best suits their landscape and culture. The work presented here follows closely that developed for Scotland. This has been used and successfully applied at both a local (national park)^{28,29} and national scale to support protected area planning and to identify planning boundaries for the protection of wild land areas³⁰. While they are different countries, Iceland and Scotland share certain biophysical and geographical similarities in terms of size, openness and low vegetation with limited forest/woodland cover wherein both landscapes are rugged, mountainous, sparsely populated with a remote interior, limited road access and a wild coastline.

2.4 It is recognised that there are differing opinions about wilderness within the Icelandic landscape and that there is no direct translation of the English word “wilderness”. The large remote areas of the central highlands have traditionally been referred to as uninhabited areas or *óbyggðir*, but more recently the idea of wilderness

²² Revised and updated translation from Jóhannsdóttir, Aðalheiður (2016) “Wilderness Protection in Iceland”, in Kees Bastmeijer (ed.) Wilderness Protection in Europe. The Role of International, European and National Law pp 367. The original legal text refers to roads as being elevated (uppbýggðir) rather than main roads. The legal text also mentions power lines as an example. Furthermore, the wording of this provision of the Nature Conservation was slightly amended in 2020.

²³ See the four proposed criteria in draft revised National Planning Strategy, put forward to the Parliament April 2021, at Subsection 6.1.6, [1184/151 stjornartillaga: endurskoðuð landsskipulagsstefna 2015--2026 | Þingtíðindi | Alþingi \(althingi.is\)](https://www.althingi.is/althingi/1184/151/stjornartillaga/endurskoedu/landsskipulagsstefna2015-2026/pingtiodindi)

²⁴ <https://www.skipulag.is/en> and <https://www.landsskipulag.is/english/> and Chapter 1.1 https://www.landsskipulag.is/media/pdf-skjol/Landsskipulagsstefna2015-2026_asamt_greinargerð.pdf

²⁵ <https://www.landsskipulag.is/gildandi-stefna/afmorkun-midhalendisins/>

²⁶ <https://www.landsskipulag.is/ferlid/tillaga-i-vinnslu> and https://www.landsskipulag.is/media/landsskipulagsstefna-vidbaetur/Landsskipulagsstefna-vidb_brefradhera.pdf

²⁷ Endurskoðuð landsskipulagsstefna 2015–2026 | Þingmálalistar | Alþingi (althingi.is)

²⁸ “Wildness study in the Cairngorms National Park” Report prepared for the Cairngorms National Park Authority and SNH, September 2008. <https://wildlandresearch.org/wp-content/uploads/sites/39/2018/10/Cairngorm2008.pdf>

²⁹ “Wildness study in Loch Lomond and The Trossachs National Park” Report prepared for the Loch Lomond and The Trossachs National Park Authority and SNH, January 2011. <http://www.lochlomond-trossachs.org/park-authority/publications/wildness-study/>

³⁰ National Planning Framework 3: The third National Planning Framework, setting out a long-term vision for development and investment across Scotland over the next 20 to 30 years. Scottish Government 2014. <https://www.gov.scot/publications/national-planning-framework-3/>

as applied to Icelandic landscapes and the word *viðerni* has come into more common use. Regardless, the preparatory work to the existing Nature Conservation Act makes a clear reference to the English term “wilderness” and IUCN management category Ib.

2.5 The physical attributes to be used in the identification of wilderness are expanded on in the table 2.1. This table lists both the main (physical) criteria used to describe these attributes, but also gives further interpretation of these regarding how they are likely to influence people's perceptions of wildness in the landscape setting. These are derived and adapted from the SNH Wildness in Scotland's Countryside policy statement (2002) which form the basis for the successful mapping of wild land in Scotland. While the 2002 SNH policy statement provides the basis for subsequent mapping work, it does not provide the exact methodology, rather an indication that the approach adopted might be based on a "simple scoring system" such as has been used successfully in the development of the Australian National Wilderness Inventory³¹ and the Human Footprint/Last of the Wild³². As such SNH supported two feasibility studies based around mapping wildness in the Scottish National Parks and, in recognising the difficulties surrounding varied perceptions of wildness and the interpretation of physical attributes, also supported two public perception surveys, one in 2007 (reporting in 2008)³³ and one in 2011 (reporting in 2012)³⁴.

2.6 The Scottish national wildness map has been developed by SNH based on an up-scaling of the National Parks' methodology. This has inevitably involved some modifications. These are outlined briefly below and the differences in respect to the original National Park mapping highlighted. The SNH approach has been to map wildness in three phases:

- Phase 1: An equally weighted multi-criteria GIS mapping of those physical attributes of wildness as defined in the 2002 SNH policy document based on practical interpretations of how these attributes affect people's perceptions of wildness to map spatial variations and patterns in wildness on a relative scale from least wild to most wild. This essentially mirrors the methodology and techniques developed for mapping wildness in the two National Parks by WRi with some minor modifications to the data used and resolution to allow up-scaling across the whole of the country. These mainly concern the use of coarser resolution models and the omission of selected datasets which would have been difficult to source and/or validate at the national scale.
- Phase 2: A statistical classification and grouping areas from the resulting Phase 1 map based on Jenks Natural Breaks Optimisation to define areas with high levels of wildness according to all four attributes and application of differing size thresholds north and south of the Highland Boundary Fault. This differs from the National Parks' mapping only in that a different statistical method is used to arrive at the classification of the wildness areas. In the National Park mapping, classifications for the Phase 1 wildness quality map was performed using fuzzy classification techniques³⁵.
- Phase 3: A simplification of the GIS-derived mapping in Phase 1 and 2 using lines drawn at 1:50,000 scale to align the wilderness area boundaries with recognisable features on the ground such as rivers, lochs, ridges, etc. and take into account local features and recent development consents. This phase is similar to that used by the two Scottish National Park authorities whereby the defined boundaries of wild areas are informed by the Phase 1 and 2 mapping and the additional expert knowledge of Park staff.

³¹ National Wilderness Inventory's *Handbook of Procedures, Content and Usage*, Second Edition, May 1995

³² Sanderson, E. W., Jaiteh, M., Levy, M. A., Redford, K. H., Wannebo, A. V., & Woolmer, G. (2002). The Human Footprint and the Last of the Wild. *BioScience*, 52(10), 891-904.

³³ SNH Commissioned Report No.291 Public Perceptions of Wild Places and Landscapes in Scotland (ROAME No. F06NC03) James Fenton Scottish Natural Heritage.

³⁴ Public Perception Survey of Wildness in Scotland. Report for Loch Lomond & The Trossachs National Park Authority, Cairngorms National Park Authority & Scottish Natural Heritage in Association With Research Now July 2012.

³⁵ Comber, A., Carver, S., Fritz, S., McMorran, R., Washtell, J., & Fisher, P. (2010). Evaluating alternative mappings of wildness using fuzzy MCE and Dempster-Shafer in support of decision making. *Computers, Environment and Urban Systems*, 34(2), 142–152.

2.7 The final map of wilderness areas was published in June 2014 along with the final SPP2 and NPF3 documents. A total of 42 wilderness areas are identified covering just under 20% of the land area of Scotland. All the maps and details of the mapping process and underpinning policy documents can be found on the SNH web pages³⁶.

2.8 Phase 1 and 2 of the Scottish national wilderness mapping approach are adapted here to fit Icelandic data sources and environmental conditions. This is best suited to mapping patterns and variations in wilderness quality in Iceland based on similarities with northwest Scotland and previous experience with applying these approaches elsewhere and in Iceland itself. Data collection, processing and model development is described in detail in sections 3 and 4 of this report. Results from the mapping of wilderness quality in the Vonarskarð are presented in section 5 and the implications discussed in section 6.

³⁶ SNH Mapping Scotland's wilderness and wild land <http://www.snh.gov.uk/protecting-scotlands-nature/looking-after-landscapes/landscape-policy-and-guidance/wild-land/mapping/>

Table 2.1 Physical attributes in the identification of wild land (After SNH, 2002)

Attributes	Main criteria	Further detail
Perceived naturalness	Vegetation cover primarily composed of functioning, natural habitats. Catchment systems largely unmodified, and other geomorphological processes unaffected by land management.	Habitat may often not be in best condition or at optimum ecological status. But there will normally be potential for recovery, and the vegetation cover should be composed of natural components. Some small plantations may be tolerated especially at the edge of an area, if they are the only detracting feature and of limited effect on wildness.
Lack of constructions or other artefacts	No contemporary or recent, built or engineering works within the area. Little impact from out with the area on wild qualities from built development, power lines, or masts or other intensive land uses (say forestry), or from noise or light pollution. Limited effects on the wild qualities of the area from older artefacts.	Older features (fences, bridges, stalking tracks, or small buildings may be present, if not intrusive overall. Archaeological features (normally a light imprint on the land) will contribute to visitors' appreciation of the continuity of human use of these areas. Some intrusive features (say vehicular tracks which partly penetrate into an area) may be tolerated, where their effects are limited, and where excluding such land would reject an area of high intrinsic quality.
Little evidence of contemporary land uses	Extensive range-grazing and field sports (as economic uses of the land) will often be present, as well as public recreation. Land uses of an intensive nature should not be present.	The cumulative effects of the economic uses of the land should not be intrusive. Evidence of muirburn or over-grazing, habitat management, footpath deterioration and erosion, or the effects of the use of off-road vehicles may be visible. But the effects of any one of these activities, or their cumulative expression should not be of a scale or intensity so as to significantly devalue visitors' perceptual experience.
Rugged or otherwise Challenging terrain	Striking topographic features, or land having extensive rough terrain or extensive bog lands, difficult to traverse. Natural settings for recreational activities requiring hard physical exercise or providing challenge.	Different kinds of terrain can offer an inspiring or challenging experience for people but, in the main, it is those landscapes which are of arresting character (by virtue of the scale and form of the terrain) which are most valued for their wildness.
Remoteness and inaccessibility	Distance from settlements or modern communications. Limited accessibility, either by scale of the area, difficulty in passage, or the lack of easy access, say by vehicular tracks, bridges, or by boat.	Distance is not an absolute guide on its own, but most of the wild land resource will lie in the remaining remote areas, as defined by distance from private and public roads and other artefacts.
Extent of area	An area of land sufficient to engender a sense of remoteness; to provide those who visit them with physical challenge; and to allow for separation from more intensive human activities.	Smaller areas of land of high intrinsic merit or inaccessibility can hold the qualities which underpin a sense of wildness, say an inaccessible rocky gorge, and the same applies to some small uninhabited islands, or stretches of isolated coast.

3. Developing a wildness model

3.1 Maps of the four attributes of wildness – perceived naturalness of land cover, remoteness from mechanised access, absence of modern human artefacts, and ruggedness - can be combined to produce a series of wildness maps for the Vonarskarð area using the MCE and fuzzy methods developed and used in previous studies^{37,38,39,40} including Drangar Peninsula⁴¹. MCE methods allow the combination of predefined and standardised attribute layers (criteria) describing the relative merits of a solution or location using a set of user-defined weights to describe the relative importance or priorities assigned to each input layer. This process is illustrated as a flow chart in Figure 3.1.

3.2 The model illustrated in Figure 3.1 needs to be populated by attribute maps derived from raw data and a set of weights reflecting the relative importance of the attributes in defining the overall wildness map. The attribute maps are prepared from the interpretation of raw spatial data such that they represent the components of wildness derived from SNH policy and applied here to the Vonarskarð area with adaptations to suit Icelandic data and landscape conditions. These are described in detail in section 4. Attribute weights can be defined either numerically (e.g. Carver et al., 2002) or using fuzzy methods (e.g. Fritz et al., 2000). The weights allocated to each of the attribute maps can be defined in consultation with the partners and local stakeholders using appropriate perception surveys. The exact detail of the hypothetical re-opening of the 4x4 route is unclear but is likely to follow the approximate route of the previously existing track between the two roadhead car parks⁴². Several different wildness maps are produced as part of this study using MCE and fuzzy methods to reflect the likely conditions and scenarios associated with the hypothetical re-opening of the 4x4 route in order to take different scenarios into account. A wildness map that combines each of the four attribute maps using equal weights is produced and used as a benchmark reflecting current conditions. These wildness maps indicate the perceived wildness using a continuous scale rather than discrete areas. The current pattern in the variation of wilderness quality across the Vonarskarð area is shown in Figure 3.2.

3.3 Care needs to be taken during this process to ensure that the input attribute maps do not exhibit a high degree of spatial correlation such that one particular theme does not dominate the results. For example, it is conceivable that the remoteness and ruggedness might be closely correlated in the core mountain areas away from the main valley routes. Checks are performed to make sure attribute maps are not correlated and to flag up any possible problem areas where spatial correlations are found to exist (see section 4.5).

3.4 All map layers need to be standardised (normalised) onto a common relative scale to enable cross comparison. For example, remoteness and perceived naturalness are measured using time (minutes) and nominal naturalness class, and so cannot be directly compared. In addition, the “polarity” of individual map

³⁷ Carver, S.J. "Integrating MCE with GIS-modelling urban system." *International Journal of Information System* 5 (1991): 321-339.

³⁸ Fritz, Steffen, Steve Carver, and Linda See. "New GIS approaches to wild land mapping in Europe." In *McCool, Stephen F.; Cole, David N.; Borrie, William T.; O'Loughlin, Jennifer, comps. 2000. Wilderness science in a time of change conference—Volume 2: Wilderness within the context of larger systems; 1999 May 23–27; Missoula, MT. Proceedings RMRS-P-15-VOL-2. Ogden, UT: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 120-127, vol. 15. 2000.*
https://www.fs.fed.us/rm/pubs/rmrs_p015_2/rmrs_p015_2_120_127.pdf

³⁹ Carver, Steve, A. J. Evans, and Steffen Fritz. "Wilderness attribute mapping in the United Kingdom." *International Journal of Wilderness* 8, no. 1 (2002): 24-29. <http://eprints.whiterose.ac.uk/934/1/evansaj7.pdf>

⁴⁰ Carver, Steve, Alexis Comber, Rob McMorran, and Steve Nutter. "A GIS model for mapping spatial patterns and distribution of wild land in Scotland." *Landscape and Urban Planning* 104, no. 3-4 (2012): 395-409.
https://lra.le.ac.uk/bitstream/2381/27733/2/7_carver_et_al_LUP.pdf

⁴¹ Hvalá power plant proposal: review of impacts on wilderness: a report
<https://rafhladan.is/handle/10802/28566>

⁴² Baldursson, Trausti, and Magnússon, Borgþór. Umsögn um Vonarskarð. Náttúrufræðistofnun Íslands. (2019).
https://www.ni.is/sites/default/files/atoms/files/uttekt_um_vonarskard.pdf

layers needs to be maintained such that higher values in the standardised maps are deemed to be “better” (i.e. indicative of greater wildness). Standardisation of the attribute maps is achieved here using a linear re-scaling of the input values onto a 0-255 scale on an equal interval basis and lower values are “worse” (i.e. indicative of lower wildness). The weights applied to the map layers are defined on an equal weighted basis for the purposes of this report. These are then applied within a simple Weighted Linear Combination MCE model within the GIS. Alternative wildness maps are created to demonstrate the influence of different weighting schemes on the results. These alternative weighting schemes and resulting wildness maps are described in section 5.

3.5 Weighted Linear Combination is simply based on the sum of the weighted standardised map layers as follows:

$$S_{ij} = \sum_{j=1}^n (W_{ij}X_{ij})$$

where S = suitability of the choice alternative (site or grid cell), W = criterion weights, X = standardised criterion score, i = ith choice alternative, j = jth criteria.

3.6 The equal weightings option weighs all of the components of wildness equally so that there is no implied difference in importance attached to any of the four wilderness attributes. There are several reasons for doing this. Firstly, under the assumption of equal salience, where all four components are deemed to be equally as important, it provides an objective unbiased approach. Secondly, the data from any future perception survey would need to be interpreted in order to be used as these are likely to show cognition bias where unfamiliar terms are less well supported than familiar ones by survey respondents. The equal weighting option for the overall wildness map is therefore in this case a more reliable approach.

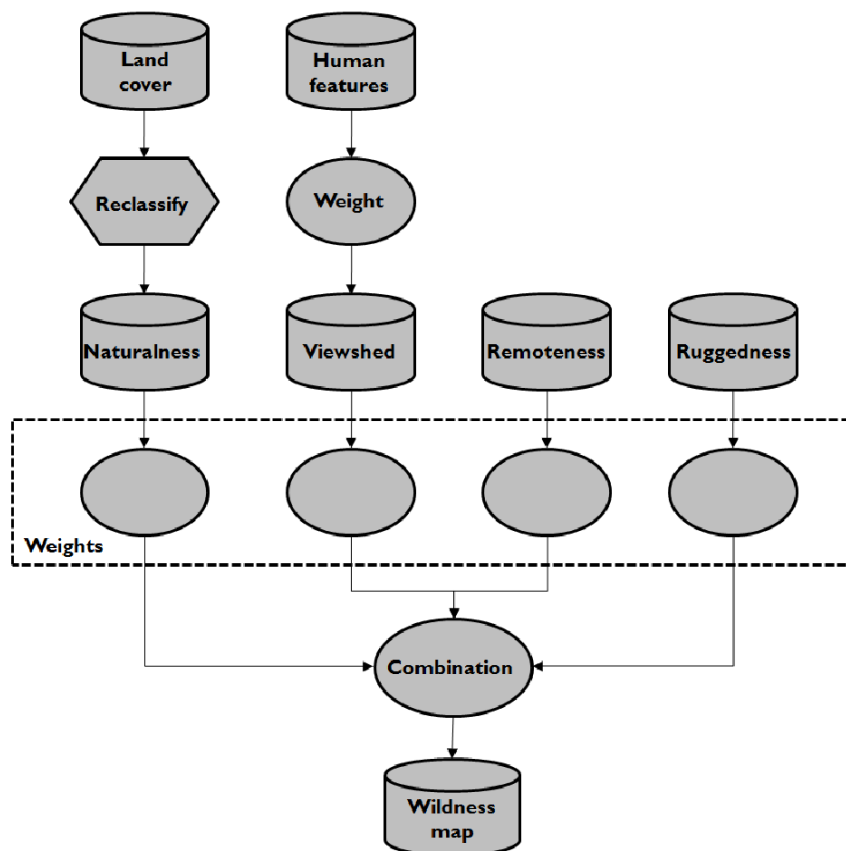


Figure 3.1 Flow chart showing how the data are parameterised by weights and combined to generate a wildness map

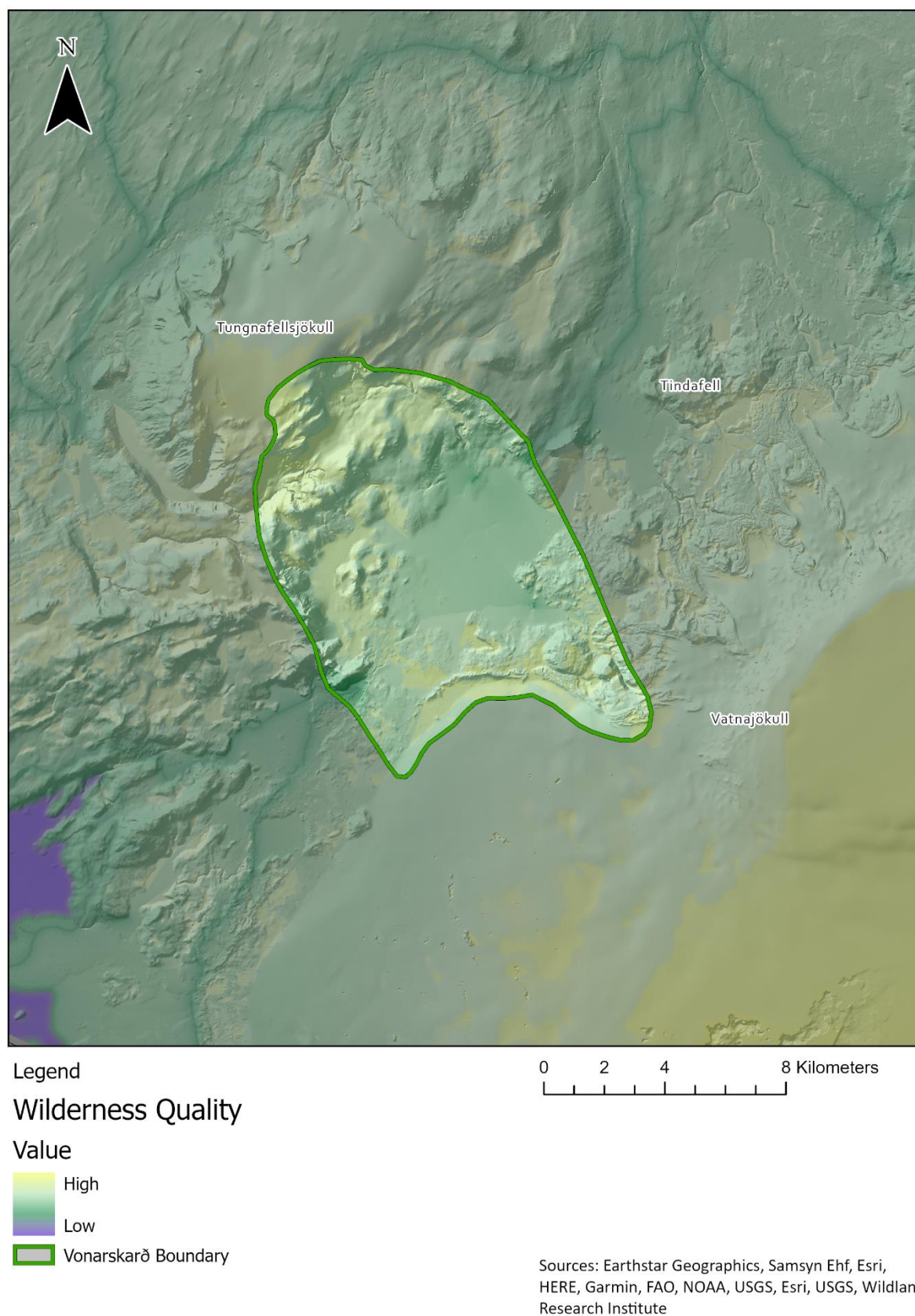


Figure 3.2 Current patterns of wildness in the Vonarskarð area

4. Attribute maps

4.1 The four attributes of wilderness as defined by SNH (2002)⁴³ are modified for Icelandic wilderness and mapped using a combination of readily available datasets and the latest GIS-based techniques. These attribute maps are produced for the Vonarskarð area. The immediate area outside of the defined Vonarskarð area is mapped to ensure that there are no edge effects arising from visible human features and points of access immediately outside the Vonarskarð area. These are described in turn, together with the data used, the method of mapping and associated caveats and assumptions. The following descriptions are based on and closely follow those developed for the assessment of impacts on wilderness from the proposed Hvalá hydro power plant and associated infrastructure in the Drangar Peninsula⁴⁴.

Perceived naturalness of land cover

4.2 Perceived naturalness of land cover is described here as the extent to which land management, or lack of it, creates a pattern of vegetation and land cover which appears natural to the casual observer. Perceptions of wilderness are in part related to evidence of land management activities such as fencing, improved pasture and stocking rates, as well as presence of natural or near-natural vegetation patterns. Here the Nyttjaland /Landnýting 2016 datasets⁴⁵ are brought together to best describe perceived naturalness in the Vonarskarð area.

Data sources

4.3 Aspects of land management are identifiable from national land cover datasets like Nyttjaland. These datasets are available from the Kortavefsja Landbúnaðarháskóla Íslands⁴⁶. The distribution, presence and absence of features related to wilderness can often be inferred from their classes and relative positions.

4.4 Previous work by Carver (2005)⁴⁷ and Carver et al. (2008)⁴⁸ has based naturalness of land cover on a reclassification of the LCM2015⁴⁹, and the earlier products, into a smaller number of naturalness classes. The land cover classes from the Nyttjaland were reviewed with local experts for ground truthing and then were applied to equivalent naturalness classes. The naturalness classes used here are shown in table 4.1.

Method

4.5 The Nyttjaland land cover map, re-projected at a nominal resolution of 20m to match other data in the overall model, is reclassified into 5 naturalness classes based on similar classifications used by SNH as shown in Table 4.1. To account for the influence that the pattern of land cover in the area immediately adjacent to the target location has upon perceived naturalness of a certain grid cell, the mean naturalness class is calculated for each location within a 250m radius neighbourhood. This value is then assigned to the target cell to represent the overall naturalness score for that location. Edge effects are avoided by calculating perceived naturalness for the whole Vonarskarð area. The resulting attribute map is shown in Figure 4.1.

⁴³ SNH Policy Statement WILDNESSE IN SCOTLAND'S COUNTRYSIDE Policy Statement No. 02/03
<https://www.nature.scot/sites/default/files/2019-10/Wildness%20in%20Scotland%27s%20Countryside%20-%20Policy%20Statement.pdf>

⁴⁴ Hvalá power plant proposal: review of impacts on wilderness: a report
<https://rafhladan.is/handle/10802/28566>

⁴⁵ <http://www.nyttjaland.is/landbunadur/wgrala.nsf/key2/nyttjaland.html>

⁴⁶ <http://lbhi.maps.arcgis.com/apps/webappviewer/index.html?id=227b358de2ec4738b9d51c8e86457c0d>

⁴⁷ Carver, S. (2005) Opportunity Mapping for New Wildwoods: a report submitted to the North Pennines AONB Partnership by the University of Leeds. University of Leeds.

⁴⁸ Wilderness study in the Cairngorms National Park. Report prepared for the Cairngorms National Park Authority and SNH, September 2008. <https://wildlandresearch.org/wp-content/uploads/sites/39/2018/10/Cairngorm2008.pdf>

⁴⁹ Centre for Ecology and Hydrology Land Cover Map 2015 <https://www.ceh.ac.uk/services/land-cover-map-2015>

Caveats and assumptions

4.6 The Nytjaland index data is known to suffer from some misclassification errors at a local scale on a cell-by-cell basis. However, the dataset is considered here to be the best available basis for developing indicators of naturalness for landscape scale studies in Iceland. The reclassification of the Nytjaland into 5 naturalness classes from natural/semi-natural to improved and built on land is based on the subjective reading of the class descriptions given in the dataset documentation. There is likely to be differing levels of naturalness within Nytjaland land cover classes due to differing levels of impact (e.g. from hydro reservoirs) or topological relationships with other land classes (e.g. bare rock and barely vegetated) that are not fully accounted for within the data descriptions.

Absence of modern artefacts

4.7 Absence of modern human artefacts is considered here to refer to the lack of obvious artificial forms or structures within the visible landscape, including roads, vehicle tracks, pylons, dams, buildings and other built structures. The choice of which human features to include here is driven largely by what is understood to act as a wilderness detractor based on SNH wild land policy (SNH, 2002), relevant sections of the perception survey and what data is available. Previous work on the effects of human artefacts on perceptions of wilderness carried out at national to global scales has tended to focus on simple distance measures^{50,51,52}. More recent work has used measures of visibility of human artefacts in 3D landscapes described using digital terrain models^{53,54}. This is feasible at the landscape scale utilising viewshed algorithms and land cover datasets to calculate the area from which a given artefact can be seen. Work by Carver (2007)⁵⁵ for the Nidderdale AONB has utilised cumulative and distance weighted viewshed algorithms to give a more accurate impression of the spatial pattern of the impacts of visible human artefacts on peoples' perceptions of wilderness in guiding decisions about suitable areas for regeneration of native woodland. A similar approach to that used for the SNH work is adopted here using artefacts are deemed to have an impact on wilderness, together with more a digital surface model (DSM) derived from ArcticDEM and a novel and rapid viewshed assessment method developed for the earlier Cairngorm wilderness mapping project (2008).

Data sources

4.8 Visibility analysis and viewshed calculations rely on the ability to calculate line-of-sight from one point on a terrain surface to another. It has been shown that the accuracy of viewsheds produced in GIS is strongly dependent on the accuracy of the terrain model used and the inclusion of intervening features (buildings, woodland, etc.) or terrain clutter in the analysis (Fisher, 1993). The terrain data used here is the ArcticDEM 2m resolution digital surface model (DSM) and derived digital terrain model (DTM). This data is derived from DigitalGlobe Satellite Constellation imagery and is accurate to within $-0.01 \text{ m} \pm 0.07 \text{ m}$ ⁵⁶.

4.9 Modern human artefacts are extracted from the OSM buildings dataset⁵⁷ or digitised manually. These are divided into several discrete height classes using ground truth based on expert local knowledge.

⁵⁰ Lesslie, R. (1993) The National Wilderness Inventory: wilderness identification, assessment and monitoring in Australia. International wilderness allocation, management and research. Proceedings of the 5th World Wilderness Congress. 31-36.

⁵¹ Carver, S. (1996) Mapping the wilderness continuum using raster GIS. in S. Morain and S. Lopez-Baros (eds) Raster imagery in Geographic Information Systems. OnWord Press, New Mexico, 283-288.

⁵² Sanderson, E. W., Jaiteh, M., Levy, M. A., Redford, K. H., Wannebo, A. V. and Woolmer, G. (2002) The human footprint and the last of the wild. Bioscience. 52(10): 891-904.

⁵³ Fritz, S., Carver, S. and See, L. (2000) New approaches to wild land mapping in Europe. Proceedings of 15-VOL-2 (2000) Missoula, Montana.

⁵⁴ Carver, S. and Wrightham, M. (2003). Assessment of historic trends in the extent of wild land in Scotland: a pilot study. Scottish Natural Heritage Commissioned Report No. 012 (ROAME No. FO2NC11A).

⁵⁵ Carver, S. (2007) Regeneration of native woodland in the Nidderdale AONB. University of Leeds.

⁵⁶ <https://www.pgc.umn.edu/data/arcticdem/>

⁵⁷ <https://www.openstreetmap.org/relation/299133>

Method

4.10 The use of visibility analyses in GIS that incorporate both a DSM and feature data showing the location and pattern of modern human artefacts allows the creation of cumulative viewsheds that can be weighted according to artefact type and distance. These can be combined and used to describe the attribute layer showing the relative effects associated with the presence and absence of human artefacts. These are applied in the cumulative viewshed methodology. Bishop's (2002)⁵⁸ work on the determination of thresholds of visual impact, and the SNH report on "Visual Assessment of Windfarms: Best Practice" (SNH, 2002)⁵⁹, were used to help define the limits of viewsheds and the distance decay function used.

4.11 Viewshed analyses such as these are extremely costly in terms of computer processing time. Detailed analyses can take weeks, months or even years to process depending on the number of human artefacts included in the database. It is usual to reduce processing times by generalising the artefact database by aggregating the number of human features in a cell of a given size. Work by Carver (2005 and 2007) used cell sizes of 500x500m and 250x250m, respectively. Recent work by Washtell (2007)⁶⁰ has shown that it is possible to both dramatically decrease the processing times required for GIS-based viewshed analyses and improve their overall accuracy, through judicious use of a voxel-based landscape model and a highly optimised ray-casting algorithm.

4.12 While studies exist comparing the advantages of various optimised viewshed algorithms in their own right (Kaučič and Zalik, 2002)⁶¹ as of yet few of these seem to have percolated through into proprietary GIS packages. It is not clear whether the relative lack of sophistication of viewshed analyses sought within the Environmental Sciences (usually restricted to calculating the visibility of a handful of point features), owes itself to limitations in the pervading software, or whether the reverse is true. However, researchers in the domain have for some time been pushing the capabilities of the available tools - for example, by refining workflows for producing cumulative viewsheds (Wheatley, 1995)⁶².

4.13 The algorithm used herein, which is similar to those used in real-time rendering applications and in some computer games, was designed to perform hundreds of traditional point viewshed operations per second. By incorporating this into a custom-built software tool which has been designed to work directly with GIS data (see Figure 4.2), it is possible to estimate the visibility between every pair of cells in a high-resolution landscape model utilising only moderate computing resources. In this way, features of interest are no longer limited to a finite collection of points, but any set of features which can be described by a GIS data layer. This approach (called a 'viewshed transform') can be regarded as a maturation of traditional cumulative viewshed techniques. It was chosen for this project owing to the complexity of the surface and feature layers involved and the importance of applying methods that can realistically model the human perception of visual isolation in complex terrain. Figure 4.2 shows the voxel viewshed transform software interface with both the DSM and feature layers loaded (Figure 4.2a) and with an example inverse square distance weighted viewshed (Figure 4.2b).

4.14 The approach adopted here utilises the Arctic DEM and feature data extracted from the OSM data to:

- calculate a viewshed for every single human artefact;
- incorporate estimates of the proportional area of each artefact that is visible; and
- run separate viewshed calculations for each of the different categories of features listed above and combine these to create the absence of human artefacts attribute map.

⁵⁸ Bishop, I. (2002) Determination of thresholds of visual impact: the case of wind turbines. *Environment and Planning B*. 29(5) 7070-718.

⁵⁹ <https://pdfs.semanticscholar.org/47b7/7e7fd1fb08fb00e05cdfb2bdd9379ce6e635.pdf>

⁶⁰ Washtell, J. (2007) Developing a voxel-based viewshed transform for rapid and real time assessment of landscape visibility. Unpublished course Paper. MSc in Multi-disciplinary Informatics, University of Leeds.

⁶¹ Kaučič, B. and Zalik, B. (2002) Comparison of viewshed algorithms on regular spaced points. In *Proceedings of the 18th Spring Conference on Computer Graphics* (Budmerice, Slovakia, April 24 - 27, 2002). SCCG '02. ACM, New York, NY, 177-183. DOI=<http://doi.acm.org/10.1145/584458.584487>

⁶² Wheatley, D (1995), "Cumulative Viewshed Analysis: a GIS-based method for investigating intervisibility, and its archaeological application", in G.Lock and Z.Stancic (eds.) *Archaeology and GIS: A European Perspective*. pp 171-185, London: Taylor & Francis.

4.15 An inverse square distance function is used in calculating the significance of visible cells. This function gives the relative area in the viewer's field of view that a cell or feature occupies; its relationship to perceived visual intrusion is borne out by the studies previously mentioned. This function is very sensitive to small changes in relative distance and in order that the results of these visibility calculations can be appreciated visually, a log scale is applied such that in the extreme case where a feature fills the observer's field of view, the maximum value is output, with each successive value thereafter representing an order of magnitude less visual intrusion. As even very small levels of visual intrusion are visible on such a scale, it also serves very well to highlight areas which are in total shadow from all visual features owing to the shape of the local landscape. While occurring less frequently in the proximity of modified areas (such as roads, dams and airstrips), pockets entirely bereft of visual intrusion can be found everywhere, owing to the high relief and general ruggedness of the terrain.

4.16 Example outputs from the voxel viewshed transform showing the visibility of each separate feature class are given in Figures 4.3 and 4.5. The completed absence of modern human artefacts attribute map created from the combination of these output layers is shown in Figure 4.6. In all viewshed maps, high values equal low visibility of the features and low values represent high visibility. Areas where no feature is visible are also highlighted on the maps.

Caveats and assumptions

4.17 For this work certain compromises and customisations are necessary in order to make the task manageable. These include:

- The cell resolution in this instance was limited to 20m for all features
- A re-sampling⁶³ was done to generate the buildings feature data in order to guarantee that smaller and larger features in the area were weighted differently by height and size so that the viewsheds produced may be viewed as a realistic representation of the visual impact of the artefacts present;
- The landscape was split into several overlapping tiles, such that they could be worked on in parallel by a cluster of desktop computers; and
- The maximum viewshed distance is 15km for all features (Bishop, 2002).

Rugged and physically challenging nature of the terrain

4.18 The nature of the terrain within the Vonarskarð area is varied and requires careful analysis to determine variations in its morphology (i.e. ruggedness) and challenging nature. Here, rugged and physically challenging terrain is taken to refer to the physical characteristics of the landscape including effects of steep and rough terrain that is frequently found across the area. A digital terrain model is used to derive indices of terrain complexity that take slope (gradient), aspect and relative relief into account to create an attribute map describing the rugged and physically challenging nature of the terrain in the Vonarskarð area.

Data sources

4.19 The ArcticDEM is used here to represent the terrain surface of the Vonarskarð area for these analyses as described in 4.8, resampled at 20m resolution⁶⁴.

⁶³ Re-sampling of feature layers in GIS is normally carried out on a “majority class” basis wherein the value of a grid cell takes on the value of the largest feature by area that it contains. Using this rule, a 5x5m building in a 20x20m grid cell that was otherwise not classified as an artefact, say heather moor, would not be recorded on re-sampling. The “pessimistic” re-sampling used here operates on a presence/absence basis such that any grid cell containing a human artefact will be classified as such even though the actual area or footprint of the artefact may not cover most of the grid cell.

⁶⁴ The ArcticDEM resource was created from both the tiles and the 2014 - 2016 summer strip files which were obtained from the 2m index shapefiles for tiles and strips acquired from: <https://www.pgc.umn.edu/data/arcticdem/>. Files from each index were selected by location with selected files overlapping with the Drangajökull Peninsula shapefile as the criteria. The information for the selected files were exported to tables and the download links were then moved into a .csv file. This file was inputted into a custom script to automatically download all files in batch from links. The Tiles were examined within ArcGIS for any key areas of missing data and where available the best strip file was co-registered using python script from

Method

4.20 Ruggedness is calculated from the ArcticDEM 20m resampled DEM as a simple index defined as the standard deviation (SD) of terrain curvature within a 250m radius of the target location. This is calculated. This generates values representing the amount of convex and/or concave curvature of the surface in both plan form and profile. Areas where curvature changes frequently are identified because they are deemed to represent rapidly changing terrain and hence ruggedness. This is achieved by applying a standard deviation function to the curvature surface within a 250m radius filter as shown in Figures 4.6 and 4.7.

Caveats and assumptions

4.21 It is understood that there are many ways of looking at and measuring ruggedness or roughness of a terrain surface. Other methods considered included fractal complexity⁶⁵, combinations of slope and aspect and statistical indices derived from these. As with the perceived naturalness map, a radius of 250 m is used to estimate ruggedness within a fixed neighbourhood around the target location. This is used to spatially limit the ruggedness index to the immediate vicinity of the observer. It is noted that there are different characters of wilderness in Iceland that relate to ruggedness versus openness, wherein ruggedness is not always connected to wildness but rather openness (large area of open terrain without obvious signs of human land use) is more significant. Nonetheless, the influence of the ruggedness attribute in this mapping exercise is not influenced by the 4x4 access route and so does not affect the overall result when gauging its impact in the Vonarskarð area.

Remoteness

"Distance, 10 miles; total climb, 6,300 feet; time, six and a half hours (including short halts). This tallies exactly with a simple formula, that may be found useful in estimating what time men in fair condition should allow for easy expeditions, namely, an hour for every three miles on the map, with an additional hour for every 2,000 feet of ascent." Naismith (1892)⁶⁶

4.22 Given the varied and challenging nature of the terrain found within the Vonarskarð area it is essential to include terrain as a principal variable governing remoteness across the region. Remoteness is mapped in the Vonarskarð area based on a GIS implementation of Naismith's Rule using detailed terrain and land cover information to estimate the time required to walk from the nearest point of mechanised access be that a road or track or boat landing point. Maps showing remoteness from public roads and hill tracks are included in the SNH policy document 'Wildness in Scotland's Countryside' (SNH, 2002). These are based on linear distance from the nearest public road or hill track taking barrier features such as lochs and reservoirs into account. Work by Carver and Fritz (1999) has developed anisotropic measures of remoteness based on a GIS implementation of Naismith's Rule incorporating Langmuir's corrections⁶⁷. This model assumes a person can walk at a speed of 5km/hr over flat terrain and adds a time penalty of 30 mins for every 300m of ascent and 10 mins for every 300m of descent for slopes greater than 12 degrees. When descending slopes between 5 and 12 degrees a time bonus of 10 mins is subtracted for every 300 metres of descent. Slopes between 0 and 5 degrees are assumed to be flat. This has been subsequently applied in modelling the historic trends in wild lands in the central

<https://github.com/dshean/demcoreg>. The outputted strip files and tiles were then mosaicked into a new 2m Raster and clipped to the Drangajökull Peninsula. The DEM was then converted to 20m using the "resample" tool any remaining missing data being taken from the 10 National Land Survey DEM acquired from <https://www.arcgis.com/home/item.html?id=5bb01c378d2e4d0381c49e38bd96d4d9>. Verk

⁶⁵ Fractal complexity refers to the degree to which an object can be divided into separate objects each of which is similar to the original. For example, a tree can be split into a series of branches each of which may resemble the original tree. These branches can then be divided themselves into twigs, each of which again may resemble the original tree and its branches.

⁶⁶ Naismith, W. W. (1892) Scottish Mountaineering Club Journal. II: 136

⁶⁷ Langmuir, Eric. (1984) Mountaineering and leadership: a handbook for mountaineers and hillwalking leaders in the British Isles. Edinburgh: Scottish Sports Council, 1984.

Highlands of Scotland (Carver and Wrightham, 2007)⁶⁸ and wild land quality in the Scottish national parks (Carver et al., 2012)⁶⁹.

4.23 This anisotropic⁷⁰ approach to modelling remoteness is based on the relative time taken to walk into a roadless area from the nearest point of mechanised access taking the effects of distance, relative slope, ground cover, and barrier features⁷¹, such as open water, large fast-flowing rivers and very steep ground, into account. This assumes remoteness to be directly proportional to the time taken to walk from A to B across varied terrain and is therefore analogous to the concept of the long walk in which is a long-established principle in Scottish mountaineering and could equally be applied to the terrain of the Vonarskarð area with some modifications for river crossings and the Vatnajökull icecap. The implementation of this model of remoteness requires a detailed terrain model and ancillary data layers that are used to modify walking speeds according to ground cover (e.g. Naismith's approximation of 5 kilometres per hour on the map can be reduced to 4 kilometres per hour or less when walking across open heath, soft sand or tundra), and include barrier features as null values which force a detour to find a safe and suitable crossing point.

Data sources

4.24 Calculating remoteness based on Naismith's Rule requires a range of data including a detailed terrain model, land cover data and information on the location of rivers, open water, roads, tracks and other access features. These are all sourced from datasets described in the previous sections on naturalness, human artefacts and ruggedness. The ArcticDEM data is used for the terrain model, the Nyttjaland forsiða for the land cover data and OSM for the road, track, open water and river data. Barriers to access were taken from paper maps and digital map databases. These were confirmed using local knowledge of national park rangers.

Method

4.25 Remoteness is calculated here using a GIS implementation of Naismith's Rule incorporating Langmuir's Correction based on the PATHDISTANCE function in ArcGIS. This estimates walking speeds based on relative horizontal and vertical moving angles across the terrain surface together with appropriate cost or weight factors incurred by crossing different land cover types and the effects of barrier features such as lakes, large rivers and very steep ground (cliffs). Remoteness is calculated considering access over land only. The outputs from the land models were combined to produce a total remoteness map. The theory and practical application of this model is described by Carver and Fritz (1999). The walking model is applied using the following conditions:

Source grid: This is taken to be those roads and tracks that provide vehicular access via private car or "super-jeps".

Cost surface: This is assumed to be 5 km/h for all land cover types except heathland, sand and barren land which is 3 km/hr and wetland which is 2 km/hr. Fords across rivers were deemed to take 20 mins to which equates to approximately 0.06 km/h as the pixel size was 20 m.

Barriers to movement: These are taken to include slopes that exceed 45° and rivers identified by local experts as unpassable. Most rivers in the study area are ephemeral and can most often be crossed on foot. These sections

⁶⁸ Carver, S. and Wrightham, M., 2007. Shrinking wild lands: Assessing human intrusion in the Highlands of Scotland, 1870 to 2004, using Geographical Information Systems. In In: Watson, Alan; Sproull, Janet; Dean, Liese, comps. Science and stewardship to protect and sustain wilderness values: Eighth World Wilderness Congress symposium; September 30-October 6, 2005; Anchorage, AK. Proceedings RMRS-P-49. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 357-366 (Vol. 49).

⁶⁹ Carver, Steve, Alexis Comber, Rob McMorran, and Steve Nutter. "A GIS model for mapping spatial patterns and distribution of wild land in Scotland." *Landscape and Urban Planning* 104, no. 3-4 (2012): 395-409.

⁷⁰ Anisotropic models do not assume equal ease of travel/movement in all direction, rather movement is either aided or restricted by other factors such as steepness of slope and the presence of impassable barriers such as lochs such that the cost of movement is not-directly proportional to horizontal distance. Isotropic models are much less realistic because they do assume equal ease of movement in all directions and therefore oversimplify the concept of remoteness in this context.

⁷¹ NoData or null values in a raster grid contain no data and so are disregarded in most calculations unless the model explicitly references these. NoData values are useful in building access models in that they can be used to describe the locations of barrier features that cannot be crossed.

of river are assumed to be crossable where there is a bridge or where these rivers are crossed by a path and so can be assumed to be passable at these locations with a short time delay.

4.26 The inputs to the remoteness modelling for the current conditions existing within the Vonarskarð area are shown in Figure 4.8. The current remoteness from mechanised access as modelled using these methods and data is shown in Figure 4.9.

Caveats and assumptions

4.27 Naismith's Rule and the model used to implement it here assumes a fit and healthy individual, and does not make any allowance for load carried, weather conditions (such as poor visibility and strong head winds) and navigational skills. The model does, however, take barrier features and conditions underfoot into account as described above. Lakes and reservoirs are considered impassable on foot and are included as barrier features by coding these as NoData (null values) in the model inputs. This forces the model to seek a solution that involves walking around the barrier. The model also uses a cost or friction surface that controls the walking speed according to the land cover or conditions underfoot. A speed of 4km/hr (1.389m/s) is assumed for most land cover types, while speeds of 3km/hr (0.833m/s) and 2km/hr (0.555m/s) are assumed for the heathland and wetland examples, respectively⁷². The angle at which the terrain is crossed (i.e. the horizontal and vertical relative moving angles) is used to determine the relative slope and height lost/gained⁷³. These values are input into the model using a simple look up table as shown in Table 4.2. The road network, both within and outside the boundary of the Vonarskarð area is used as the access points from which to calculate remoteness of off-road areas. In considering the effects of selected large and fast-flowing rivers deemed to be barrier features, these are assumed crossable by 4x4 super jeep.

Table 4.1 Naturalness classifications applied to land cover features

Naturalness class	Land cover class
0	NoData
2	Cultivated Land/Shrubland
3	Grassland/Unknown (Lowland Vegetated)
4	Rich Heathland/Poor Heathland
5	Mossland/Damp Wetland/Wetland/Poorly Vegetated/Barren/Lakes/Glacier/Unknown

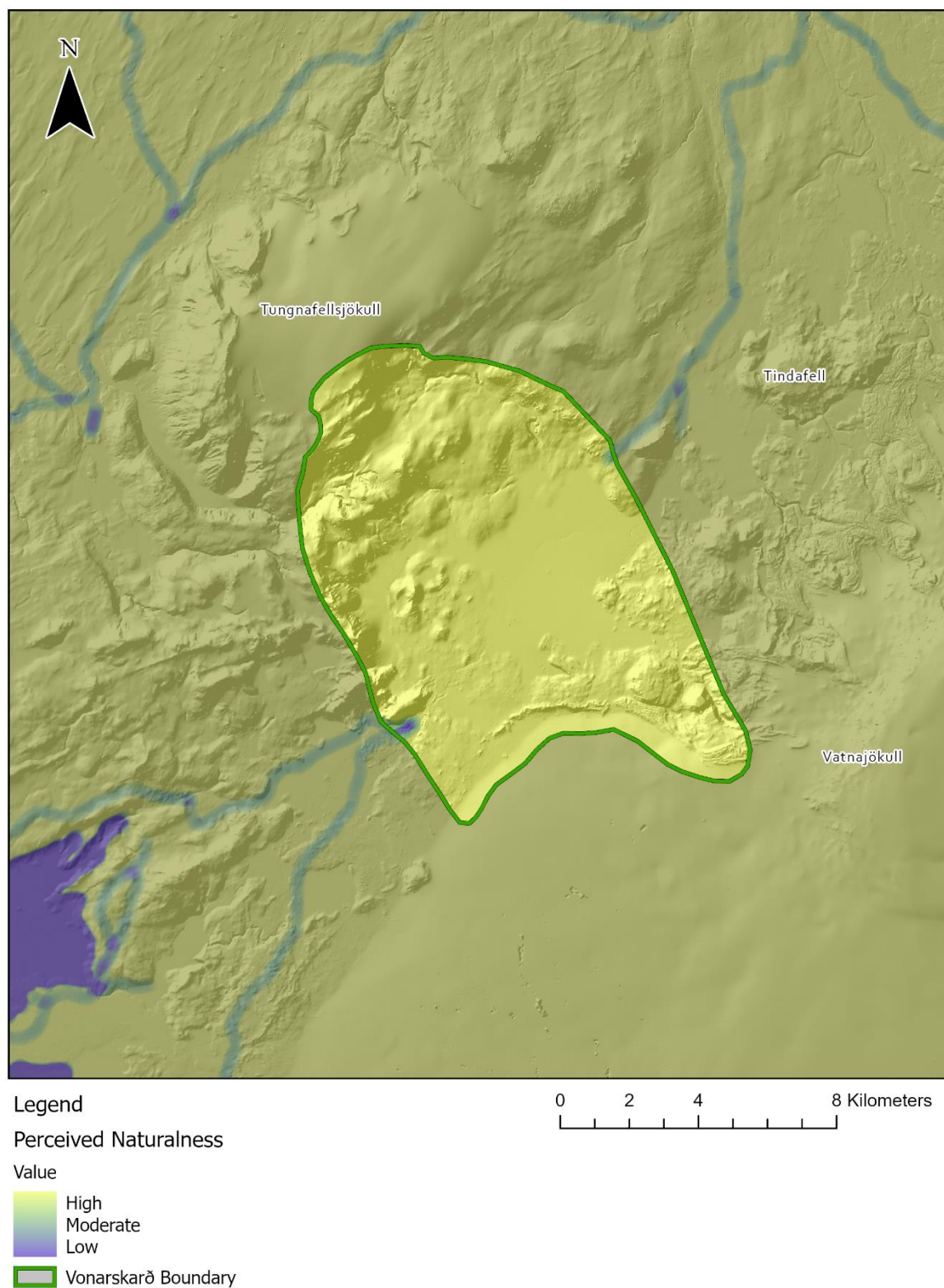
⁷² Lower walking speeds are included here based on discussion about the maximum likely speeds attainable across these two land cover types.

⁷³ Vertical and horizontal factors determine the difficulty of moving from one cell to another while accounting for the vertical or horizontal elements that may affect the movement, these include slope and aspect as they determine the relative angle of the slope in the direction it is crossed and hence the height gained or lost

Table 4.2 Speed applied to land cover classes

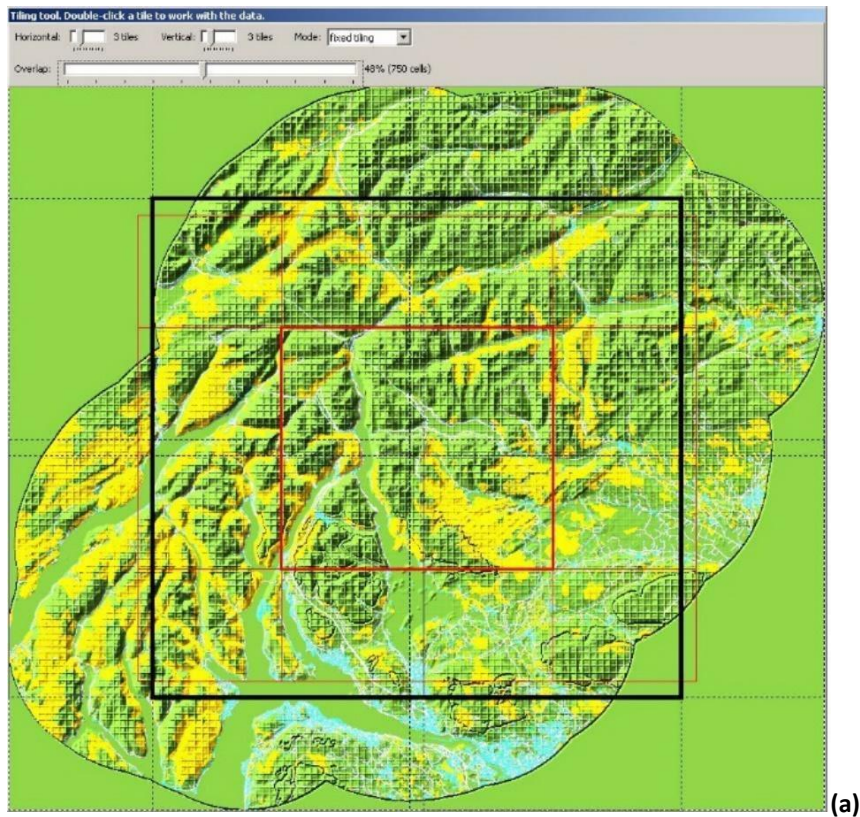
Id	Class	Speed (km/h)
0	NoData	NoData
1	Grassland	4
2	Rich Heathland	4
3	Cultivated Heathland	4
4	Poor Heathland	3
5	Scrubland	3
6	Moss land	2
7	Damp Wetland	2
8	Wetland	2
9	shrub land (Forestry)	3
10	Poorly vegetated	3
11	Barren (inc. sand)	3
12	Lakes	NoData
13	Glacier	1
14	Unknown	3

Note: These tables display the entire range of values across the range of landscapes covered within them. Not all land cover types are included within the study area.

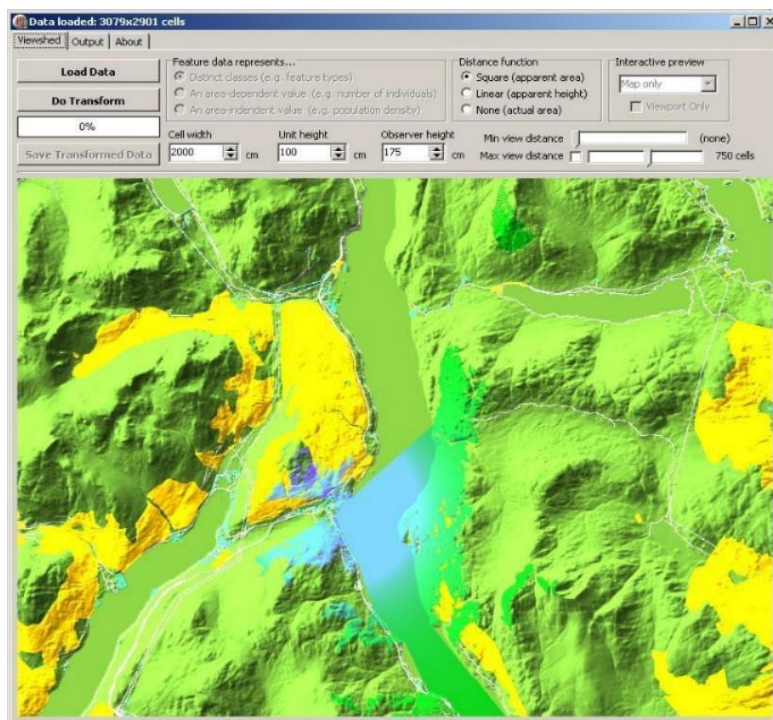


Sources: Earthstar Geographics, Samsyn Ehf, Esri, HERE, Garmin, FAO, NOAA, USGS, Esri, USGS, Wildland Research Institute

Figure 4.1 Perceived naturalness of land cover



(a)



(b)

Figure 4.2 The Viewshed tool interface demonstrating (a) the tiling tool (b) sample DSM and feature tiles loaded into the model

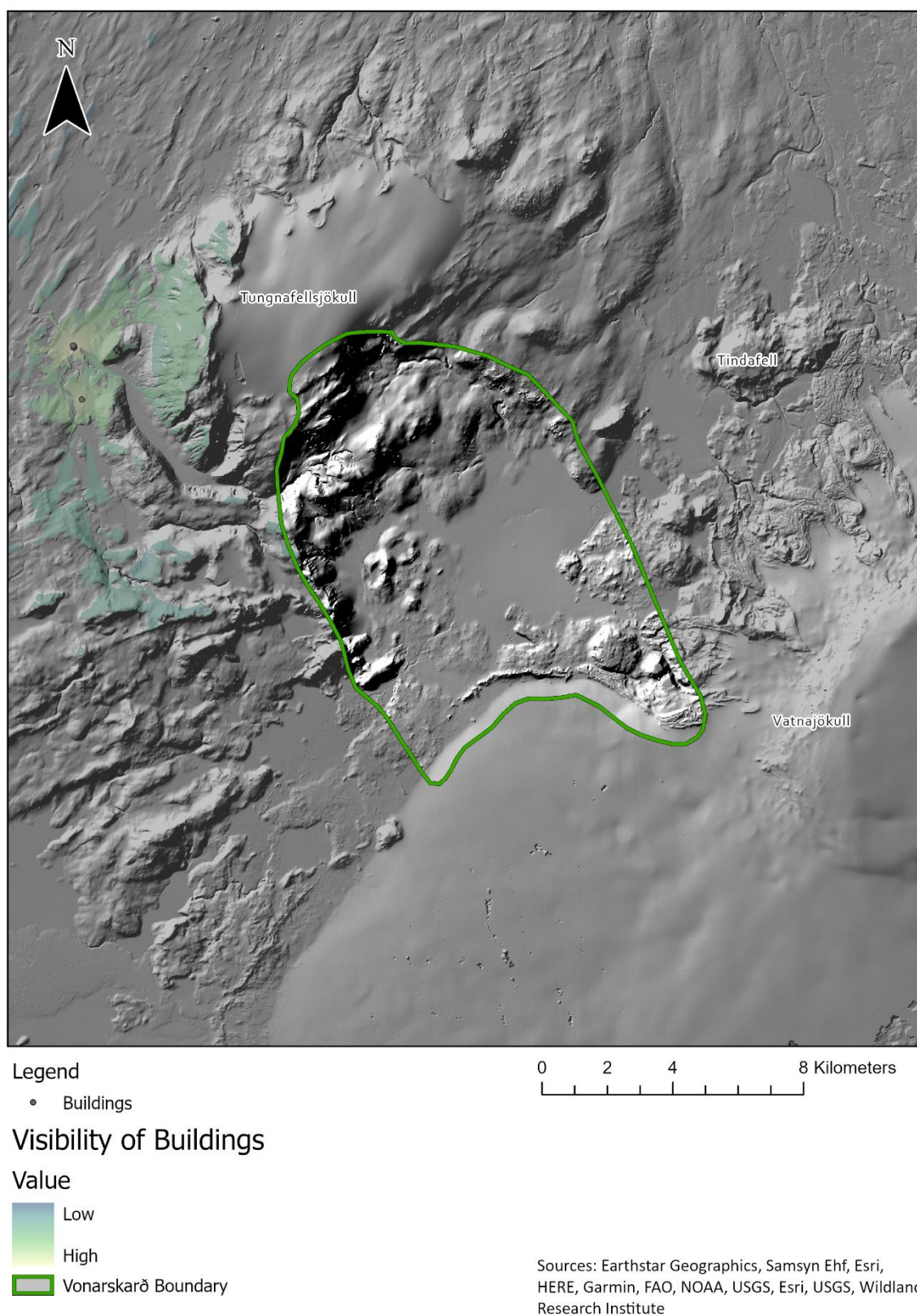


Figure 4.3 Visibility of existing buildings

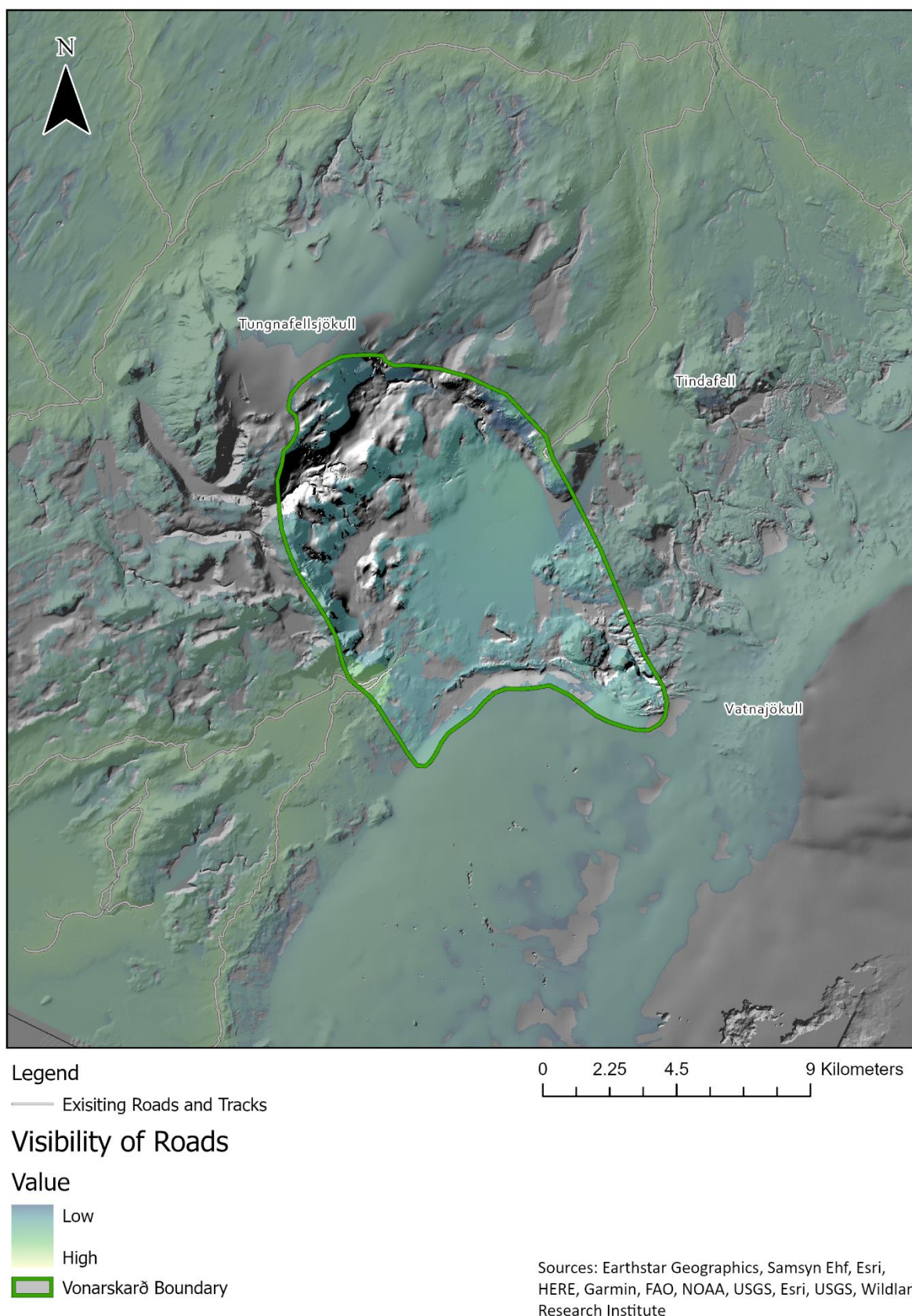


Figure 4.4 Visibility of existing roads/tracks

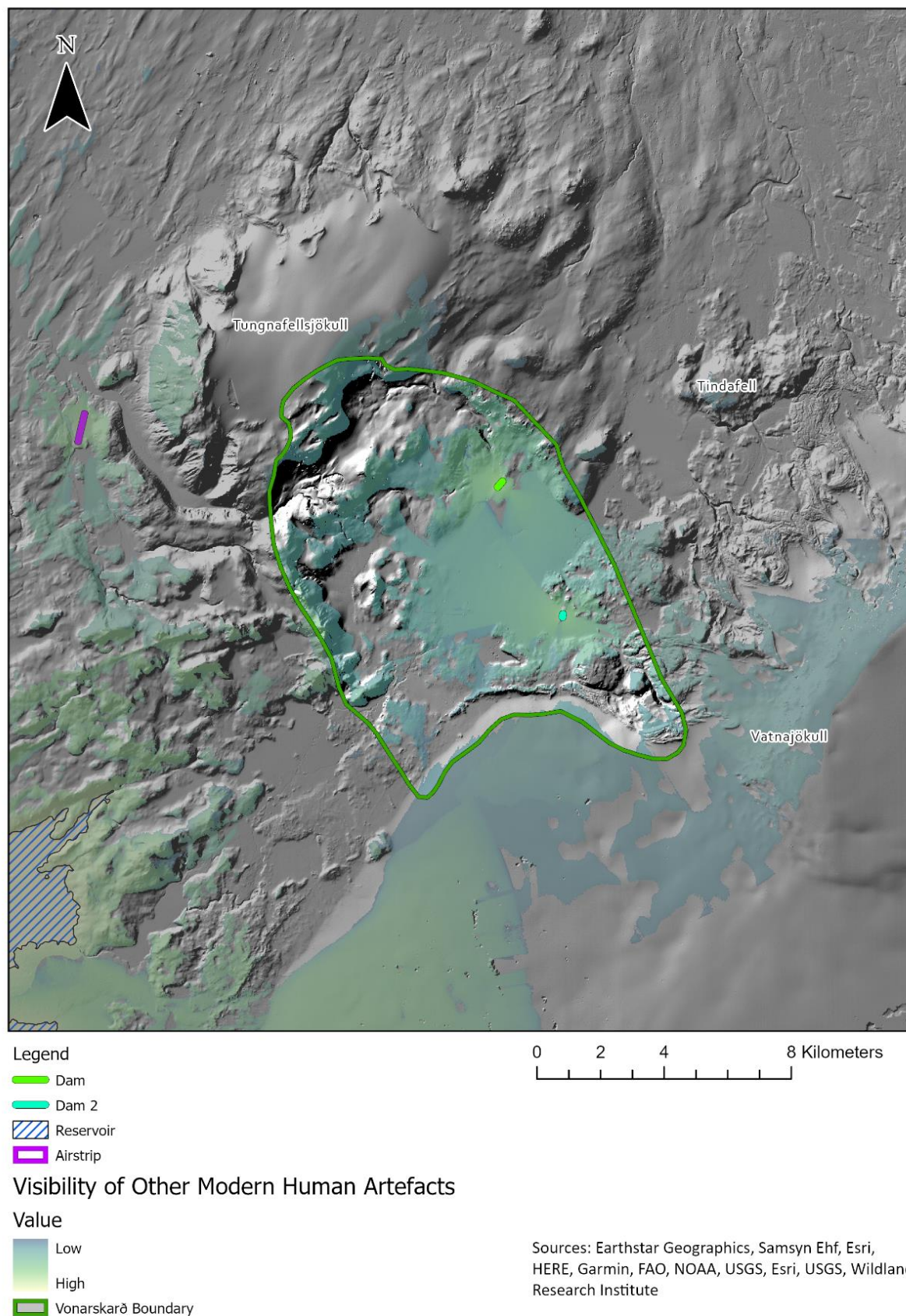


Figure 4.5 Visibility of other existing modern human artefacts (including airstrip and dams)

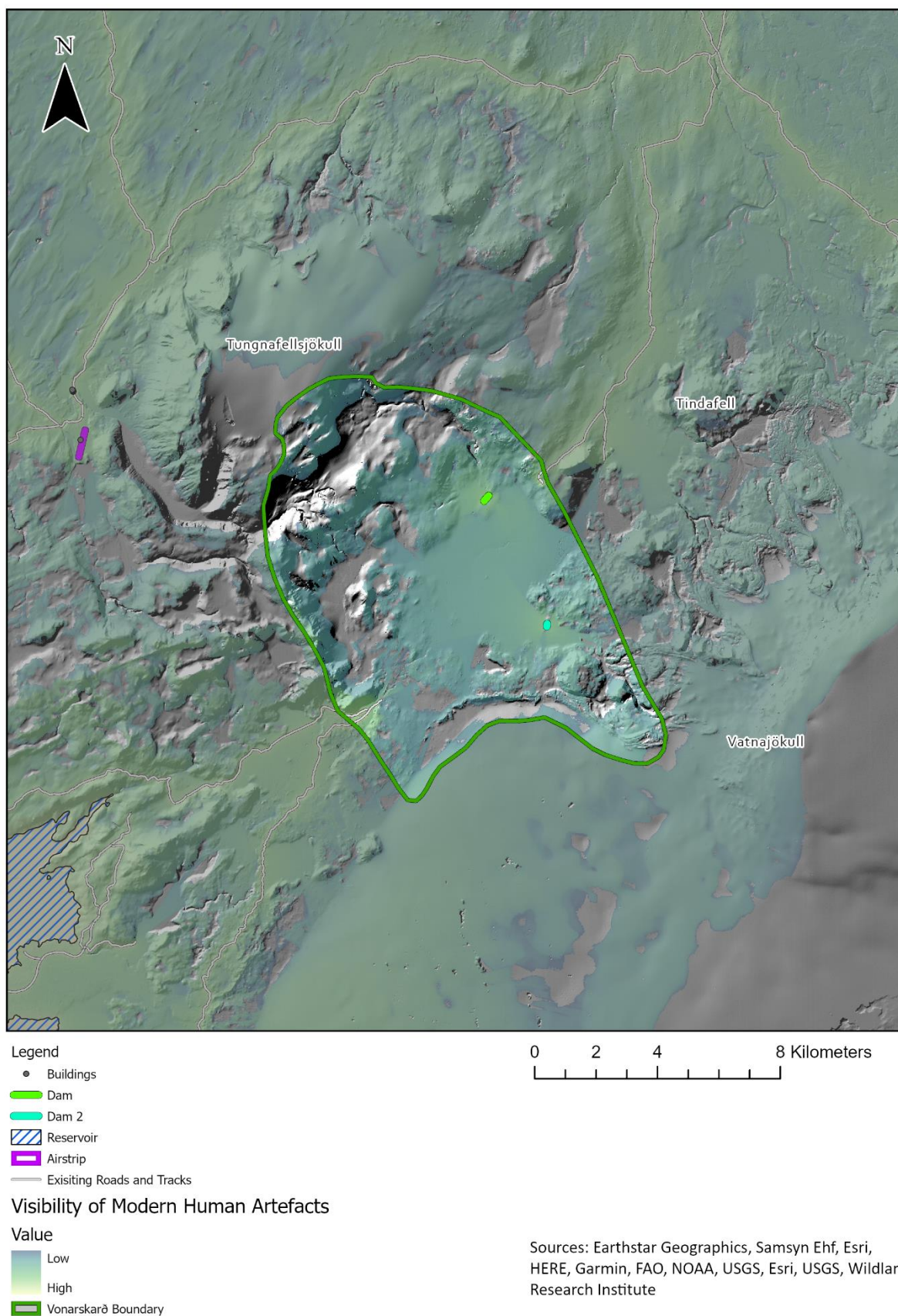


Figure 4.6 Combined visibility of all modern human artefacts

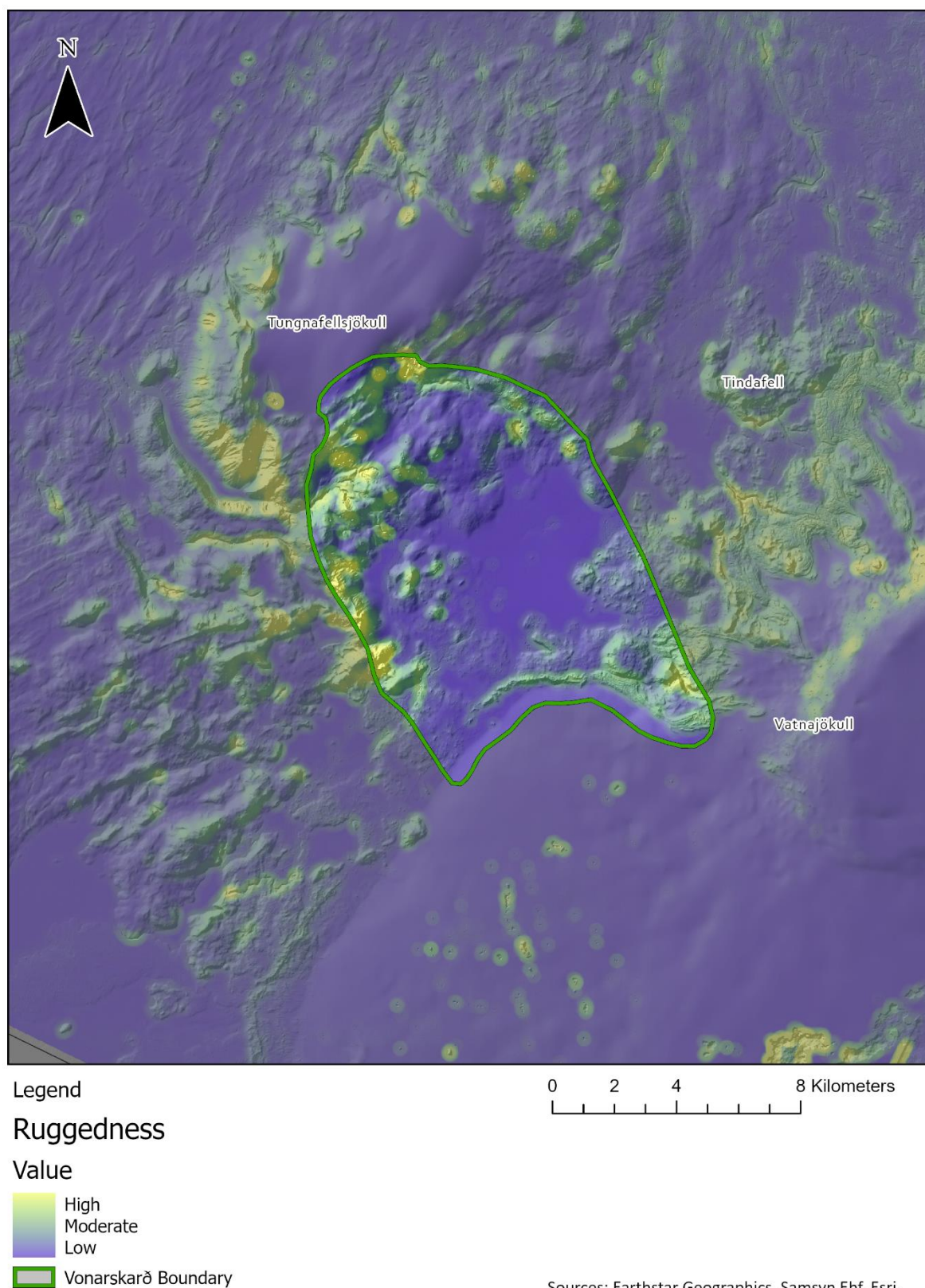


Figure 4.7 Rugged and challenging nature of the terrain

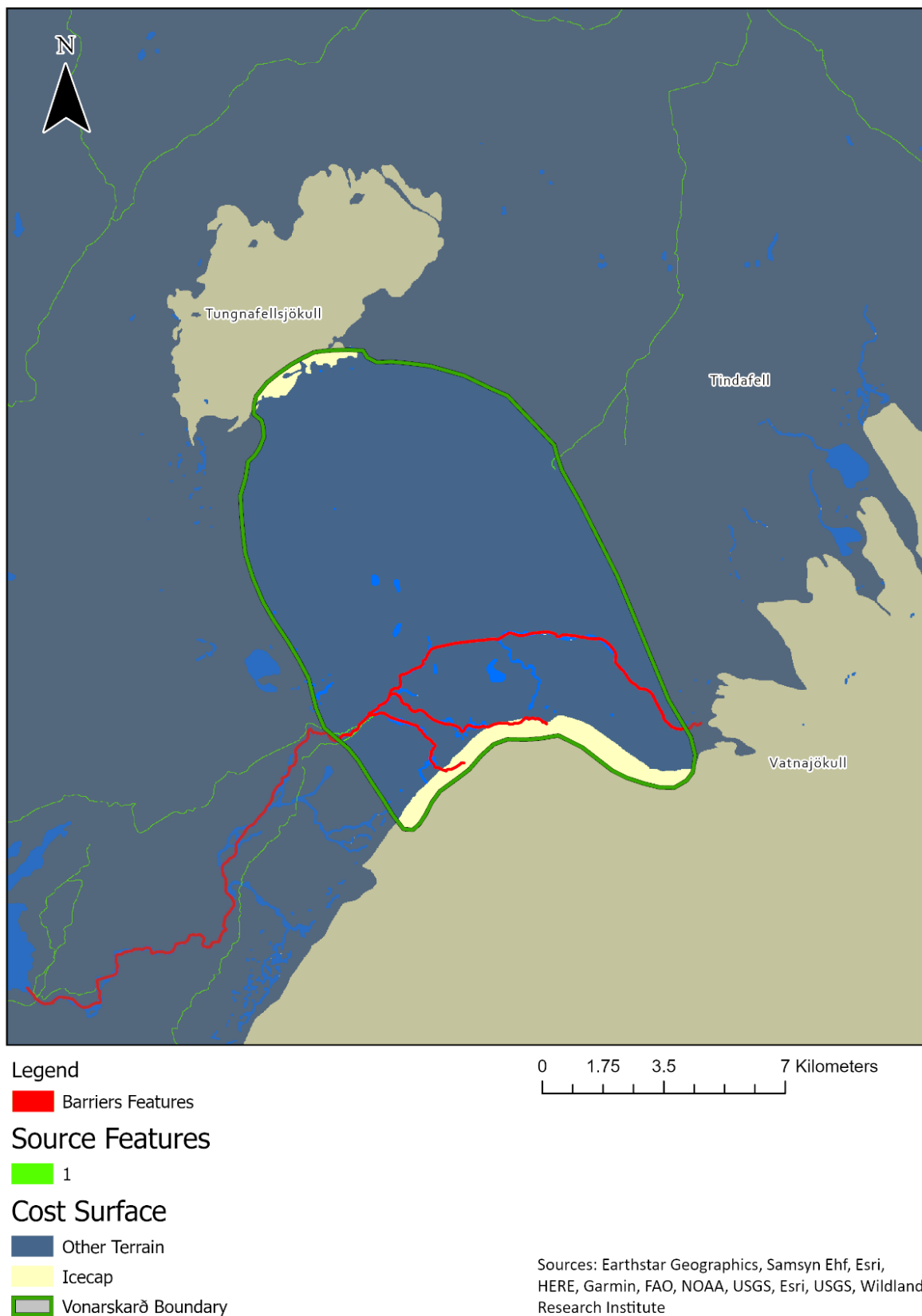


Figure 4.8 Inputs to the remoteness model under current conditions showing mechanised access (source), cost surface and barriers to movement.

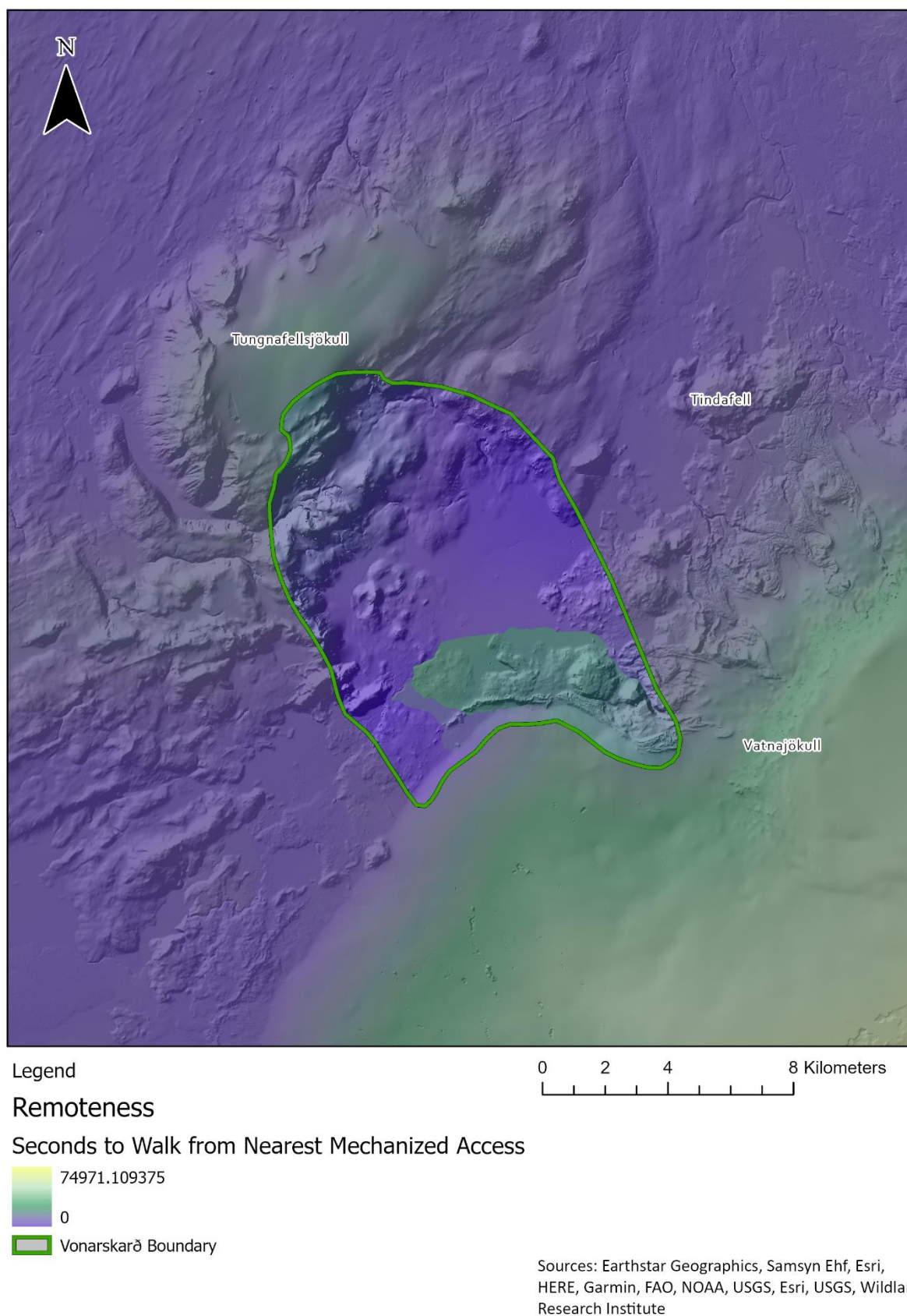


Figure 4.9 Current remoteness from mechanised access

5. Results: impacts on the patterns of wilderness in the Vonarskarð area

5.1 The spatial variation in wilderness quality across the Vonarskarð area under current conditions is shown in Figure 3.2. This is based on applying the model described in Section 3 to each of the four attributes of wilderness described in Section 4. This provides a rigorous and robust spatial baseline for wilderness quality across the study area against which the predicted impacts of the hypothetical re-opening to 4x4 access can be measured through repeat mapping. This requires that the four wilderness attributes described and illustrated in Section 4 are recalculated with the hypothetical 4x4 access track in place for comparisons to be made with existing conditions.

5.2 To do this, each of the input layers used in calculating the perceived naturalness of land cover, absence of modern human artefacts, ruggedness and remoteness from mechanised access are amended and updated to include the hypothetical access route shown in Figure 1.2. The impact from the hypothetical re-opening to 4x4 access on each of these four attributes can be determined by subtracting the attribute maps with the hypothetical 4x4 access route in place from the current maps with no 4x4 access.

5.3 The wilderness quality maps can be classified into core, buffer and edge zones based on the application of the Phase 2 mapping methods used in the mapping of Scottish Wild Land Areas⁷⁴. Here, SNH applied a classification of their Phase 1 wilderness quality index based on dividing the spread of wilderness quality values using the Jenks natural breaks method⁷⁵ with 8 classes as shown in Figures 5.8 and 5.9, from which the top two classes (8&7) are taken to define the core areas, the next two classes (6&5) are taken to define the buffer zone, and the remain 4 classes (4-1) are taken to define the edge or non-wilderness areas. This approach is adapted and applied here, and the results shown in Figures 5.10 and 5.11. These are then subtracted to show the changes in core and buffer areas if the 4x4 access track would be re-opened. This allows the calculation of both absolute areas and percentage changes to the existing core wilderness and buffer zones that would result from re-opening to 4x4 access in the Vonarskarð area. The Vatnajökull ice cap is excluded from these maps to avoid skewing the results towards the large empty ice cover areas.

⁷⁴ SNH's Mapping of Scotland's Wildness and Wild Land: Non-technical Description of the Methodology (June 2014) <https://www.nature.scot/snhs-mapping-scotlands-wildness-and-wild-land-non-technical-description-methodology>

⁷⁵ The Jenks natural breaks method seeks to minimize each the deviation within each class from the average deviation from the class mean, while maximizing each class's deviation from the means of the other groups.

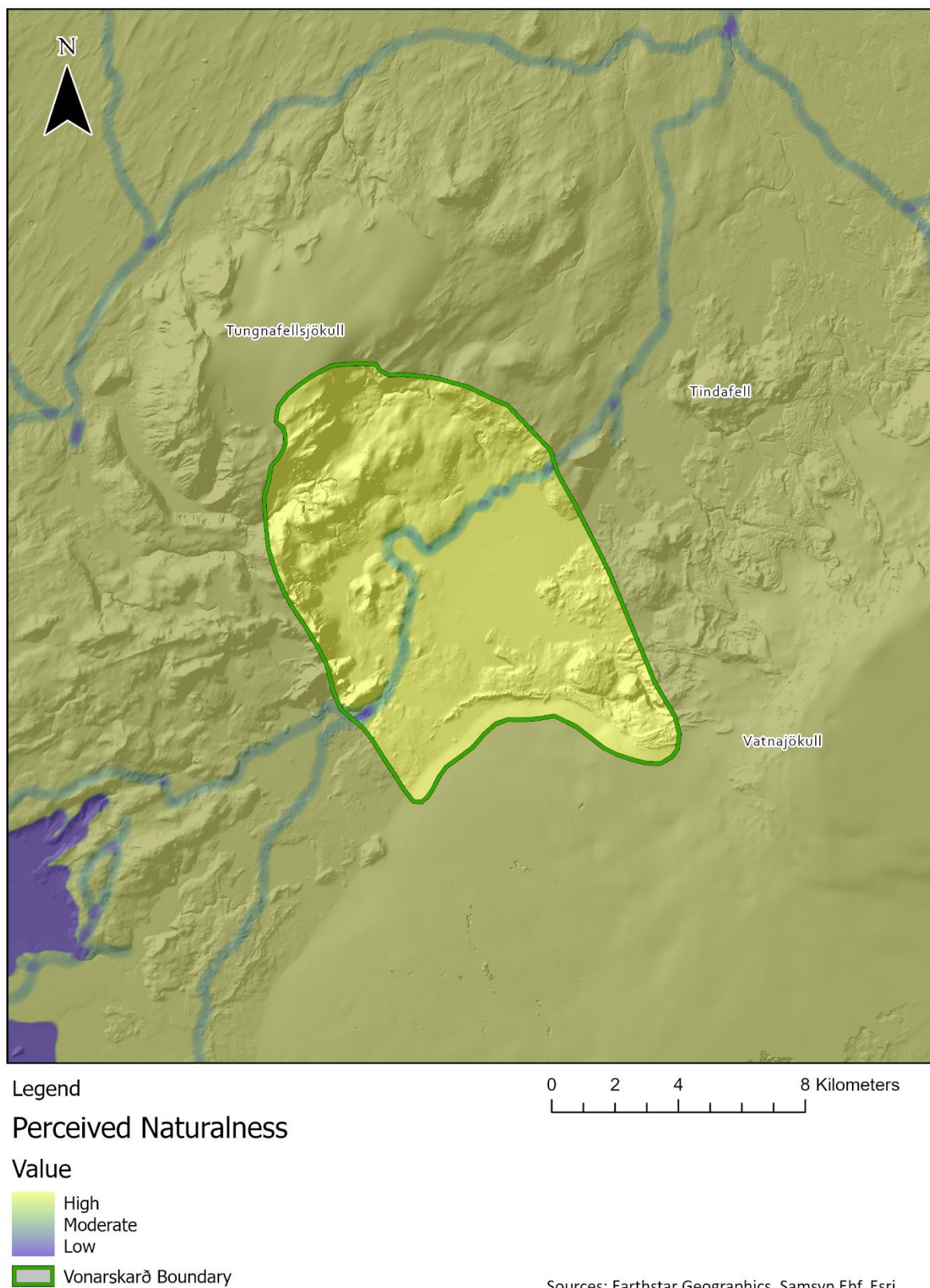
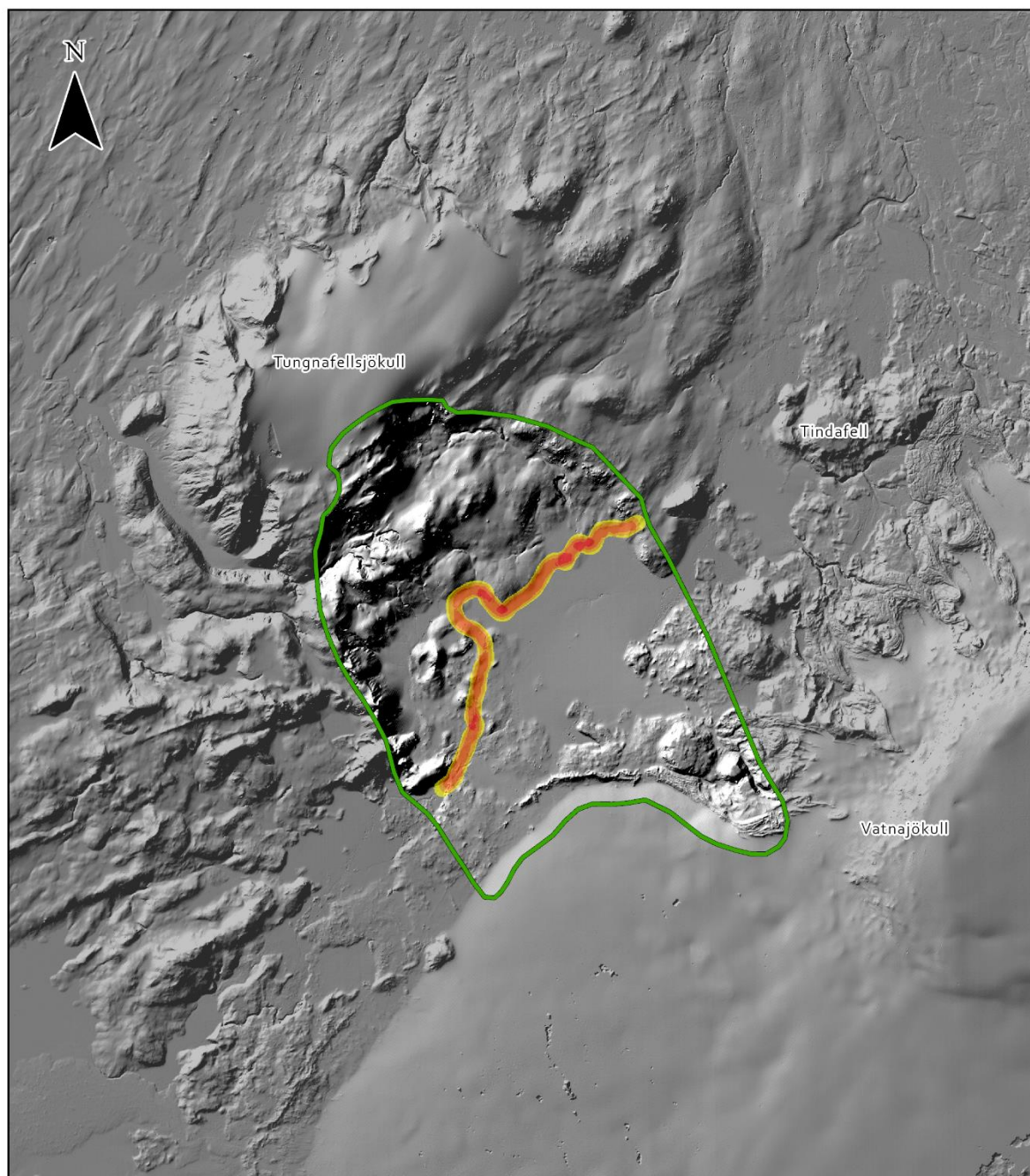


Figure 5.1 Perceived naturalness post-re-opening of hypothetical 4x4 access route



Legend

Decrease in Naturalness

Value

Very High

High

Moderate

Low

No Change

Vonarskarð Boundary

0 2 4 8 Kilometers

Sources: Earthstar Geographics, Samsyn Ehf, Esri, HERE, Garmin, FAO, NOAA, USGS, Esri, USGS, Wildland Research Institute

Figure 5.2 Impact of hypothetical re-opening 4x4 access track on perceived naturalness

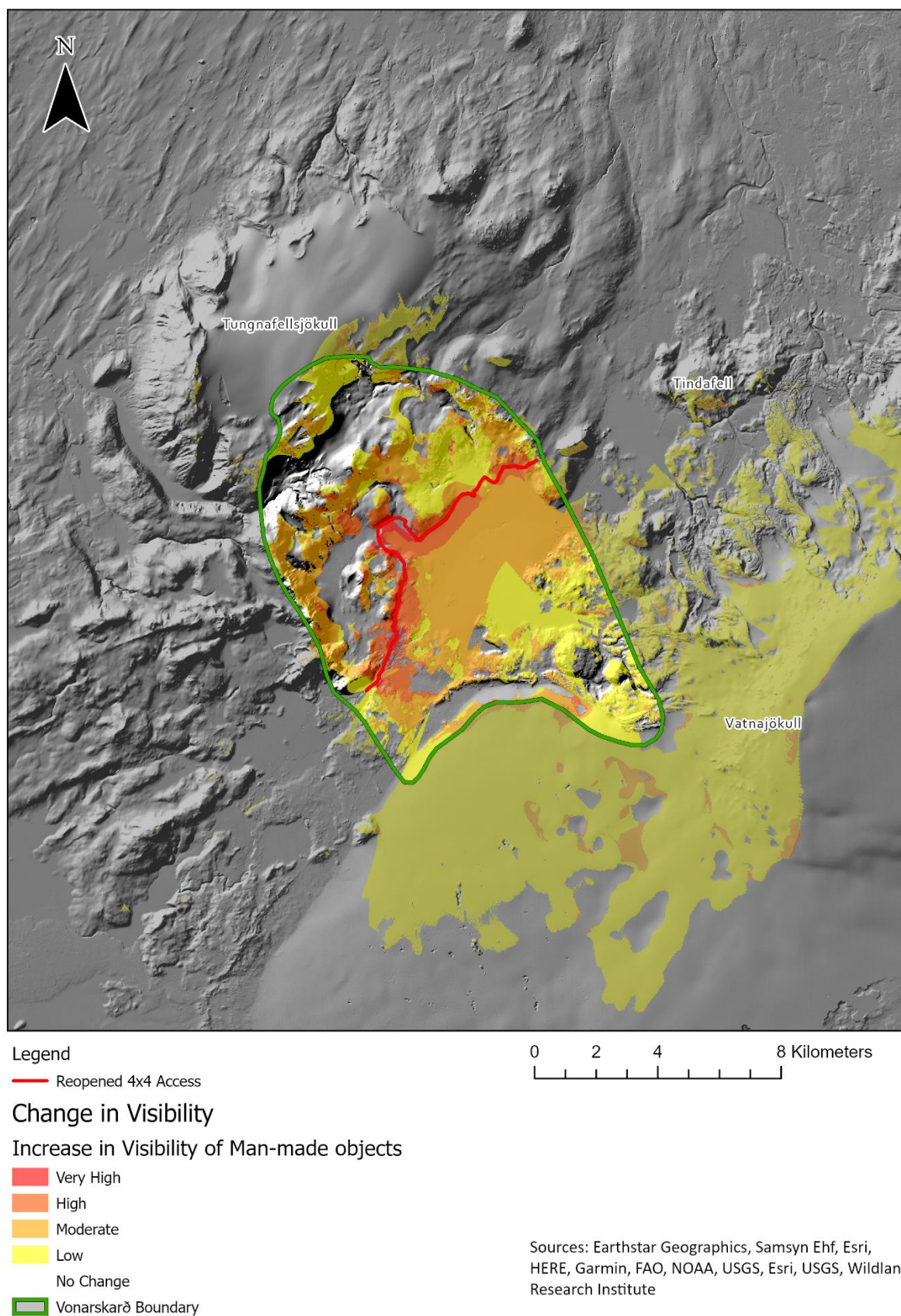


Figure 5.4 Impact of 4x4 access track on absence of modern human artefacts

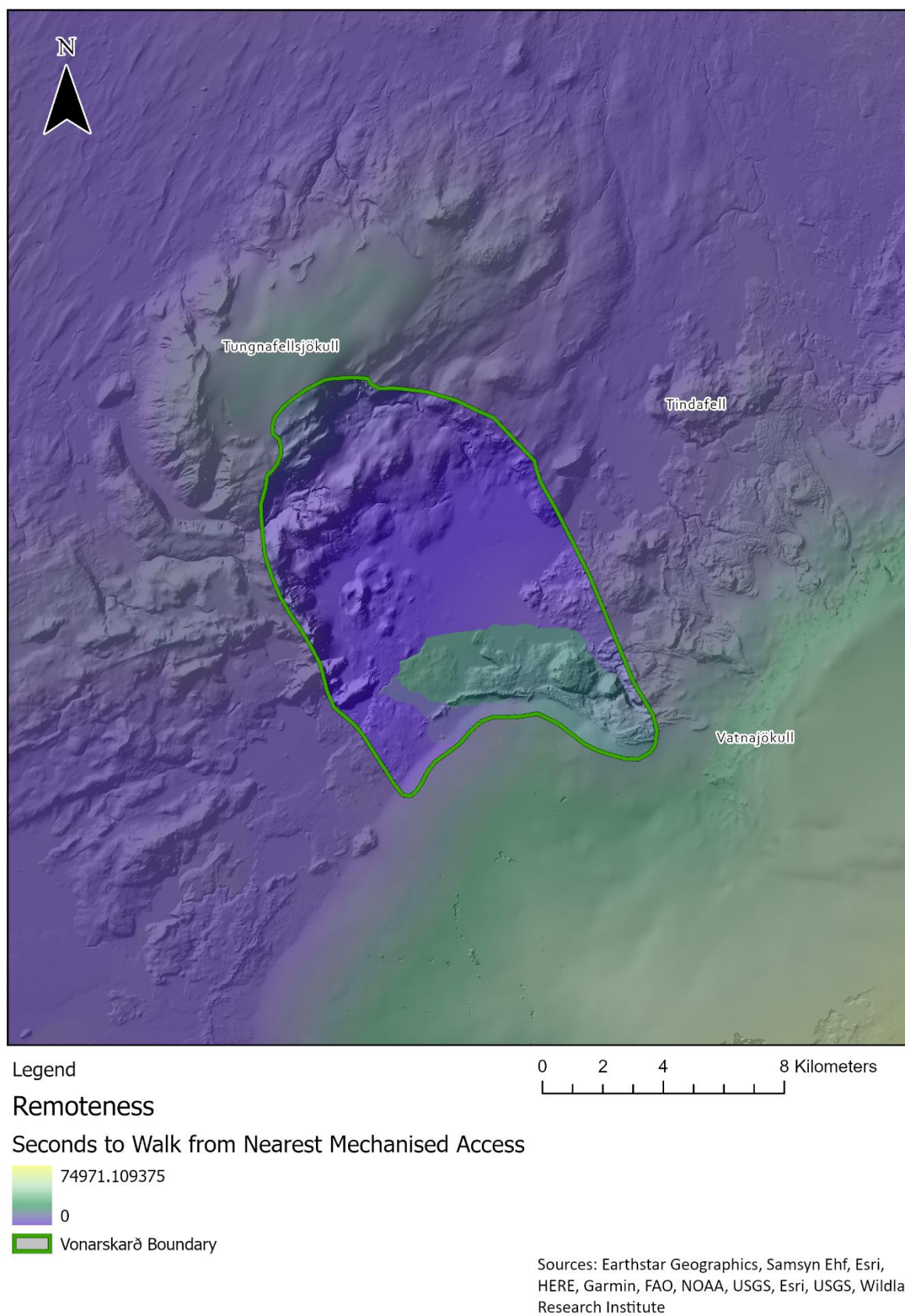
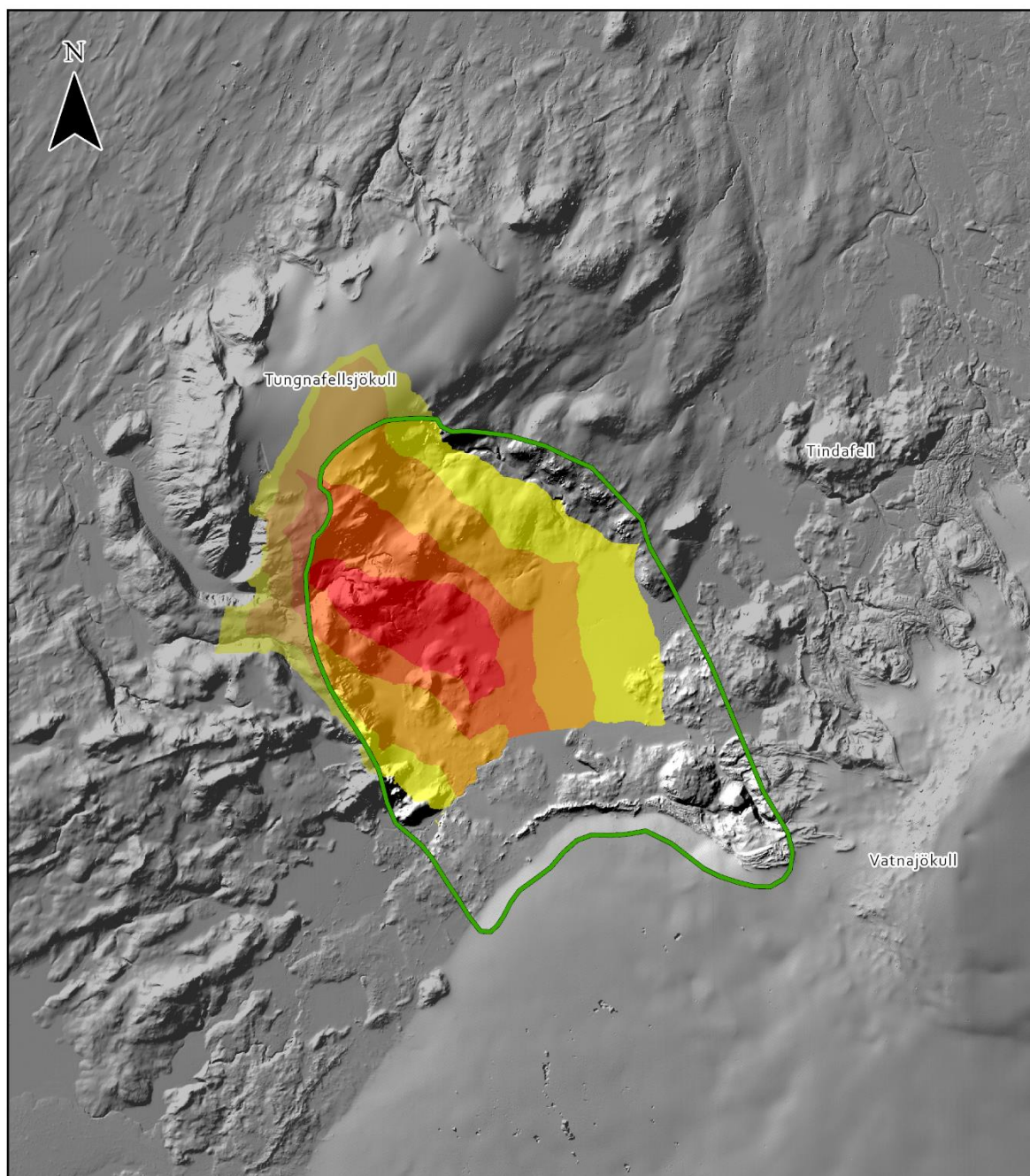


Figure 5.5 Remoteness post-4x4 access track



Legend

Change in Remoteness

Level of Decrease

Very High

High

Moderate

Low

No Change

Vonarskarð Boundary

0 2 4 8 Kilometers

Sources: Earthstar Geographics, Samsyn Ehf, Esri, HERE, Garmin, FAO, NOAA, USGS, Esri, USGS, Wildland Research Institute

Figure 5.6 Impact of 4x4 access track on remoteness

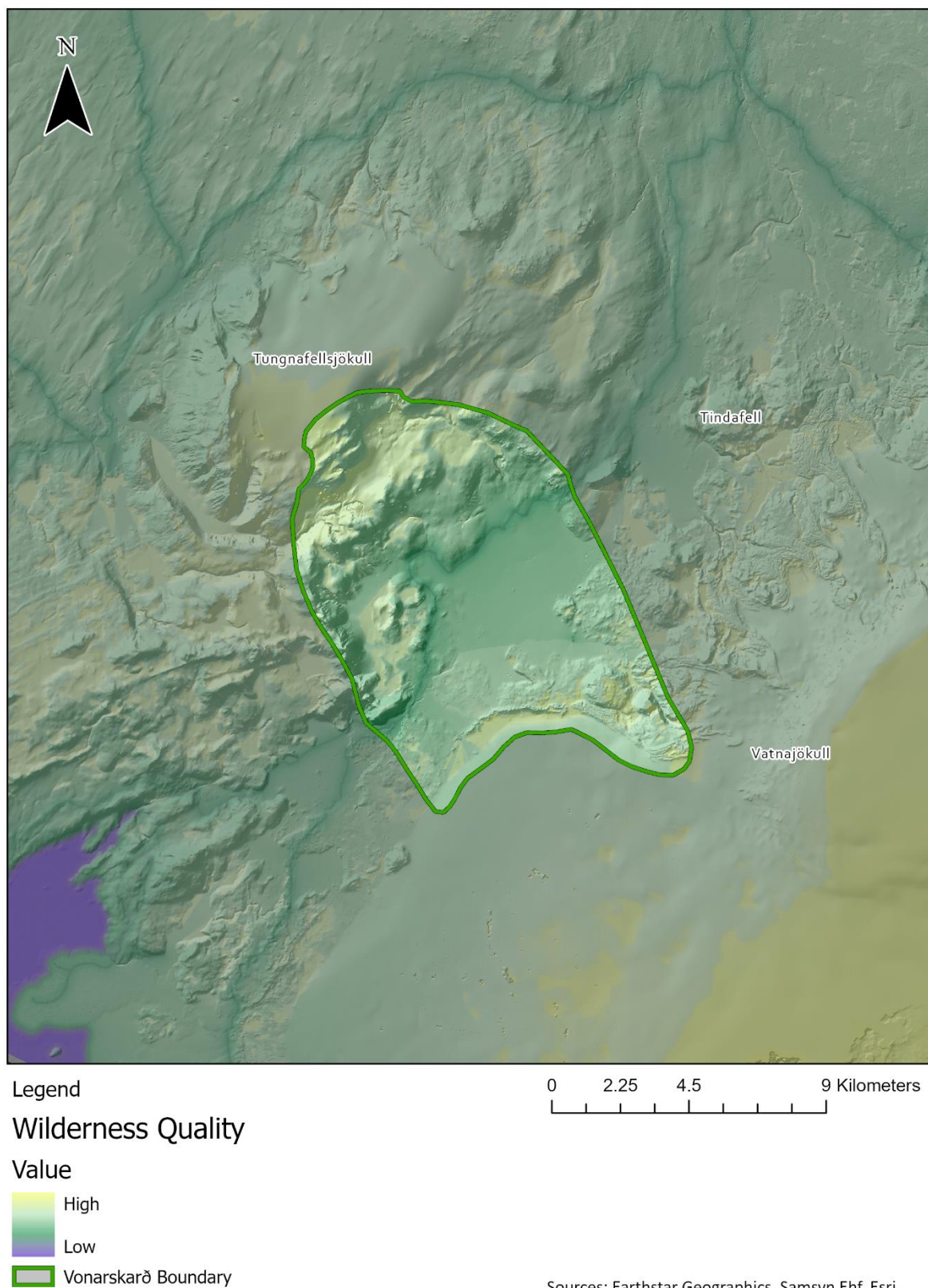


Figure 5.7 Wilderness quality post-4x4 access track

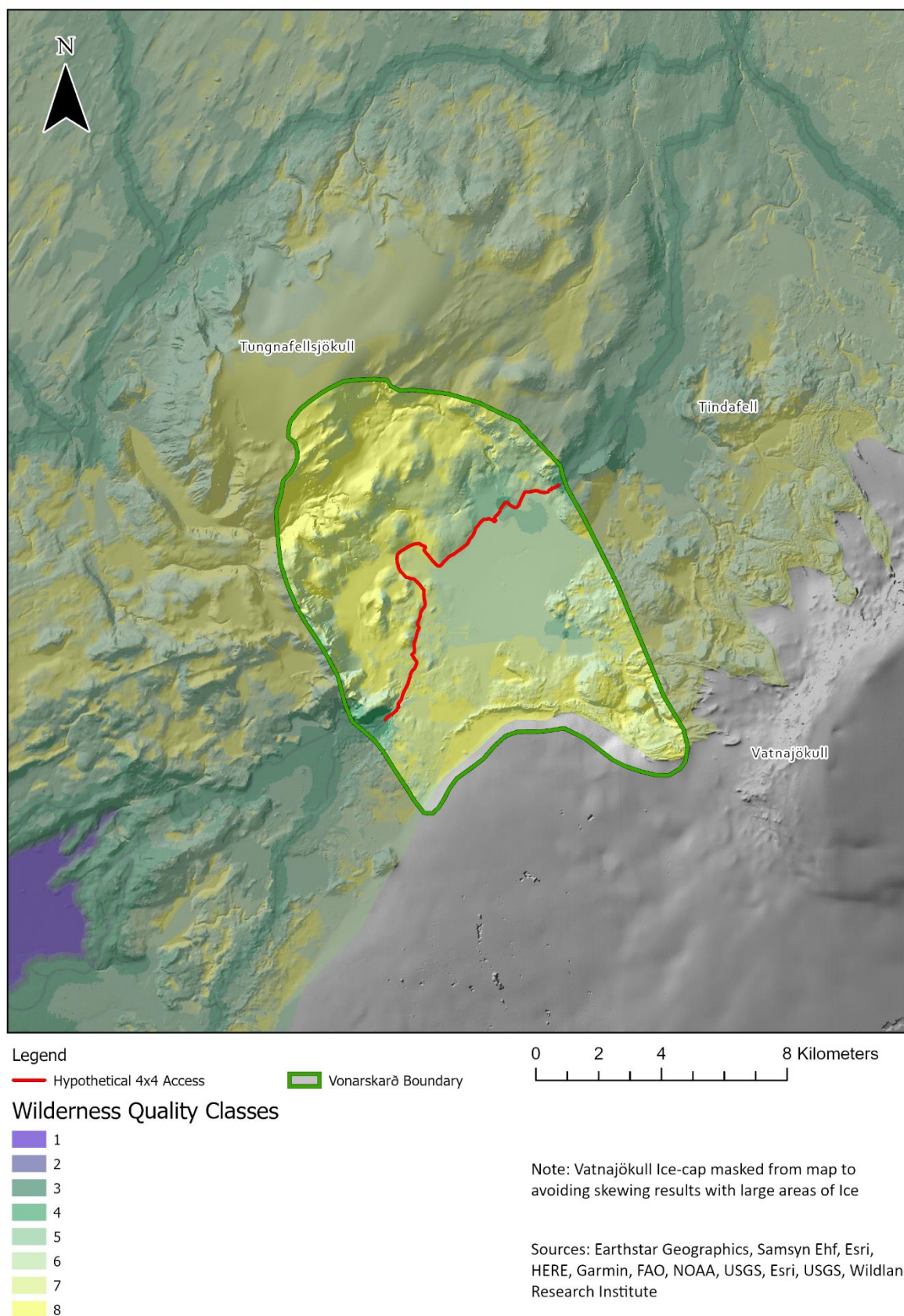


Figure 5.8 Current wilderness quality classes

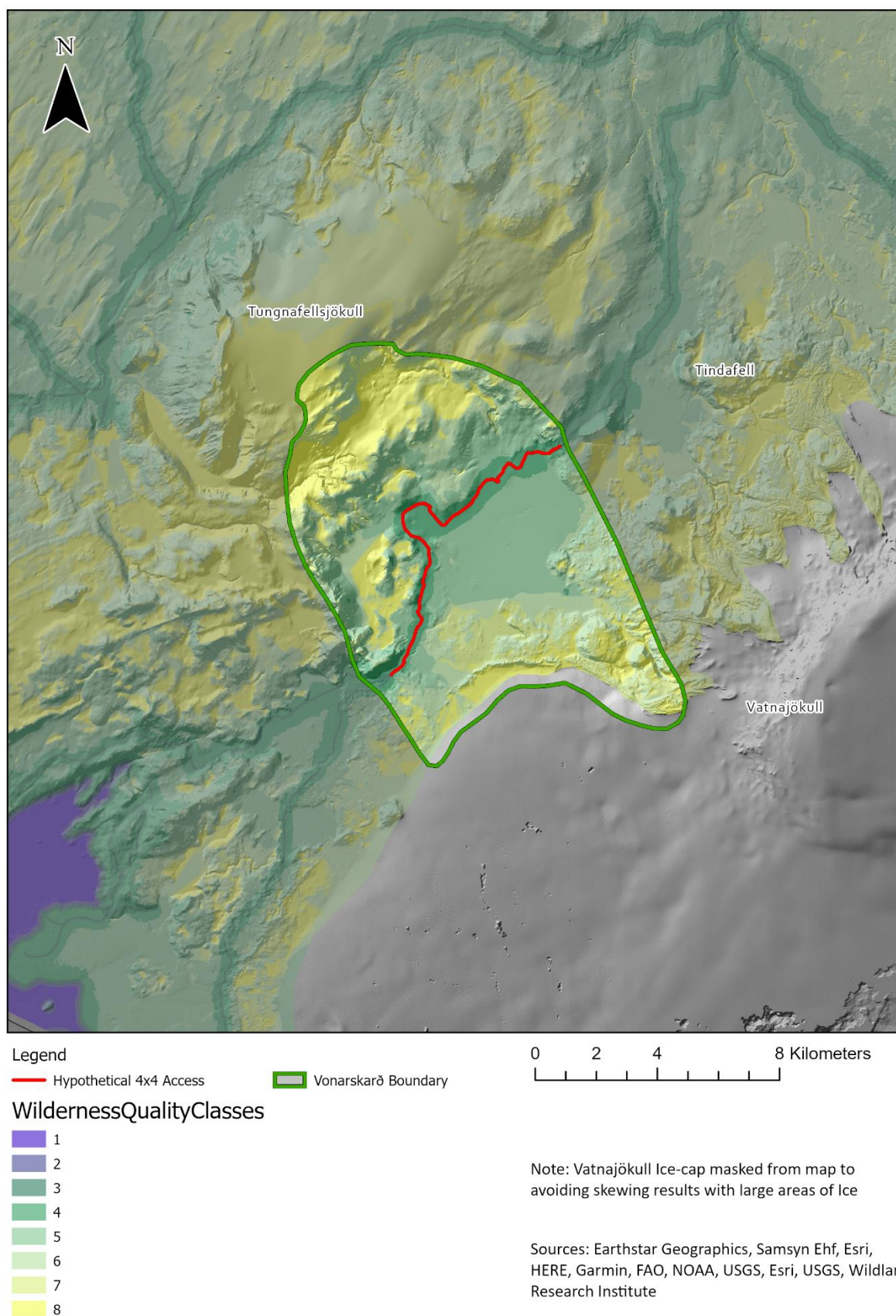


Figure 5.9 Wilderness quality classes post-4x4 access track

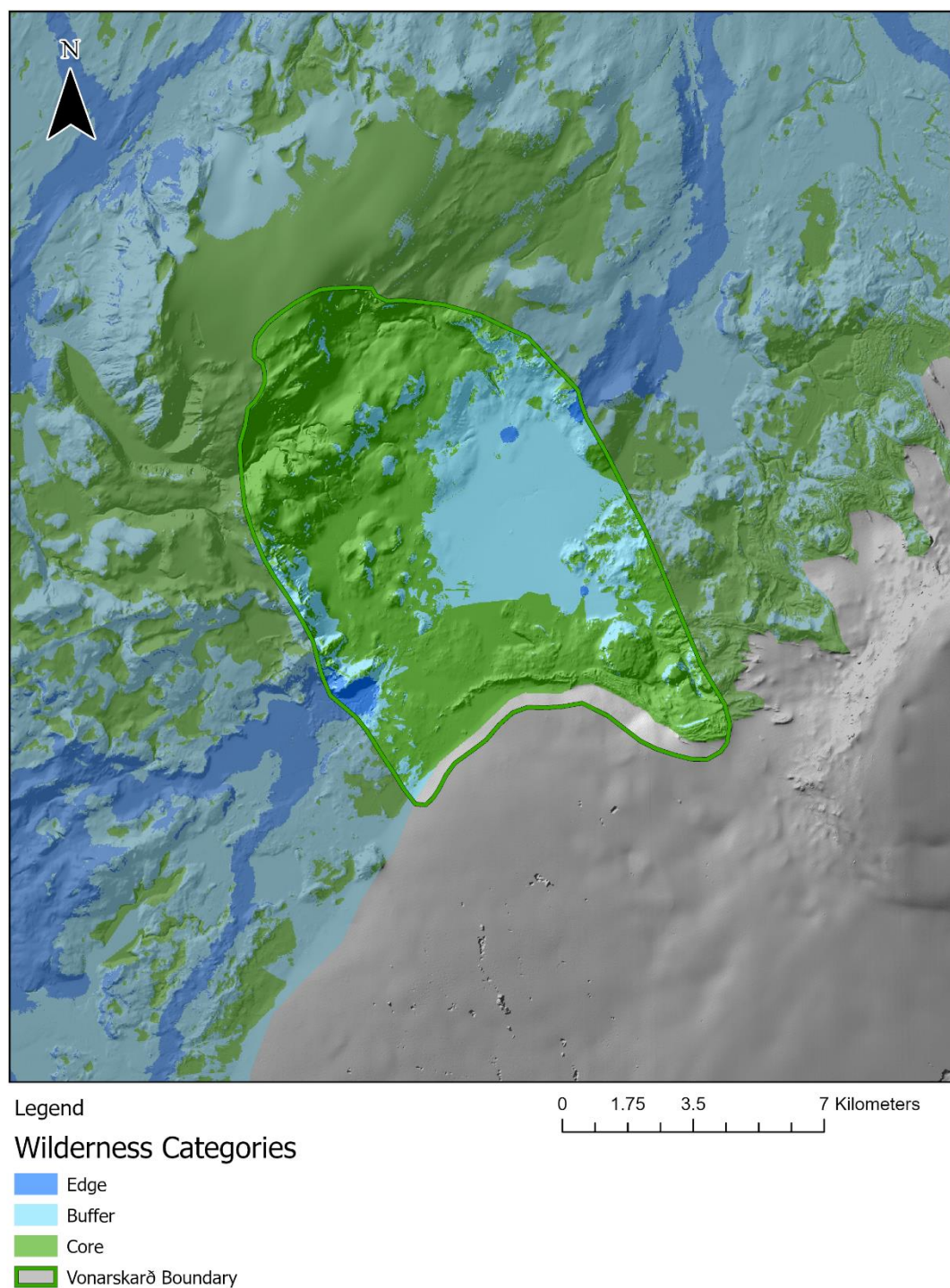
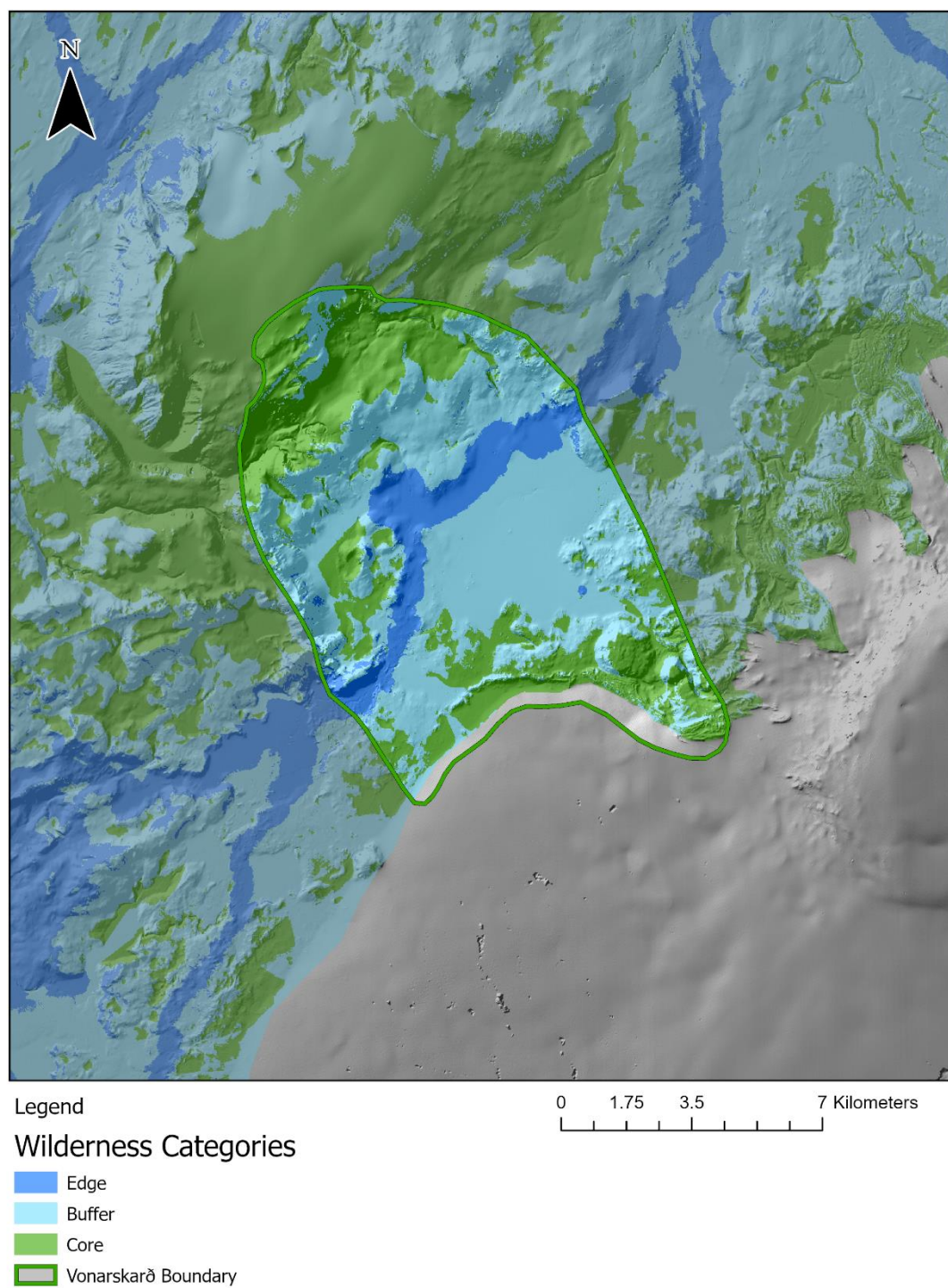


Figure 5.10 Current core wilderness, buffer and edge areas



Sources: Samsyn Ehf, Esri, HERE, Garmin, FAO, NOAA, USGS, Esri, USGS, Wildland Research Institute

Figure 5.11 Core wilderness, buffer and edge areas post 4x4 access track

6. Potential impact on wilderness

6.1 The hypothetical 4x4 access route lies just to the northwest of the Vatnajökull icecap within the boundaries of its associated national park in the wild and remote Vonarskarð area. It should be obvious - even without further analysis and consideration - that should the hypothesised 4x4 access route be allowed it would have a significant adverse impact on the qualities of this area of wilderness, with the likely outcome that if the 4x4 access route would be re-opened the area of wilderness in the vicinity would be considerably reduced.

The reconnecting of the existing gravel roads or tracks to the north and south of Vonarskarð with the hypothetical north-south 4x4 access track would have significant impacts on both remoteness from mechanised access and absence of modern human artefacts in the Vonarskarð area. The purpose of this section of the report, having outlined the mapping process and the data used, is to demonstrate the level of impact of the hypothetical re-opening of the 4x4 access route on wilderness and the surrounding landscape.

6.2 The hypothetical 4x4 access track would impact significantly on at least two out of the four wilderness attributes used to map the spatial distribution and patterns of wilderness quality across the Vonarskarð area. These are absence of modern human artefacts, and remoteness from mechanised access plus minor (localised) impacts on perceived naturalness of the land cover. Rugged and challenging nature of the landscape would remain unaffected.

6.3 Perceived naturalness of the land cover would be impacted by the 4x4 access track and associated vehicle use affecting the natural land cover. Naturalness values of affected cells would be reduced from high to low in all the areas thus affected on and immediately surrounding the route. While the spatial pattern of disturbance will be limited to the access track itself, wider impacts will be felt through changes to remoteness and visibility of human artefacts. The maps in Figures 4.1 and 5.1 illustrate the perceived naturalness of the area before and after the hypothetical 4x4 access track, respectively, while Figure 5.2 highlights the degree of change in the perceived naturalness of land cover attribute should the route be re-opened. The main feature that stands out here is the track itself, highlighting the localised nature of impact on this attribute.

6.4 Absence of modern human artefacts would be one of the two most heavily impacted of the attribute layers. The presence of the access roads and vehicles using it would have a significant impact on the visual integrity of the landscape in terms of wilderness quality. The visibility of the proposed route is extensive and it would be visible from inside much of the Vonarskarð area, most notably Köldukvíslarjökull, Fremsta-Bálfell and indeed the Hverabotnar geothermal area. A list of mountain summits potentially impacted is given in Table 6.1 and a map given in Figure 6.1. Figures 4.3-4.6 and 5.3 show the absence of modern human artefacts before and after the hypothetical 4x4 access track, respectively. Figure 5.4 highlights the degree of change in the absence of modern human artefacts should the route be re-opened. It is clear that the visual impact from the hypothetical re-opening of the route is extensive and stretches across a wide swathe of the Vonarskarð area.

6.5 The rugged and challenging nature of the terrain attribute would largely be unaffected by the hypothetical development.

6.6 The remoteness from mechanised access attribute would be significantly affected by re-opening the 4x4 access track. This will have a marked impact on reduced remoteness of the area. This is shown in Figures 4.8 and 5.5 which illustrate the remoteness from mechanised access around the route in question, both currently and if 4x4 access would be re-allowed. Figure 5.6 highlights the degree of change in the remoteness from mechanised access layer should the route be re-opened. The effect of the 4x4 access track would be to greatly reduce the overall remoteness in the region by reducing off-road access times to much of the Vonarskarð area. Access times in this part of the Central Highlands would be reduced by as much as 1 hour and 18 minutes.

6.7 The current wilderness map for the landscape around the hypothetical 4x4 access track is shown in Figure 3.2. The four modified attribute layers and their variants are combined to give a new wilderness map for the Vonarskarð area that includes the modelled impacts from the hypothetical 4x4 access track. The four attribute maps are combined by a simple un-weighted multi-criterion overlay as described in section 3. This can then be

compared to the current wilderness map shown in Figure 3.2. Figure 5.8 shows the current core wilderness areas which can be compared to Figure 5.9 which shows the same zones should the 4x4 access be re-opened. This highlights the degree of change in the spatial distribution and patterns of wilderness should the route be re-opened. Again, it is apparent looking at these figures that the wilderness quality values in the Vonarskarð area would be significantly and adversely affected by re-opening the 4x4 access track.

6.8 This enables direct comparison and highlighting of the area that will be impacted. It can be seen from these maps that the greatest impact is, as expected, in the immediate vicinity of the proposed route but extends across the Vonarskarð Valley and particularly around the Hverabotnar geothermal area. This is perhaps the area of greatest significance in terms of impact on core wilderness areas located within this area, with the proposed route and vehicles using it being visible from a wide area due to the nature of the local terrain. There are smaller patches of significant impact at greater distance, particularly on the slopes of the Köldukvíslarjökull where it faces the hypothetical route wherein most of the route will be in full view.

6.9 The reduction in total wilderness in the areas impacted by the re-opened route can be estimated using these wilderness maps as a basis for classifying the core wilderness areas. The current wilderness quality classes are shown in Figures 5.8, while the new and reduced wilderness classes drawn using the new wilderness map are shown in Figure 5.9. These maps are drawn using the same data and methods used by SNH in the original Phase 2 mapping. These maps highlight the degree of change in the spatial distribution and patterns of wilderness quality classes should the 4x4 access track be re-opened. This can be seen to be very significant in the Vonarskarð area.

6.10 Using the core wilderness areas from Figures 5.10 and 5.11, it is estimated that should the route be re-opened, the total area of core wilderness in the Vonarskarð area would be reduced by approximately **6515 ha** or **54%**. These figures are calculated by subtracting the post-4x4 access track core, buffer and edge areas from the existing core and buffer areas to identify the predicted areas of change as shown in Figure 6.2.

Table 6.1 Mountain summits from which the hypothetical re-opened track would be visible

Number	Name	Height (m)
1	Sléttihjalli	949
2	Svarthöfði	1082
3	Deilir	1127
4	Fremsta-Bálkafell	1149
5	Tindafell	1175
6	Valafell	1187
7	Innsta-Bálkafell	1206
8	Nefsteinn	1221
9	Mið-Bálkafell	1232
10	Hverakúla	1236
11	Kolufell	1242
12	Göngubrún	~1260
13	Stakfell	1276
14	Eggja	1279
15	Laugakúla	1305
16	Skrauti	1326
17	Bárðartindur	1356
18	Systrafell	1376
19	Kista	1549

Note: Italicized height values were extracted from the Digital Elevation Model (DEM) used for the GIS analysis and may not represent the actual height of the summit.

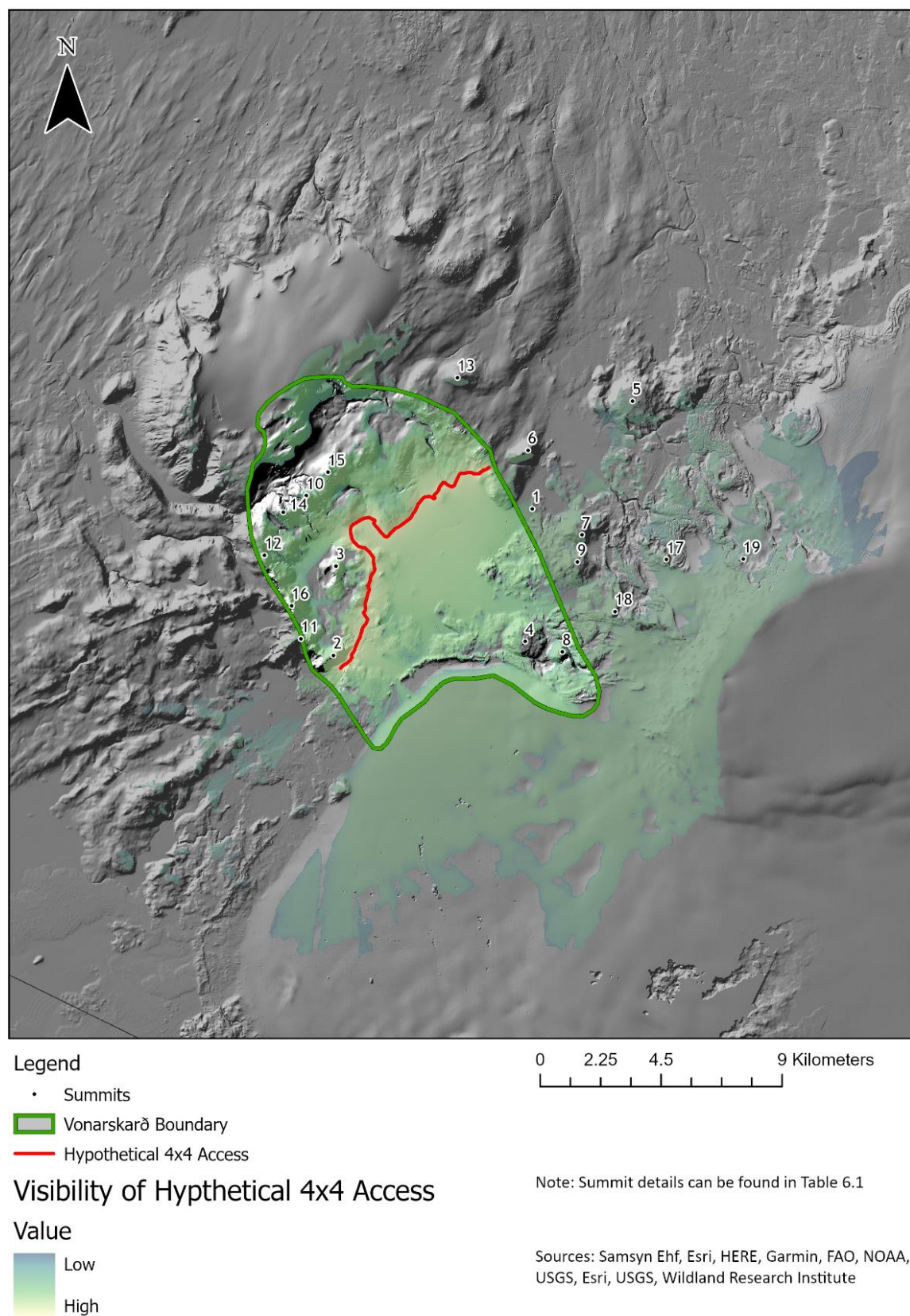


Figure 6.1 Summits with a view of a hypothetical 4x4 access track

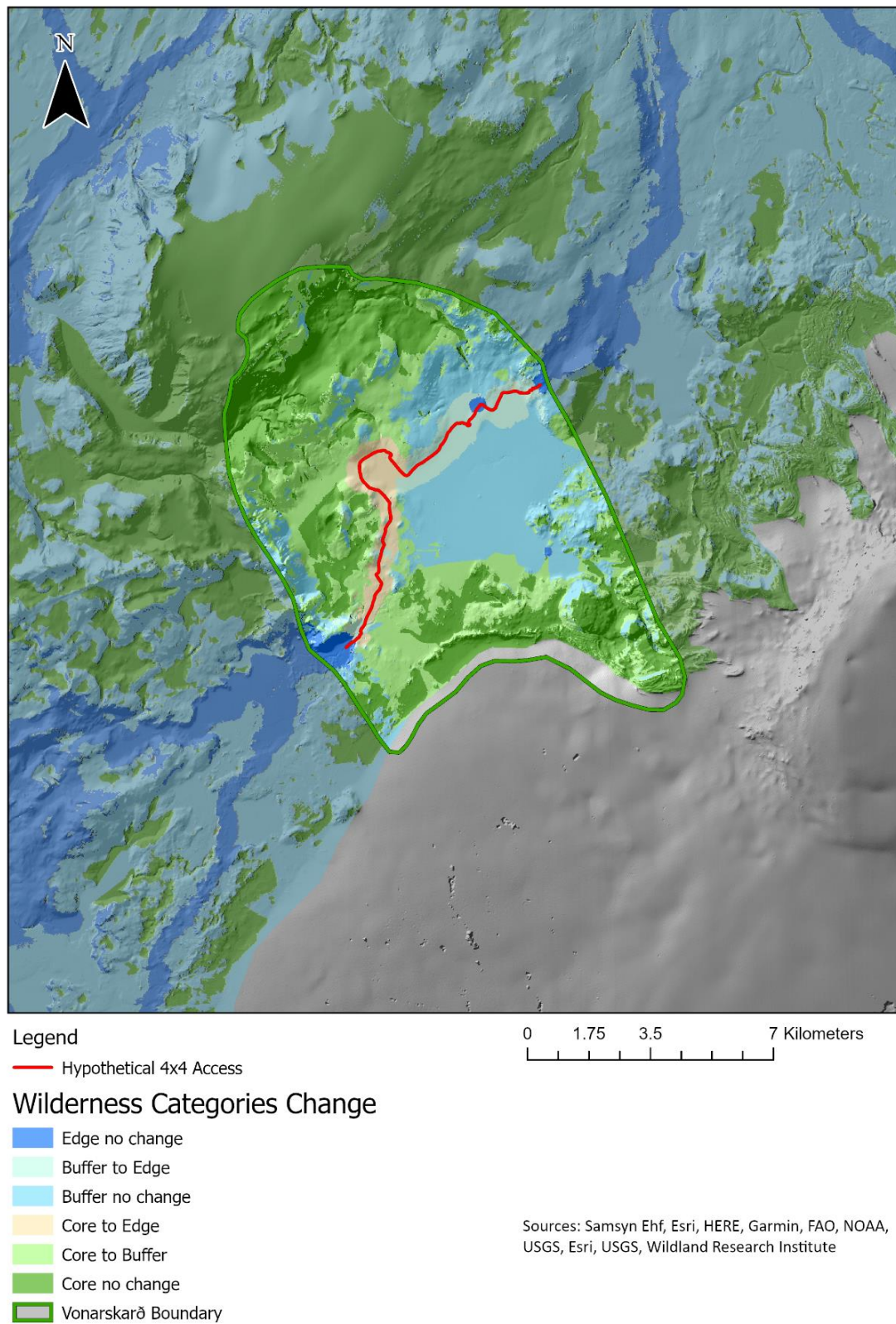


Figure 6.2 Change in core wilderness

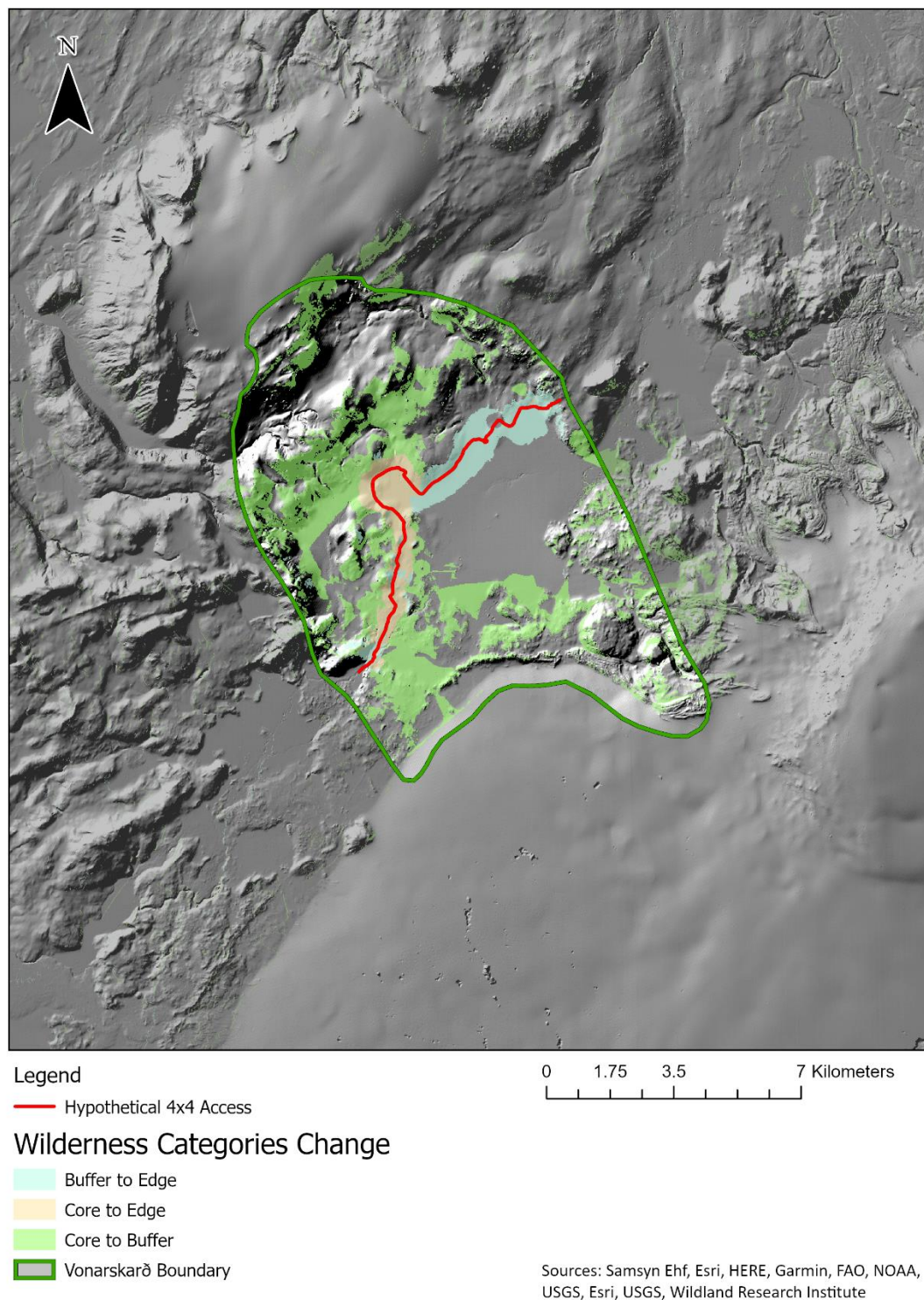


Figure 6.3 Change in wilderness categories

7. Conclusions

7.1 Mountains, volcanoes, highlands, lakes, icecaps, free-flowing rivers, waterfalls and rugged coastlines are valued hallmarks of Iceland's landscape, providing a major focus for history, culture, tourism, recreation and conservation. These qualities of the Icelandic landscape are strongly expressed in areas dominated by bare ground, natural vegetation, lack of human intrusion from built structures and the rugged and remote nature of the terrain⁷⁶. They are wildernesses in the truest sense and the Vonarskarð area possess all the requisite attributes of wildness despite not being currently protected as such⁷⁷. These iconic landscapes are closely linked to Iceland's national identity and represent a key draw for visitors^{78, 79}.

7.2 However, despite recognition of their value, Iceland's wilderness areas face a growing threat from improvements to access from road building and upgrades. Previous studies have shown these factors can impact significantly on an area's wildness and result in a gradual attrition of the wild land resource^{80, 81}.

7.3 WRI are world leaders in the development of mapping methodologies applied to identifying wild land areas. This is underpinned by use of the best available data and techniques, supported by expert advice and information from leading academics and practitioners, and developed over more than twelve years of careful research and development, building over 25 years of experience in the field.

7.4 The hypothetical 4x4 access track in Vonarskarð area is located inside one of the wildest areas in Europe and Iceland and therefore cannot fail to impact heavily on this wilderness area. The access track would also have a significant visual impact on adjacent wilderness areas and be visible from the summits of several local mountains.

7.5 The hypothetical 4x4 access track would significantly impact at least two out of the four wilderness attributes. Only the Rugged and challenging nature of the terrain attribute would remain relatively unaffected. This inevitably means that the track would have a significant impact on the relative wilderness values in both the immediate vicinity of the hypothetical route in terms of naturalness, and much further afield in terms of its visual impact and remoteness.

7.6 Should the route be re-opened then it is expected that the total area of core wilderness in the area would be reduced by 6,515ha, representing an overall reduction amounting to around 54% of the total core areas.

7.7 The hypothetical 4x4 access track would be located in an area that is currently free from any physical or visual impact from existing large infrastructure development. The development of hydro and geothermal energy plants over the past few decades has placed a consistent pressure on Iceland's landscape and wilderness resources and significantly reduced the area of wilderness. This includes the insertion of roads and tracks necessary for construction and maintenance into previously roadless areas. Additional tracks for recreation place additional stresses on the environment particularly in remote and sensitive wilderness areas like

⁷⁶ Olafsdóttir, Rannveig, and Micael C. Runnström. "How wild is Iceland? Wilderness quality with respect to nature-based tourism." *Tourism Geographies* 13, no. 2 (2011): 280-298.

⁷⁷ Wilderness register and indicator for Europe Final report 2013 (draft) Contract N°: 07.0307/2011/610387/SER/B.3. See page 65-67.

https://ec.europa.eu/environment/nature/natura2000/wilderness/pdf/Wilderness_register_indicator.pdf

⁷⁸ Sæþórsdóttir, Anna Dóra, C. Michael Hall, and Jarkko Saarinen. "Making wilderness: Tourism and the history of the wilderness idea in Iceland." *Polar Geography* 34, no. 4 (2011): 249-273.

⁷⁹ [Nýdalur / Vonarskarð / Tungnaáröræfi | Vatnajökulsþjóðgarður \(vatnajokulsthjodgardur.is\)](http://nýdalur.vonarskarð.is/tungnaáröræfi/vatnajökulsþjóðgarður/vatnajökulsthjodgardur.is)

⁸⁰ Carver, S., & Wrightham, M. (2003). Assessment of historic trends in the extent of wild land in Scotland: A pilot study. Scottish natural heritage commissioned report No. 012 (ROAME No. FO2NC11A).

⁸¹ Taylor, Victoria Frances. „GIS assessment of Icelandic wilderness from 1936- 2010.“ Meistararitgerð. Háskóli Íslands, 2011. <http://hdl.handle.net/1946/9876>

Vonarskarð. Re-opening the route would represent a significant impact in the middle of one of these remaining areas of un-impacted land, considerably reducing the "development free" landscape in the Vonarskarð area.

7.8 In addition to the conclusions of this report, derived from wilderness mapping, several local Icelandic reports and papers have come to similar conclusions; that it is optimal for wilderness conservation that the 4x4 access route stays closed. An expert report commissioned by the Vatnajökull National Park in 2013 on the Vonarskarð area discusses in detail its various fragile biological and geographical characteristics and why they make it important to protect the area⁸². The Icelandic Institute of Natural History also highlights in their report of the area from 2019 that by closing the 4x4 route in 2011, human traffic, and thereby pressure put on the fragile ecosystems present in the area, is considerably reduced⁸³.

7.9 The 2013 Nature Conservation Act states that areas of wilderness should receive adequate legal protection and that this *"protection should aim to safeguard the characteristics of the areas e.g. to maintain diverse and unusual landscapes, panoramas and/or conserve complete large ecosystems, and ensure that present and future generations can enjoy therein solitude and nature without disturbance from man-made infrastructures or traffic from motor vehicles"*. Given the results of the wilderness mapping presented here, the location of the hypothetical route within such a wilderness area and the undeniably significant impacts that would result, this makes re-opening the 4x4 access route untenable.

⁸² Rögnvaldur Ólafsson, Þorvarður Árnason, Þóra Ellen Þórhallsdóttir, and Gyða Þórhallsdóttir. Vonarskarð í Vatnajökulsþjóðgarði. Vatnajökull National Park. (March 2013).

https://rafhladan.is/bitstream/handle/10802/7004/Vonarskard_m_myndum.pdf?sequence=1

⁸³ Baldursson, Trausti, and Magnússon, Borgþór. Umsögn um Vonarskarð. Náttúrufræðistofnun Íslands. (2019). https://www.ni.is/sites/default/files/atoms/files/uttekt_um_vonarskard.pdf