



Rangeland Health Assessment of Theodore Roosevelt National Park

Natural Resource Report NPS/THRO/NRR—2023/2580



ON THE COVER

Field technicians from Theodore Roosevelt National Park clipping vegetation for annual production monitoring.
NPS

Rangeland Health Assessment of Theodore Roosevelt National Park

Natural Resource Report NPS/THRO/NRR—2023/2580

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Contents

	Page
Figures.....	iv
Tables.....	v
Abstract.....	vi
1. Introduction and Summary	1
2. Methods.....	4
2.1 Study Area.....	4
2.2 Sampling.....	6
2.3 Interpreting Indicators of Rangeland Health	7
2.4 Summary of Field Procedures	7
2.5 Data Summarization	7
3. Results.....	8
3.1 Overview	8
3.2 By Management Unit	10
3.2.1 North Unit.....	11
3.2.2 Elkhorn Ranch.....	12
3.2.3 South Unit.....	13
3.3 By Ecological Site Description	14
3.4 Compromised Sites.....	16
3.4.1 North Unit.....	17
3.4.2 Elkhorn Ranch Unit.....	20
3.4.3 South Unit.....	23
4. Discussion and Recommendations.....	26
4.1 Sites with Plant Communities Dominated by Introduced Grasses	26
4.2 Sites Lacking Disturbance	28
Literature Cited	30
Appendix A. Attribute Result Maps	32
Appendix B. Summary Data	35

Figures

	Page
Figure 1. Theodore Roosevelt National Park location.	4
Figure 2. Drought conditions for Billings (A) and McKenzie (B) Counties from January 2017-July 2022.....	5
Figure 3. Sampling locations at THRO.....	6
Figure 4. Distribution of indicator and final attribute ratings for the 3 locations assessed in the North Unit.	12
Figure 5. Distribution of indicator and final attribute ratings for the 3 locations assessed in the Elkhorn Ranch Unit.	13
Figure 6. Distribution of indicator and final attribute ratings for the 6 locations assessed in the South Unit.	14
Figure 7. Location of ecologically compromised sites at THRO (identified by red boxes).	17

Tables

	Page
Table 1. Indicators used in IIRH.	3
Table 2. Characteristics of units assessed in Theodore Roosevelt (THRO) in 2022.	5
Table 3. Distribution of ratings for the 17 indicators for all 12 IIRH locations.....	9
Table 4. Distributions of ratings for the three attributes for all 12 IIRH locations.	10
Table 5. Mean attribute ratings for each of the management units included in the assessment.....	10
Table 6. Mean values for indicator ratings among management units.....	11
Table 7. List of Ecological Site Descriptions (ESD) used in the IIRH assessments, along with the number of IIRH locations that corresponded to each ESD.	15
Table 8. The number of locations corresponding to each ecological site across the management units included in the assessment.	15
Table 9. Mean attribute ratings for each ecological site encountered during assessment.	16
Table 10. Distribution of locations with a moderate or greater departure from reference condition (compromised sites) for at least one IIRH attribute.....	17
Table 11. Indicator ratings leading to overall attribute ratings for Soil and Site Stability at North Unit compromised sites.	18
Table 12. Overall rating for Hydrologic Function and ordinal ratings for Indicators at North Unit compromised sites1.	18
Table 13. Indicator ratings leading to overall attribute ratings for Biotic Integrity at North Unit compromised sites.....	18
Table 14. Indicator ratings leading to overall attribute ratings for Hydrologic Function at Elkhorn Ranch Unit compromised sites.....	21
Table 15. Indicator ratings leading to overall attribute ratings for Biotic Integrity at Elkhorn Ranch Unit compromised sites.....	21
Table 16. Indicator ratings leading to overall attribute ratings for Hydrologic Function at South Unit compromised sites.	24
Table 17. Indicator ratings leading to overall attribute ratings for Biotic Integrity at South Unit compromised sites.....	24

Abstract

We assessed rangeland health at 12 locations distributed across Theodore Roosevelt National Monument (THRO) in June 2022. Assessments were conducted using version 5 of Interpreting Indicators of Rangeland Health (IIRH), a qualitative protocol designed to assess departures from reference condition for three rangeland attributes: Soil and Site Stability, Hydrologic Function, and Biotic Integrity. In this report, we review assessment locations and further discuss locations with at least one IIRH attribute rated as a moderate or greater departure from reference, considering them “ecologically compromised” for the purposes of this report; two locations in the North Unit, three locations in the South Unit, and three locations in the Elkhorn Ranch Unit were considered ecologically compromised. Compromised assessment locations in the North Unit departed significantly from reference condition in all three attributes while compromised assessment locations in the South Unit and Elkhorn Ranch Unit departed significantly from reference condition in Hydrologic Function and Biotic Integrity. Across all assessment locations, departure from reference condition was most consistent for Biotic Integrity and Hydrologic Function, primarily due to the presence of introduced grasses. IIRH is a point-in-time assessment protocol and findings do not communicate trends, positive or negative; thus, managers should seek out other pertinent information (e.g., management history) to contextualize the findings of this report before changing management practices.

1. Introduction and Summary

Defining and implementing proper management of rangeland has been a challenge in range science and management since its inception. This challenge can largely be attributed to the difficulty of balancing the need for small-scale experimentation, aimed at identifying mechanistic drivers, with the ability to generalize and interpolate findings across large landscapes, where site-specific characteristics often yield varied outcomes for similar management tactics. Adding to the complexity is the need to consistently assess the ecological condition of rangelands in an unambiguous manner. In an attempt to achieve this overarching goal, the Interpreting Indicators of Rangeland Health (IIRH) protocol was developed (Pellant et al. 2020; Pyke et al. 2002).

Specifically, an IIRH assessment is used to assess the overall rangeland health, or “the degree to which the integrity of the soil, vegetation, water, and air, as well as the ecological processes of the rangeland ecosystem are balanced and sustained” (NRCS, 2003, p. 4–263). An assessment consists of a point-in-time evaluation of ecosystem function relative to its potential (Herrick et al. 2005) and should not be confused with monitoring, which is defined by Elzinga et al. (1998) as the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective. This primarily qualitative protocol assesses three fundamental attributes of rangeland health: Soil and Site Stability, Hydrologic Function, and Biotic Integrity. These are defined as:

Soil/site stability: the capacity of an area to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water and to recover this capacity when a reduction does occur.

Hydrologic function: the capacity of an area to capture, store, and safely release water from rainfall, run-on, and snowmelt (where relevant), to resist a reduction in this capacity, and to recover this capacity when a reduction does occur.

Biotic integrity: the capacity of the biotic community to support ecological processes within the natural range of variability expected for the site, to resist a loss in the capacity to support these processes, and to recover this capacity when losses do occur. The biotic community includes plants (vascular and nonvascular), animals, insects, and microorganisms occurring both above and below ground. (Pellant et al. 2020, pp. 7)

A direct assessment of each of the three attributes would be largely inconsistent across assessors and nearly impossible to measure in a meaningful way. To account for this, the published protocol uses 17 distinct indicators (Table 1) to rate the attributes listed above. Rating categories are standard across IIRH assessment and are made according to the “degree of departure” from a reference condition and include five levels: none to slight (NS), slight to moderate (SM), moderate (M), moderate to extreme (ME), or extreme to total (ET) departure. The reference condition describes the “standard” ecological condition for an ecological site that can be used as a comparative standard. IIRH Technical Reference 1734-6, Version 5 (Pellant et al. 2020) defines an ecological site as a “conceptual division of the landscape that is defined as a distinctive kind of land based on recurring soil, landform, geological, and climate characteristics that differs from other kinds of land in its

ability to produce distinctive kinds and amounts of vegetation and in its ability to respond similarly to management actions and natural disturbances” (Caudle, 2013, p. 12).

Information about the reference condition for a specific ecological site can be found in the appropriate Ecological Site Description (ESD) for the assessment location. The Natural Resource Conservation Service (NRCS) develops and analyzes ESDs and manages these ESD data and database (access via EDIT; [Ecological Sites Tools | Natural Resources Conservation Service \(usda.gov\)](https://www.nrcs.usda.gov/technical/fieldoffice/edis/)). NRCS EDIT documentation states that ESDs provide a consistent framework for classifying and describing rangeland and forestland soils and vegetation; thereby delineating land units that share similar capabilities to respond to management activities or disturbance. ESD information is presented in four major sections:

- Site Characteristics – physiographic, climate, soil, and water features
- Plant Communities – plant species, vegetation states, and ecological dynamics
- Site Interpretations – management alternatives for the site and its related resources
- Supporting Information – relevant literature, information, and data sources (www.nrcs.usda.gov, accessed November 20, 2022)

The information included in the four major sections listed above is refined into 17 indicators (Table 1) which are used to create reference sheets for ESDs. The reference sheets and information about the 17 indicators are assessed while performing IIRH assessments.

This report details the results of an IIRH assessment performed at 12 locations across Theodore Roosevelt National Park (THRO) in June of 2022. Results may guide future monitoring efforts and may inform adaptive management and resource protection strategies. To maintain consistency with other published NPS rangeland health assessments, the structure and wording of several sections of this report closely resemble the work of Jablonski et al. 2021 and Courkamp et al. 2022.

Table 1. Indicators used in IIRH.

Indicator and brief description	Attributes ^a			Quantitative data
	S	H	B	
1. Rills — frequency and spatial distribution of linear erosion rivulets	X	X	–	–
2. Water-flow patterns — amount and distribution of overland flow paths that are identified by litter distribution and visual evidence of soil and gravel movement	X	X	–	–
3. Pedestals and/or terracettes — frequency and distribution of rocks or plants where soil has been eroded from their base (pedestals), and/or occurrence of erosional terracettes	X	X	–	–
4. Bare ground — size and connectivity among areas of soil not protected by vegetation, biological soil crusts, litter, standing dead vegetation, or rocks	X	X	–	% bare ground
5. Gullies — amount of channels cut into the soil and the amount and distribution of vegetation in the channel	X	X	–	–
6. Wind-scoured areas and/or depositional areas — frequency of areas where soil is removed from under or around vegetation OR frequency of accumulation areas of soil associated with large structural objects	X	–	–	–
7. Litter movement — frequency and size of litter displaced by wind and overland flow of water	X	–	–	–
8. Soil surface resistance to erosion — ability of soils to resist erosion through the incorporation of organic material into soil aggregates	X	X	X	Soil aggregate stability
9. Soil surface loss or degradation — frequency and size of areas missing all or portions of the upper soil horizons	X	X	X	–
10. Plant community composition and distribution relative to infiltration and runoff — the community composition or distribution of species that restrict the infiltration of water on the site	–	X	–	% composition by F/S group
11. Compaction layer — thickness and distribution of the structure of the soil near the soil surface (≤ 15 cm)	X	X	X	–
12. Functional / structural (F/S) groups — relative dominance of groups, number of groups not expected, total number of groups, and changes in relative dominance of species within groups	–	–	X	Plant foliar and basal cover by F/S group or species
13. Dead or dying plants or plant parts — frequency of dead or moribund (dying) plants or plant parts	–	–	X	–
14. Litter cover and depth — deviation in the amount of litter	–	X	X	% litter cover
15. Annual production — amount of aboveground plant production relative to the potential for that year based upon recent climatic conditions	–	–	X	Plant production by F/S group
16. Invasive plants — abundance and distribution of invasive plants based on a plant's potential to dominate a site to which it is not native, regardless of the plant's status as a noxious weed or exotic species	–	–	X	Invasive plant cover
17. Vigor with an emphasis on reproductive capability of perennial plants — evidence of inflorescences or of vegetative tiller production relative to the potential for that year based upon recent climatic conditions	–	–	X	–

^a S= Soil/site stability, H= Hydrologic Function, B= Biotic Integrity; “X” indicates that indicator contributes to final attribute rating. Table replicated from Jablonski et al. 2021.

2. Methods

2.1 Study Area

Theodore Roosevelt National Park (THRO) is a roughly 28,470 ha National Park Service unit in western North Dakota (Figure 1). The park is split into three distinct management units: South Unit, North Unit, and Elkhorn Ranch Unit (Table 2). All three units are situated along the Little Missouri River with the North Unit being approximately 62 km due North of the South Unit. Given their spatial displacement, average temperature and precipitation vary across THRO with the North Unit receiving, on average, slightly more moisture, followed by the South then Elkhorn Ranch Units (PRISM 2022; Table 2).

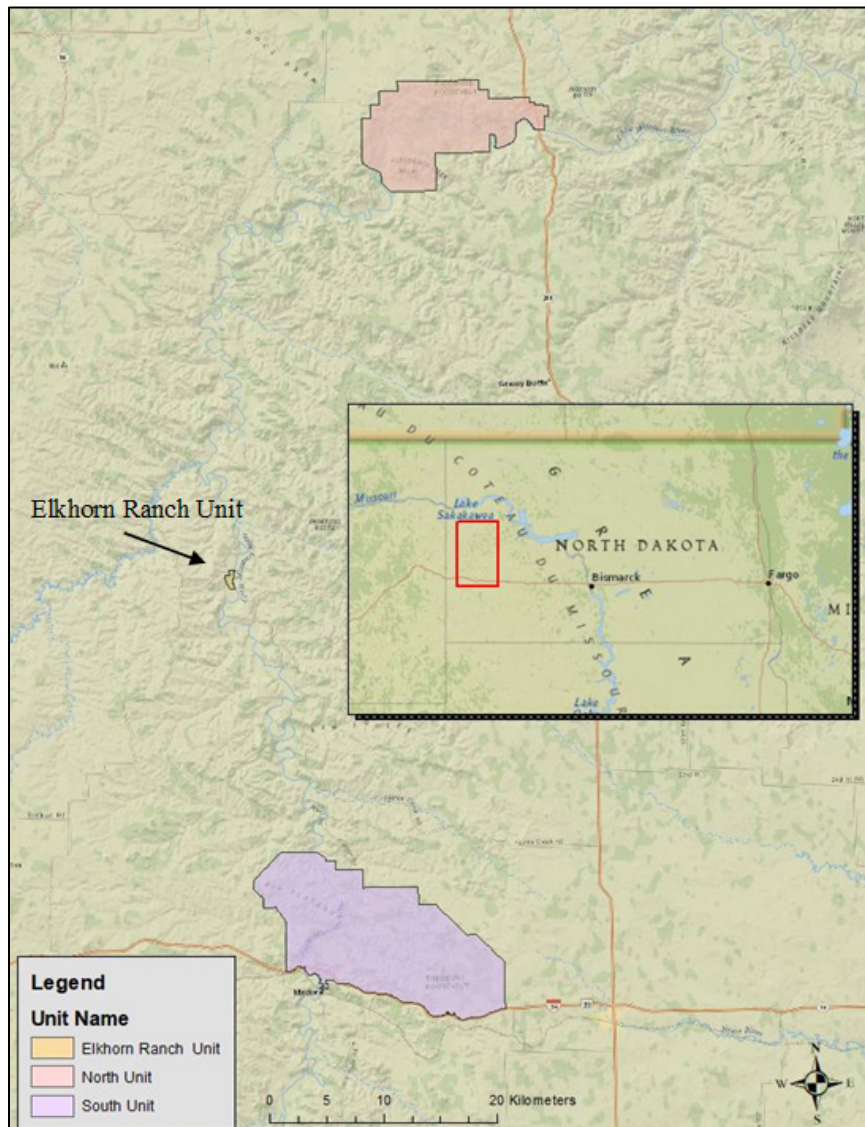


Figure 1. Theodore Roosevelt National Park location.

Table 2. Characteristics of units assessed in Theodore Roosevelt (THRO) in 2022.

Management Unit	Hectares	30-Year Average Precipitation (mm)	30-Year Average Temperature (°C)
North Unit	9,152	426	5.9
Elkhorn Ranch	92	395	5.8
South Unit	18,635	416	6.1

IIRH assessments require ratings to be made in the context of recent (last two years) weather conditions. Because of this, it is important to note that a majority of Billings County was classified as D2-Severe Drought from January 2021 through April 2022, with at least 60% of the county classified as D3-Extreme Drought from April 2021 through October 2021 (Figure 2). A majority of McKenzie County was also classified as D2-Severe Drought from October 2020 through April 2022, with portions of the county being classified as D3-Extreme Drought to varying degrees from April 2021 until April 2022. Neither county was considered in drought at the time of this assessment. To account for the change in drought condition between the time of the assessment and the several years prior, the crew assessed the 2022 growing season as average condition, as described in each ESD.

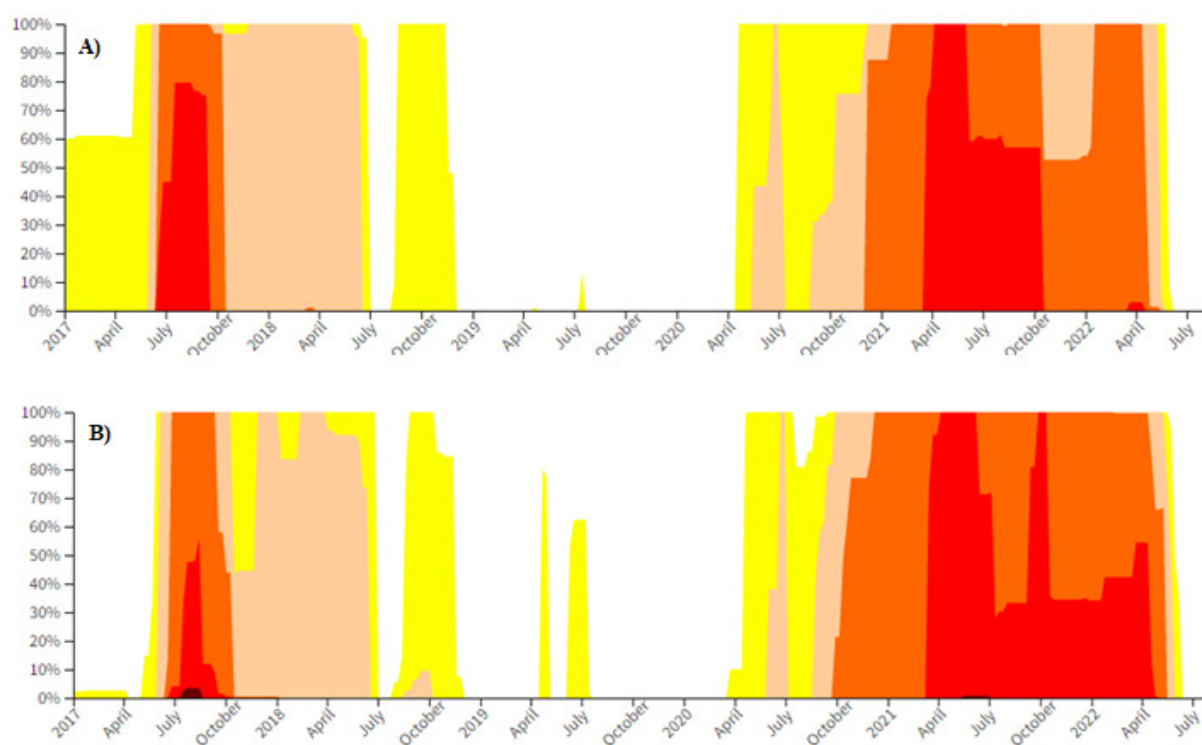


Figure 2. Drought conditions for Billings (A) and McKenzie (B) Counties from January 2017-July 2022. Yellow = D0-Abnormally Dry; Beige = D1-Moderate Drought; Orange = D2-Severe Drought; and Red = D3-Extreme Drought. Data were gathered from the National Drought Mitigation Center, University of Nebraska-Lincoln.

Most of THRO is comprised of mixed grass prairie, bottomland forests, and open shrublands. Species include Western wheatgrass (*Pascopyrum smithii*), western snowberry (*Symphoricarpos occidentalis*), plains cottonwood (*Populus deltoides*), Rocky Mountain juniper (*Juniperus scopulorum*) and the non-native species Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*). NPS Northern Great Plains Inventory and Monitoring Network documented 223 species of plants in 2018; Of the 223 species, 34 were exotic. There are 680 vascular plant species verified at THRO (Manuel et al. 2019).

All three management unit are subject to herbivory by bison (*Bison bison*), horses [*Equus caballus*], cattle [*Bos taurus*]), elk (*Cervus canadensis*), pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), whitetail deer (*Odocoileus virginianus*), bighorn sheep (*Ovis canadensis*), and small mammals such as prairie dogs (*Cynomys spp*).

2.2 Sampling

Assessment locations were selected to capture the variability across the important ecological sites within each management unit. Attributes taken into consideration during site selection include: 1) management unit boundaries; 2) soil map units; 3) ecological sites; 4) topography; and 5) distance from existing long-term monitoring locations. All sampling locations were surveyed for potential impacts to natural and cultural resources prior to assessment. A total of 14 sites were identified, however final assessments were performed on 12 total sites (Figure 3).

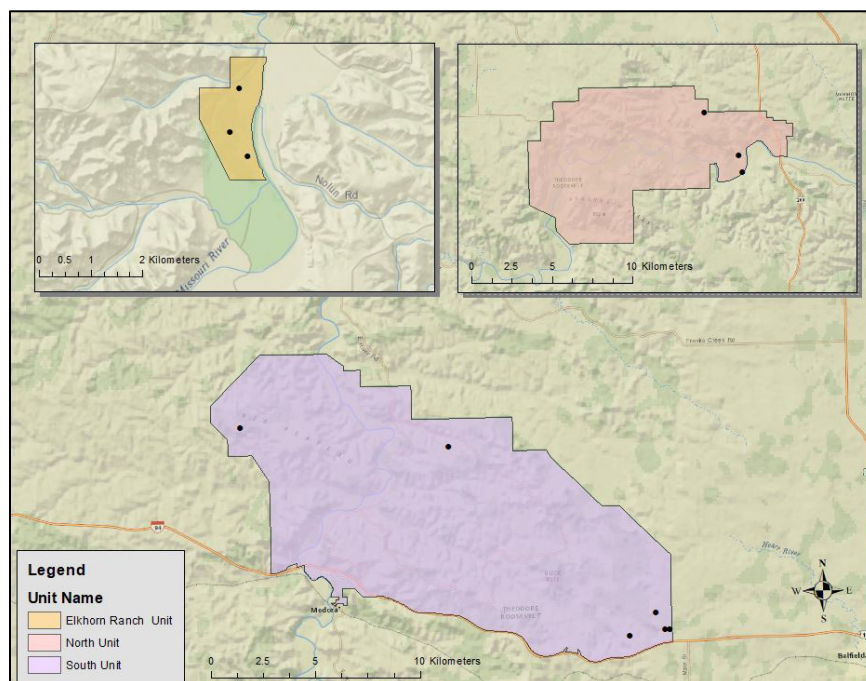


Figure 3. Sampling locations at THRO.

2.3 Interpreting Indicators of Rangeland Health

Determining the appropriate ecological site for each of the selected assessment points is vital for completing the IIRH protocol. Prior to any field work, soils data were used to identify up to three potential ecological sites that may be found at each assessment location. Once in the field, the IIRH version 5 protocol, as described in *Interpreting Indicators of Rangeland Health*, (Pellant et al. 2020) was followed. All indicator ratings were determined by coauthors with prior training in IIRH (IIRH version 4 – JS; IIRH version 5 – AS).

2.4 Summary of Field Procedures

Field crews used handheld GPS units to navigate to assessment locations. Once at the site, the crew identified a suitable area for a soil pit and surveyed for cultural resources prior to digging. In situations where the assessment location fell on a transition or non-representative area (i.e., on a steep slope), the site was relocated to be more representative of the area. Once a site was selected, the field crew dug a soil pit to determine the soil unit and identify the appropriate ecological site and reference sheet for the assessment location.

Methods used to collect the quantitative data for the IIRH assessment included line-point-intercept (LPI), soil aggregate stability, and annual production. LPI measurements included running a 25 m transect along a randomly selected azimuth and recoding the vegetative and soil cover every half meter. These data were used to calculate percent cover, percent bare ground, and percent litter and, in conjunction with annual production data, were used to determine relative dominance of functional/structural groups. The soil stability test, as described in Herrick et al. (2005), was used to assess the soil surface resistance to erosion. To do so, 18 peds were collected along the LPI transect, both under plant canopies and in uncovered gaps. Peds were then subjected to submergence and dipping in distilled water and a stability class was assigned. Annual production was estimated using the total harvest method (Pellant et al. 2020). A 4.8-m² ring was randomly placed in three separate locations at the assessment area. All vegetation inside the ring was clipped, placed in a paper bag by vegetative class (i.e., grass, forb, shrub), and weighed using a gram scale. Annual production values were calculated using the dry matter conversions located in the IIRH version 5 technical reference.

The remaining qualitative indicators were rated based on field observations informed by the quantitative data that had been collected. The total area being assessed was approximately 0.4 ha. After an observation period of roughly 40–60 minutes, crew members consulted with one another and utilized the assessment matrix in the IIRH v. 5 technical reference to assign ratings to each of the 17 indicators. Once all indicators were rated, final attribute ratings were assigned.

2.5 Data Summarization

Qualitative IIRH ratings were converted to numbers for the purpose of summarizing findings (Courkamp et al. 2022; Jablonski et al. 2021). This was done in the same fashion as previous NPS IIRH assessments performed by Courkamp et al. (2022) and Jablonski et al. (2021) where departure ratings were converted to an ordinal scale where none to slight equals one and extreme to total equals five.

3. Results

3.1 Overview

Throughout this section, and unless otherwise indicated, numbers in parentheses following an indicator name or description refer to the indicator numbers found in Table 1. Distributions of attribute and indicator ratings for all 12 locations are shown in Table 3 and Table 4, respectively. Across all 12 sites most indicators were rated as having a slight to moderate departure or below, with the exception of Functional/structural groups (12), which had three sites rated as moderate departure and three sites rated as moderate to extreme departure, and Invasive Plants (16), which had three sites rated as moderate to extreme departure and four sites rated as extreme to total departure. A majority of sites had indicator ratings of none to slight for rills (1), bare ground (4), gullies (5), wind-scoured areas, blowouts, and/or deposition areas (6), litter movement (7), compaction layer (11), dead or dying plants or plant parts (13), litter cover and depth (14), and vigor with an emphasis on reproductive capability of perennial plants (17); A majority of sites had indicator ratings as slight to moderate for water-flow patterns (2) and soil surface loss or degradation (9). It should be noted that annual production (15) and soil surface resistance to erosion (8) were omitted from one assessment site each.

Departure ratings for Soil and Site Stability were most frequently slight to moderate, with five sites being rated as none to slight and one site as moderate. A moderate rating was the most frequent for the Hydrologic Function attribute across all 12 sites; however, a majority of sites were rated as having either a none to slight or slight to moderate departure from reference. Biotic Integrity had the most extreme departure ratings, with three sites being rated as having a moderate to extreme departure from reference; four sites having a moderate departure from reference; four sites having a slight to moderate departure from reference; and only one site receiving a none to slight departure from reference rating.

Maps of ratings for the three attributes and 17 indicators are included in Appendix A, and summary data, including ratings for each indicator and attribute at each location, are included in Appendix B.

Table 3. Distribution of ratings for the 17 indicators for all 12 IIRH locations.

Indicator	Associated attributes ^a	Departure from reference condition ^b				
		N-S	S-M	M	M-E	E-T
1. Rills	S, H	9	2	1	0	0
2. Water-flow patterns	S, H	0	9	3	0	0
3. Pedestals and/or terracettes	S, H	5	6	1	0	0
4. Bare ground	S, H	10	2	0	0	0
5. Gullies	S, H	10	1	0	1	0
6. Wind-scoured areas, blowouts, and/or deposition areas	S	12	0	0	0	0
7. Litter movement	S	6	5	1	0	0
8. Soil surface resistance to erosion ^c	S, H, B	6	2	3	0	0
9. Soil surface loss or degradation	S, H, B	4	7	0	1	0
10. Plant community composition and distribution relative to infiltration and runoff	H	3	4	3	2	0
11. Compaction layer	S, H, B	8	4	0	0	0
12. Functional/structural groups	B	1	5	3	3	0
13. Dead or dying plants or plant parts	B	9	3	0	0	0
14. Litter cover and depth	H, B	7	0	3	2	0
15. Annual production ^d	B	6	3	1	1	0
16. Invasive plants	B	1	1	3	3	4
17. Vigor with an emphasis on reproductive capability of perennial plants	B	10	2	0	0	0

^a Attributes: S = Soil and Site stability, H = Hydrologic Function, B = Biotic Integrity.

^b Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate; M-E = Moderate to extreme; E-T = Extreme to total.

^c Soil surface resistance to erosion was omitted from one location due to the site being too wet to collect peds.

^d Annual production was omitted from one location due to inaccurate estimation.

Table 4. Distributions of ratings for the three attributes for all 12 IIRH locations.

Attribute	Departure from reference condition ^a				
	N-S	S-M	M	M-E	E-T
Soil and Site Stability (S)	5	6	1	0	0
Hydrologic Function (H)	3	3	5	1	0
Biotic Integrity (B)	1	4	4	3	0

^a Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate; M-E = Moderate to extreme; E-T = Extreme to total.

3.2 By Management Unit

The IIRH protocol is such that extrapolation beyond individual sites is tenuous, so it should be noted that while findings are presented by management unit, it is not the intent of the authors to make assertions regarding rangeland health at the management unit scale. Findings are presented by management unit for potential ease of comparison with other datasets that may be used in conjunction with this assessment to guide future monitoring and/or management. Mean ratings for attributes and indicators by management unit are shown in Table 5 and Table 6, respectively. Soil and Site Stability were relatively close to reference for all three management units. Hydrologic Function was closest to reference on the South Unit and moderately departed on Elkhorn Ranch. Biotic Integrity was consistently departed across all three units, with Elkhorn Ranch having the greatest departure and the North and South Units being relatively similar in their degree of departure. Invasive plants (16) and functional/structural (F/S) groups (12) had the greatest mean departure from reference across all three management units, with the South Unit displaying the greatest mean degree of departure for invasive plants (16) and Elkhorn Ranch displaying the greatest mean degree of departure for function/structural (F/S) groups (12). Several indicators, such as rills (1), bare ground (4), gullies (5), wind-scoured and/or deposition areas (6), litter movement (7), compaction layer (11), dead or dying plants or plant parts (13), and vigor with an emphasis on reproductive capability of perennial plants (17) had mean ratings similar to reference.

Table 5. Mean attribute ratings for each of the management units included in the assessment. Qualitative ratings are converted to an ordinal scale, where none to slight equals one and extreme to total equals 5.

Management Unit	Locations (#)	Attribute ^a		
		S	H	B
North Unit	3	2	2.3	2.3
Elkhorn Ranch	3	1.7	3.3	4
South Unit	6	1.5	1.8	2.3

^a Attributes: S = Soil and Site Stability; H = Hydrologic Function; B = Biotic Integrity.

Table 6. Mean values for indicator ratings among management units. Qualitative ratings are converted to an ordinal scale, where none to slight equals one and extreme to total equals five.

Management Unit	Locations (#)	Indicator																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
North Unit	3	1.7	2.3	2.0	1.3	1.0	1.0	1.3	1.7	2.3	2.3	1.7	3.0	1.3	1.7	2.0	3.3	1.3
Elkhorn Ranch	3	1.3	2.3	1.3	1.0	1.0	1.0	1.3	3.0	1.3	3.7	1.7	3.7	1.7	3.0	2.5	3.7	1.0
South Unit	6	1.2	2.2	1.7	1.2	1.7	1.0	1.8	1.3	1.8	1.7	1.0	2.0	1.0	1.7	1.3	3.8	1.2

3.2.1 North Unit

Three locations were assessed in the North Unit in 2022. Soil and Site Stability was rated as a none to slight departure at one location, a slight to moderate departure at one location, and a moderate departure at one location. Hydrologic Function and Biotic Integrity were each rated as having a moderate degree of departure at two locations and a none to slight departure at one. Attribute and indicator ratings for the three sites assessed are shown in Figure 4.

An apparent reduction in soil surface resistance to erosion (8), slight compaction (11), and the presence of pedestals (3) and water flow patterns (2) contributed to the slight to moderate Soil and Site Stability attribute ratings. The presence of rills (1), as well as pedestals (2), litter movement (7), and a reduction in the A soil horizon contributed to the one moderate rating for Soil and Site Stability. Departures in Hydrologic Function were largely a factor of increased litter (14), the presence of large bare ground patches (4), likely used by bison as wallows, and the effects of plant community composition and distribution relative to infiltration (10) due to the dominance of smooth brome (*Bromus intermis*). Similarly, the two moderate departure ratings for Biotic Integrity were predominantly driven by shifts in functional/structural (F/S) groups (12), the dominance of smooth brome (16), and increase in the thatch layer (14), and a reduction in annual production (15).

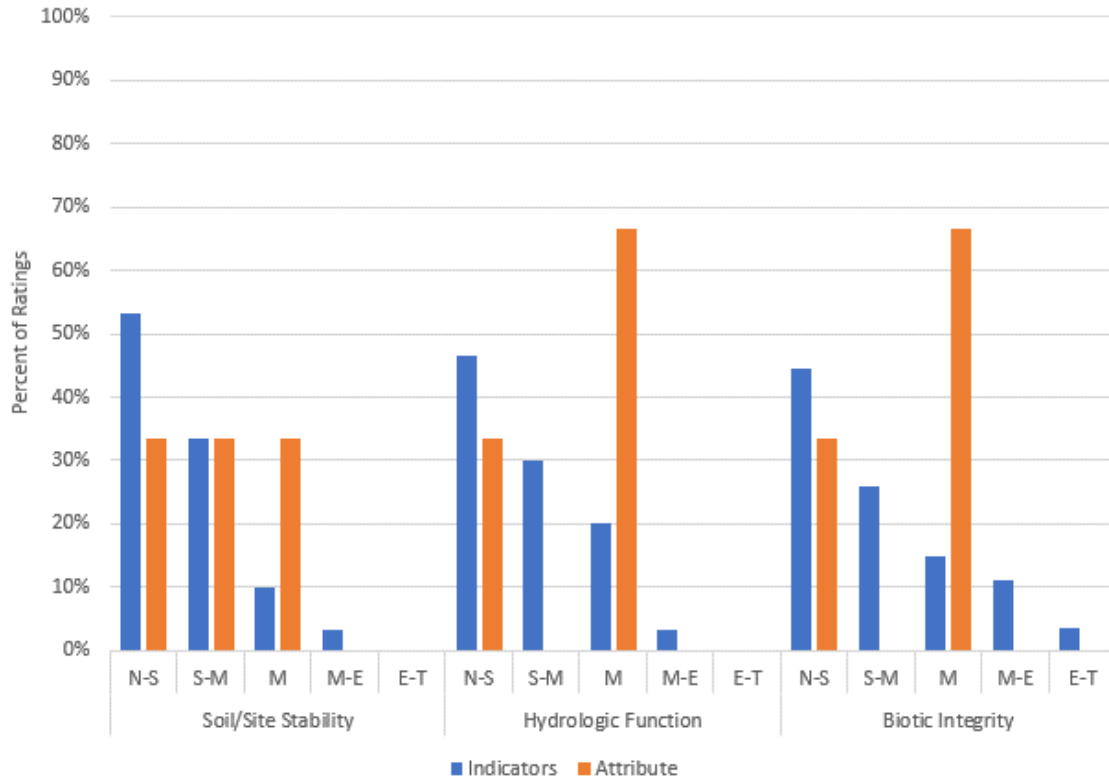


Figure 4. Distribution of indicator and final attribute ratings for the 3 locations assessed in the North Unit.

3.2.2 Elkhorn Ranch

Three locations were assessed in the Elkhorn Ranch Unit in 2022. Soil and Site Stability was rated as a none to slight departure at one location and a slight to moderate departure at two locations; Hydrologic Function was rated as moderate at two locations and moderate to extreme at one location. All three sites were rated as moderate to extreme departure for Biotic Integrity. Attribute and indicator ratings for the three sites assessed are shown in Figure 5.

At both locations with slight to moderate ratings for Soil and Site Stability, departure is partly attributed to a reduction in soil surface resistance to erosion (8) and the presence of water flow patterns (2). Other factors contributing to the ratings include litter accumulation under plant canopies (14) and the presence of rills (1) and pedestals (3); however, departure for these indicators varied between the two sites. Hydrologic Function ratings can largely be attributed to changes in the effects of plant community composition and distribution relative to infiltration (10), with the degree of change in plant community composition being the primary difference between the three assessment locations. This shift in dominance of functional/structural (F/S) groups (12) lead to the moderate to extreme departure ratings for Biotic Integrity across all three sites. Invasive species (12) presence and reduced annual production (15) also affected the Biotic Integrity ratings.

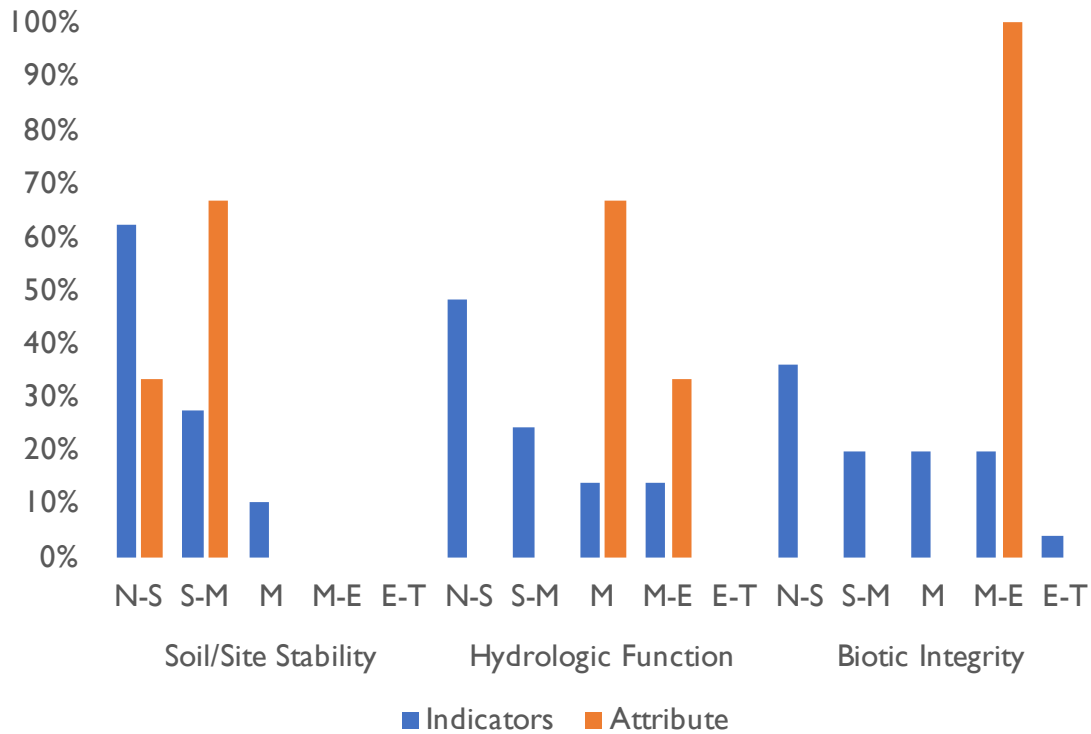


Figure 5. Distribution of indicator and final attribute ratings for the 3 locations assessed in the Elkhorn Ranch Unit.

3.2.3 South Unit

Six locations were assessed in the South Unit in 2022. Soil and Site Stability was rated as none to slight departure and slight to moderate departure at three locations each. Three of the six sites were rated as slight to moderate departure for Hydrologic Function. Two of the remaining sites received a rating of none to slight and one site was rated as moderate. Biotic Integrity received the greatest departure ratings with two sites being rated as moderate and four sites rated as slight to moderate. Attribute and indicator ratings for the three sites assessed are shown in Figure 6.

The slight to moderate locations for Soil and Site Stability varied in their individual indicator ratings, however, litter movement (7), water-flow patterns (2), pedestalling (3), increased bare ground (4), and reduced soil surface resistance to erosion (8) were factors contributing to the overall attribute rating. One Soil and Site Stability slight to moderate site also received a moderate to extreme indicator rating for presence of gullies (5), contributing to the overall attribute rating. Similarly, the drivers of the slight to moderate Hydrologic Function ratings varied between sites with shifts in the effects of plant community composition and distribution relative to infiltration (10) being the only constant across locations. Water flow patterns (2) was the only other indicator that meaningfully contributed to overall Hydrologic Function ratings across sites. Again, one site received a moderate attribute rating due to a moderate to extreme rating for gullies (5). Changes in functional/structural (F/S) group (12) relative dominance due to the presence of the introduced grasses smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) drove ratings for Biotic Integrity, with the degree of dominance being the primary driver for separation in ratings between sites. Both grasses

are considered invasive in the associated ESD reference sheets, so higher degrees of departure for the invasive plant indicator (16) also contributed to overall attribute ratings. Increases in the percent cover and depth of litter (14) also contributed to greater departure ratings for two sites.

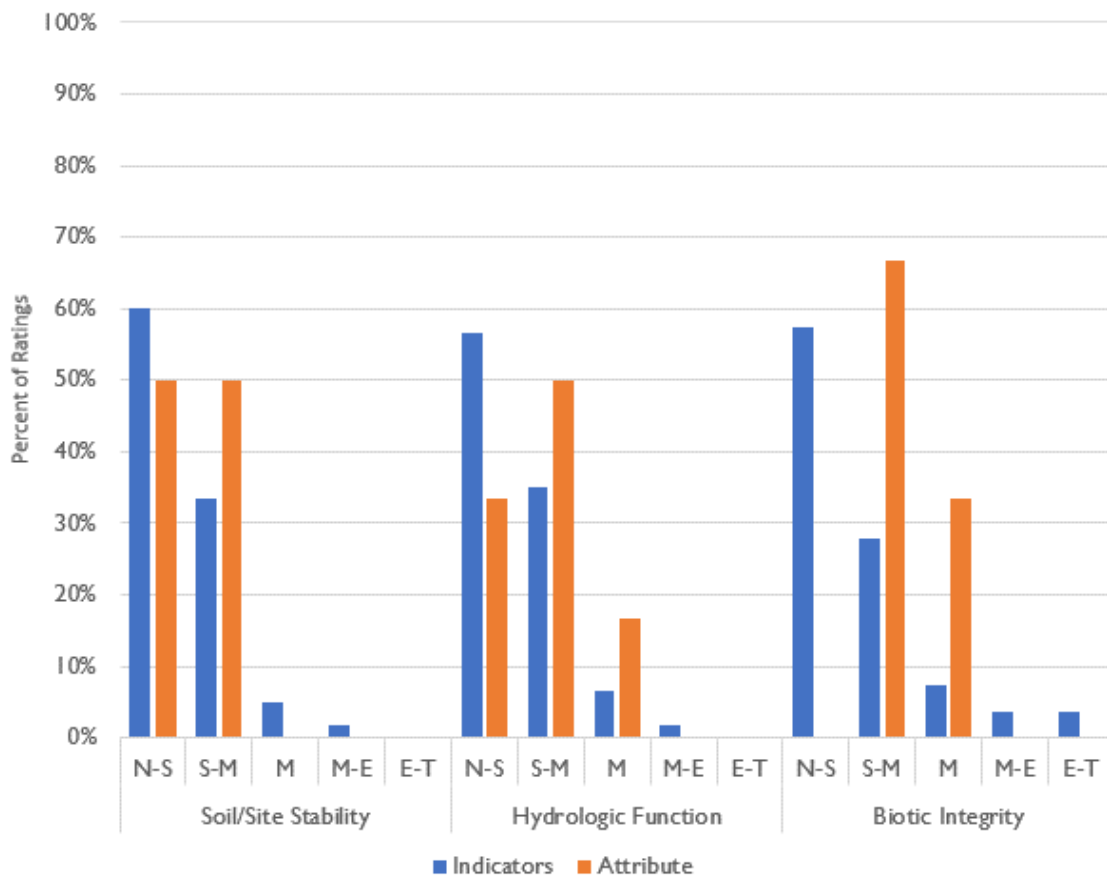


Figure 6. Distribution of indicator and final attribute ratings for the 6 locations assessed in the South Unit.

3.3 By Ecological Site Description

Seven Ecological Site Descriptions were used during this assessment. Table 7 lists the ESD codes and names, as well as the number of locations associated with each. Table 8 details the number of times each ESD was utilized in each management unit, and Table 9 shows the average attribute rating associated with each ESD.

The greatest average departure across all attributes was for sites assessed under the Sandy Terrace (R054XY042ND) ESD, with sites assessed under the Badlands Fan (R058CY070ND) and Loamy Terrace (R058CY091ND) ESDs showing similarly high average departure ratings. Individual indicator ratings driving overall attribute assessments are distinct for all sites assessed under the Sandy Terrace, Bandlands Fan, and Loamy Terrace ESDs making generalizations across sites within an ESD potentially misleading. For example, three of the five sites that correspond to these ESDs fall in the Elkhorn Ranch Management Unit, which may make geographic location or historic management a greater driver than ESD classification. It should be noted that both the Sandy Terrace

(R054XY042ND) and Badlands Fan (R058CY070ND) ESDs and reference sheets were in draft during the time of the assessment. The draft reference sheets and functional/structural worksheets were obtained from the Natural Resource Conservation Service (NRCS) and used for the assessments. Average attribute ratings for other ESDs were fairly similar to reference (Table 9).

Table 7. List of Ecological Site Descriptions (ESD) used in the IIRH assessments, along with the number of IIRH locations that corresponded to each ESD.

ESD Code	ESD Name	Number of Locations
R054XY020ND	Clayey	1
R058CY079ND	Limy Residual	1
R058CY091ND	Loamy Terrace	2
R054XY042ND ^a	Sandy Terrace	2
R054XY031ND	Loamy	3
R054XY033ND	Thin Claypan	2
R058CY070ND ^a	Badlands Fan	1

^a Reference sheets used for this assessment were still a draft from the NRCS.

Table 8. The number of locations corresponding to each ecological site across the management units included in the assessment.

ESD Code	Management Unit		
	North Unit	Elkhorn Ranch Unit	South Unit
R054XY020ND	–	–	1
R058CY079ND	–	–	1
R058CY091ND	–	2	–
R054XY042ND ^a	1	1	–
R054XY031ND	1	–	2
R054XY033ND	1	–	1
R058CY070ND ^a	–	–	1

^a Reference sheets used for this assessment were still a draft from the NRCS.

Table 9. Mean attribute ratings for each ecological site encountered during assessment. Qualitative ratings are converted to an ordinal scale, where none to slight equals one and extreme to total equals five.

ESD Code	Locations (#)	Attribute ^a		
		S	H	B
R054XY020ND	1	2	2	2
R058CY079ND	1	2	2	2
R058CY091ND	2	1.5	3	4
R054XY042ND ^b	2	2.5	3.5	3.5
R054XY031ND	3	1.0	1.7	2.7
R054XY033ND	2	1.5	1.5	2.0
R058CY070ND1 ^b	1	2	3	2

^a Attributes: S = Soil and Site Stability; H = Hydrologic Function; B = Biotic Integrity.

^b Reference sheets used for this assessment were still a draft from the NRCS.

3.4 Compromised Sites

As defined in Courkamp et al. (2021) and Jablonski et al. (2020), “ecologically compromised” site are those locations where at least one of the three IIRH attributes (Soils and Site Stability, Hydrologic Function, or Biotic Integrity) was rated as having a moderate or greater (≥ 3) departure from reference condition. As with other IIRH assessments of NPS units (Courkamp et al. 2021; Jablonski et al. 2020), this term is not intended to suggest anything other than an IIRH rating. Locations of all compromised sites at THRO are shown on the map in Figure 7, and the number of compromised sites per management unit is outlined in Table 10.

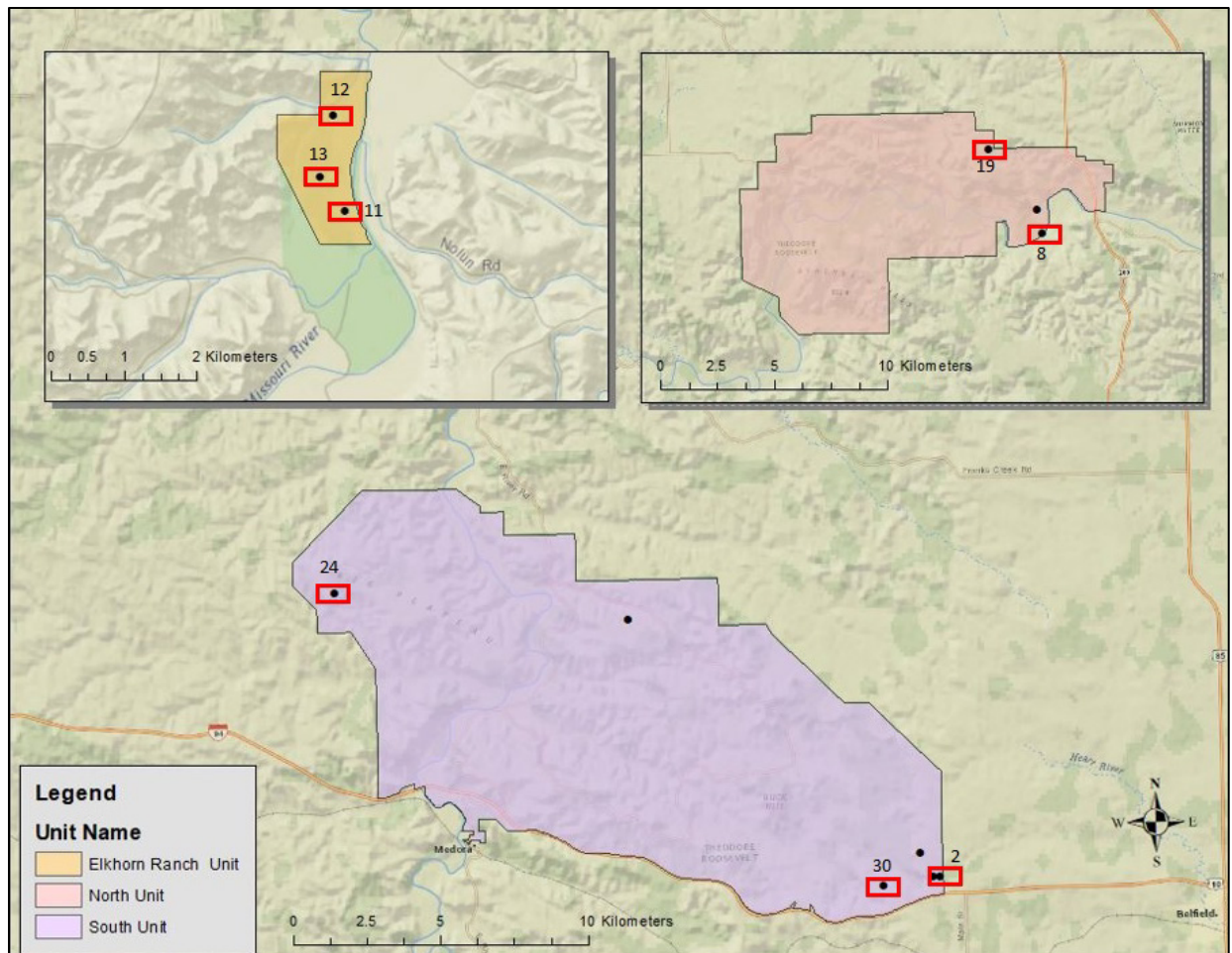


Figure 7. Location of ecologically compromised sites at THRO (identified by red boxes).

Table 10. Distribution of locations with a moderate or greater departure from reference condition (compromised sites) for at least one IIRH attribute.

Management Unit	Hectares	Total Locations (#)	Compromised Sites (#)	Percent Compromised
North Unit	9,152	3	2	66.7%
Elkhorn Ranch Unit	92	3	3	100%
South Unit	18,635	6	3	50%

3.4.1 North Unit

Of the three sites assessed on the North Unit, two were classified as compromised, Site 8 and Site 19. Site 8 received a moderate departure rating for all three attributes whereas Site 19 received a moderate rating for Hydrologic Function and Biotic Integrity but not Soil and Site Stability. Tables 11, 12 and 13 detail the attribute ratings and individual indicator ratings that contributed to them by site for all three attributes.

Table 11. Indicator ratings leading to overall attribute ratings for Soil and Site Stability at North Unit compromised sites.

Site ID	ESD Code	Attributes and Indicators										
		Soil and Site Stability	1. Rills	2. Water-flow patterns	3. Peds. and/or terr.	4. Bare grnd.	5. Gullies	6. Wind scour/ dep. areas	7. Litter mvmt.	8. Soil surf. res. erosion	9. Soil loss or degr.	11. Comp. layer
8	R054XY042ND	3 ^b	3 ^b	2 ^a	2 ^a	1 ^a	1 ^a	1 ^a	2 ^a	1 ^a	4 ^b	2 ^a

^a Ratings: N-S = None to slight; S-M = Slight to moderate.

^b Ratings: M = Moderate (shaded gray); M-E = Moderate to extreme (shaded gray); E-T = Extreme to total (shaded gray).

Table 12. Overall rating for Hydrologic Function and ordinal ratings for Indicators at North Unit compromised sites¹.

Site ID	ESD Code	Hydrologic Function Attribute	Indicators									
			1. Rills	2. Water-flow patterns	3. Peds. and/or terr.	4. Bare grnd.	5. Gullies	8. Soil surf. res. erosion	9. Soil loss or degr.	10. Infiltration	11. Comp. layer	14. Litter cover
8	R054XY042ND	3	3	2	2	1	1	1	4	3	2	3
19	R054XY031ND	3	1	2	2	2	1	3	2	3	2	1

^a Ordinal Ratings: 1 = None to slight; 2 = Slight to moderate; 3 = Moderate; 4 = Moderate to extreme; 5 = Extreme to total.

Table 13. Indicator ratings leading to overall attribute ratings for Biotic Integrity at North Unit compromised sites.

Site ID	ESD Code	Attributes and Indicators									
		Biotic Integrity	8. Soil surf. res. erosion	9. Soil loss or degr.	11. Comp. layer	12. F/S groups	13. Dead or dying plants	14. Litter cover	15. Ann. prod.	16. Inv. plants	17. Vigor
8	R054XY042ND	3 ^b	1 ^a	4 ^b	2 ^a	2 ^a	2 ^a	3 ^b	3 ^b	4 ^b	2 ^a
19	R054XY031ND	3 ^b	3 ^b	2 ^a	2 ^a	4 ^b	1 ^a	1 ^a	2 ^a	5 ^b	1 ^a

^a Ratings: N-S = None to slight; S-M = Slight to moderate.

^b Ratings: M = Moderate (shaded gray); M-E = Moderate to extreme (shaded gray); E-T = Extreme to total (shaded gray).

Site 8 received departure ratings of moderate for all three attributes. A moderate Soil and Site Stability rating was predominately driven by a substantial loss of the A horizon (9) and evidence of erosion in the form of rills (1) and pedestals (3). Rills, although uncommon, were long where present and cut into the soil; however, an old two-track road and several trailing paths can account for most of the rills observed. Pedestals (3) were not widespread throughout the site and were largely confined to rill features and led to some root exposure, although this was rare. Site 8 is located on a terrace, lower in topographic position than most of the surrounding landscape and centered between a channel to the northwest that fell within the assessment area and the river to the southeast. Evidence of moderate litter movement (7) of moderate to large size classes (i.e., logs and sticks) was observed in the channel; however, this was not ubiquitous across the site or prevalent in most of the assessment area. An increased thatch layer on the terrace likely reduces litter movement throughout most of the assessment site. Due to its topographic position, a substantial loss of the A horizon (9) was observed in the pit. This can likely be attributed to the assessment site being subjected to flooding and flowing water to a greater degree than the surrounding landscape that was slightly higher in elevation.

A moderate rating for Hydrologic Function, similar to Soil and Site Stability, is partly attributed to the substantial loss of the A horizon (9) at the site. Other indicators that featured prominently in the overall rating include litter cover and depth (14), rills (1), and shifts in the effects of plant community composition and distribution relative to infiltration (10). A thick thatch layer was present on the terrace at the assessment site, with a depth of 0–8 cm under shrubs and in the grass canopy. The apparent shift in the effects of plant community composition and distribution relative to infiltration (10) is the result of increased spacing between grass and grass-like species, as well as the prevalence of both smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) throughout the site.

The rating for Biotic Integrity was also due, in part, to the loss of the A horizon and the abundance of introduced grasses. Annual production was also an indicator of concern. In an average year, roughly 3,362 kg/ha is expected for the Sandy Terrace (R054XY042ND) ecological site; Site 8 was estimated to produce 45% of the expected annual production with a final calculated value of 1,540 kg/ha. While the assessment site received above average precipitation by June 2022 (214 mm expected, per the 30-year average, compared to the 340 mm received), the several years prior to this assessment were considered drought years, which could be impacting the annual production estimates from 2022. Finally, an increase in litter cover (14) from 40–50% expected to an observed 92% also contributed to the overall attribute rating.

Site 19 received moderate departure ratings for both the Hydrologic Function and Biotic Integrity indicators. Site 19 is situated along the northeastern boundary of the North Unit. It is important to note that Site 19 fell within the boundary of the Horse Pasture Fire that burned in early 2021. A moderate rating for Hydrologic Function was mainly due to shifts in the effects of plant community composition and distribution relative to infiltration (10) and a reduction in soil surface resistance to erosion (8). Vegetative canopy cover at the site was 94% and can largely be attributed to grasses; however, the site is dominated by smooth brome (*Bromus inermis*). While the high grass canopy cover is consistent with the reference condition, the ESD reference sheet notes that “due to differing

root structure and distribution, Kentucky bluegrass and smooth brome do not fit into reference plant community functional/structural groups”. Soil surface resistance to erosion (8) was also reduced, both under plant canopies and in 50% of plant interspaces. The reduction in resistance to erosion could also contribute to the water flow patterns (2) and terracettes (3) scattered throughout the site. It should be noted however that a majority of terracettes observed formed from hoof prints on steeper slopes.

As previously mentioned, smooth brome was the dominant species at Site 19, which greatly impacted the overall Biotic Integrity attribute rating. An extreme to total departure rating for invasive plants (16) and a moderate to extreme rating for functional/structural (F/S) groups (12) drove the overall attribute rating. Again, smooth brome is not to be considered in the reference plant community, and as such, it is thought that this site has transition away from reference and into Community 1.3 Introduced Bluegrass/Smooth Bromegrass/Shrubs. Although relative dominance has shifted such that smooth brome is the key species at this site, annual production was calculated to be 62% of what is expected in an average year (2,690 kg/ha expected compared to 1,681 kg/ha observed). Again, the assessment site received above average precipitation by June 2022 (214 mm expected, per the 30-year average, compared to the 340 mm received), but previous years in drought, as well as the 2021 fire, could be contributing to the reduced annual production values as well as the shift in functional/structural groups.

3.4.2 Elkhorn Ranch Unit

All three of the assessment sites on the Elkhorn Ranch Unit were classified as compromised for both Hydrologic Function and Biotic Integrity. For Hydrologic Function, Sites 12 and 13 received a moderate departure rating while Site 11 was rated as moderate to extreme. All three sites were rated as moderate to extreme for Biotic Integrity. Tables 14 and 15 detail the attribute ratings and individual indicator ratings that contributed to them by site for all three attributes.

Table 14. Indicator ratings leading to overall attribute ratings for Hydrologic Function at Elkhorn Ranch Unit compromised sites.

Site ID	ESD Code	Attributes and Indicators										
		Hydr. Function	1. Rills	2. Water-flow patterns	3. Peds. and/or terr.	4. Bare grnd.	5. Gullies	8. Soil surf. res. erosion	9. Soil loss or degr.	10. Infiltration	11. Comp. layer	14. Litter cover
11	R054XY042ND	4 ^b	1 ^a	2 ^a	1 ^a	1 ^a	1 ^a	3 ^b	1 ^a	4 ^b	2 ^a	4 ^b
12	R058CY091ND	3 ^b	2 ^a	2 ^a	2 ^a	1 ^a	1 ^a	3 ^b	1 ^a	4 ^b	2 ^a	4 ^b
13	R058CY091ND	3 ^b	1 ^a	3 ^b	1 ^a	1 ^a	1 ^a	—	2 ^a	3 ^b	1 ^a	1 ^a

^a Ratings: N-S = None to slight; S-M = Slight to moderate.

^b Ratings: M = Moderate (shaded gray); M-E = Moderate to extreme (shaded gray); E-T = Extreme to total (shaded gray).

Table 15. Indicator ratings leading to overall attribute ratings for Biotic Integrity at Elkhorn Ranch Unit compromised sites.

Site ID	ESD Code	Attributes and Indicators									
		Biotic Integrity	8. Soil surf. res. erosion	9. Soil loss or degr.	11. Comp. layer	12. F/S groups	13. Dead or dying plants	14. Litter cover	15. Ann. prod.	16. Inv. plants	17. Vigor
11	R054XY042ND	4 ^b	3 ^b	1 ^a	2 ^a	3 ^b	2 ^a	4 ^b	4 ^b	3 ^b	1 ^a
12	R058CY091ND	4 ^b	3 ^b	1 ^a	2 ^a	4 ^b	2 ^a	1 ^a	—	3 ^b	1 ^a
13	R058CY091ND	4 ^b	—	2 ^a	1 ^a	4 ^b	1 ^a	1 ^a	1 ^a	5 ^b	1 ^a

^a Ratings: N-S = None to slight; S-M = Slight to moderate.

^b Ratings: M = Moderate (shaded gray); M-E = Moderate to extreme (shaded gray); E-T = Extreme to total (shaded gray).

Site 11 received a moderate to extreme rating for both Hydrology Function and Biotic Integrity, and the drivers of both ratings were similar: shifts in the effects of plant community composition and distribution relative to infiltration (10) due to shifts in relative dominance of functional/structural groups (12). Site 11 falls on the Sandy Terrace (R054XY042ND) ecological site, which is characterized as being dominated by tall-statured, rhizomatous grasses with mid- and short-statured bunchgrasses, forbs, and shrubs as subdominant components. Although western wheatgrass (*Pascopyrum smithii*) was abundant at the assessment site, western snowberry (*Symphoricarpos occidentalis*) was dominant. Other factors potentially impacting infiltration at the site are the increase in litter cover (14) from an expected range of 40–50% to the observed 100% and a reduction in the percent cover of bare ground (4) from an expected 15% or less to the observed 0%. Although a reduction in the percent cover of bare ground does not lead to an increased departure rating, the presence of a thick thatch layer and no obvious bare ground is noted.

The observed shifts in relative dominance of functional/structural groups (12) could also have contributed to the reduced annual production at the site. Estimated annual production was 34% of expected (3,362 kg/ha expected compared to 1,155 kg/ha observed). Other factors influencing the moderate to extreme Biotic Integrity rating specifically include presence of invasive species (16) and a reduction in soil surface resistance to erosion (8).

Site 12 is located in the northern portion of the Elkhorn Ranch Unit and received a moderate rating for Hydrologic Function and a moderate to extreme rating for Biotic Integrity. Similar to Site 11, ratings for both attributes are primarily the result of changes in the effects of plant community composition and distribution relative to infiltration (10) and shifts in relative dominance of functional/structural groups (12). Site 12 is considered to be part of the Loamy Terrace (R058CY091ND) ecological site and is characterized by high grass canopy and basal cover and small gaps between plants, with healthy, deep-rooted native grasses enhancing site infiltration and reducing runoff. It is the judgement of the crew that this site has transitioned to Community 1.3 Non-Use Plant Community as trees have become the dominant functional group.

Hydrologic Function was rated as moderate due to the moderate to extreme rating for effects of plant community composition and distribution relative to infiltration (10), reduced soil surface resistance to erosion (8), and the presence of rills (1), water flow patterns (2), and pedestals (3). Pools of standing water were present in areas with reduced grass canopy cover across the site. In tree interspaces, grass cover increased and the spacing between plants decreased to a degree that is more akin to reference (10). Soil surface resistance to erosion (8) was reduced in both the interspaces as well as under plant canopies from an expected 5 or greater to 3.4 and 3.5, respectively.

Biotic Integrity received a moderate to extreme rating due to shifts in relative dominance of functional/structural groups (12), presence of invasive plants (16), and the reduction in soil surface resistance to erosion (8). As previously mentioned, mid, cool-season rhizomatous grasses and mid, cool-season bunchgrasses are expected to dominate this site with a sub-dominant shrub component; Trees are not necessarily expected. Site 12 was dominated by trees with grasses as the subdominant component and shrubs missing entirely (12). Smooth brome (*Bromus inermis*) and Kentucky

bluegrass (*Poa pratensis*) were scattered throughout the site as well. Annual production was omitted from Site 12 due to the abundance of trees.

Site 13 is in the central portion of the Elkhorn Ranch Unit and received a moderate rating for Soil and Site Stability and a moderate to extreme rating for Biotic Integrity. Similar to Site 12, ratings for both attributes are primarily the result of changes in the effects of plant community composition and distribution relative to infiltration (10) and shifts in relative dominance of functional/structural groups (12). Site 12 is considered to be part of the Loamy Terrace (R058CY091ND) ecological site and is characterized by high grass canopy and basal cover and small gaps between plants, with healthy, deep-rooted native grasses enhancing site infiltration and reducing runoff. The crew believes this site has transitioned to Community 1.3 Non-Use Plant Community because trees have become the dominant functional group.

Hydrologic Function was rated as moderate due to the moderate ratings for effects of plant community composition and distribution relative to infiltration (10) and presence of water flow patterns (2), and the slight to moderate rating for soil surface loss and degradation (9). Pools of standing water were present in areas with reduced grass canopy cover across the site. In tree interspaces, grass cover increased and the spacing between plants decreased to a degree that is more akin to reference (10) with rhizomatous grasses dominating the understory. In areas with reduced grass cover, standing water was common with water flow patterns extending from these pools (2). Soil surface loss and degradation (9) was rated as slight to moderate due to a slight reduction of the A horizon. Soil surface resistance to erosion (8) was omitted due to the amount of standing water throughout the site.

An extreme to total departure rating for invasive plants (16) due to the abundance of smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*), as well as a moderate to extreme departure rating for the shift in functional/structural groups (12) were largely responsible for the overall moderate to extreme rating for Biotic Integrity. While the relative dominance of expected functional/structural groups was similar to reference, the relative dominance has shifted such that trees were dominant and grasses subdominant (12).

3.4.3 South Unit

Of the six sites assessed on the South Unit, three were classified as compromised, Site 2, Site 30, and Site 24. Hydrologic Function was rated as moderate for site 24 (Table 16) while Sites 2 and 30 both received a moderate departure rating for Biotic Integrity (Table 17).

Table 16. Indicator ratings leading to overall attribute ratings for Hydrologic Function at South Unit compromised sites.

Site ID	ESD Code	Attributes and Indicators										
		Hydr. Function	1. Rills	2. Water-flow patterns	3. Peds. and/or terr.	4. Bare grnd.	5. Gullies	8. Soil surf. res. erosion	9. Soil loss or degr.	10. Infiltration	11. Comp. layer	14. Litter cover
24	R058CY070ND	3 ^b	2 ^a	2 ^a	2 ^a	1 ^a	4 ^b	1 ^a	2 ^a	2 ^a	1 ^a	3 ^b

^a Ratings: N-S = None to slight; S-M = Slight to moderate.

^b Ratings: M = Moderate (shaded gray); M-E = Moderate to extreme (shaded gray); E-T = Extreme to total (shaded gray).

Table 17. Indicator ratings leading to overall attribute ratings for Biotic Integrity at South Unit compromised sites.

Site ID	ESD Code	Attributes and Indicators									
		Biotic Integrity	8. Soil surf. res. erosion	9. Soil loss or degr.	11. Comp. layer	12. F/S groups	13. Dead or dying plants	14. Litter cover	15. Ann. prod.	16. Inv. plants	17. Vigor
2	R054XY033ND	3 ^b	1 ^a	2 ^a	1 ^a	2 ^a	1 ^a	1 ^a	1 ^a	5 ^b	1 ^a
30	R054XY031ND	3 ^b	2 ^a	1 ^a	1 ^a	3 ^b	1 ^a	1 ^a	1 ^a	4 ^b	1 ^a

^a Ratings: N-S = None to slight; S-M = Slight to moderate.

^b Ratings: M = Moderate (shaded gray); M-E = Moderate to extreme (shaded gray); E-T = Extreme to total (shaded gray).

Site 2 is located on the southeastern boundary of the South Unit. The moderate departure for Biotic Integrity of this site is due entirely to the dominance of smooth brome (*Bromus inermis*). Though not always considered invasive, this introduced grass is listed as invasive in the Thin Claypan (R054XY033ND) ecological site reference sheet and was assessed as such. While the Thin Claypan reference sheet states smooth broom is not a suitable alternative for reference plant communities, relative dominance is calculated using annual production estimates and all grasses were pooled during estimation at this site and we were unable to differentiate the proportion of production attributed to smooth brome compared to native grasses. All other attributes were similar to reference with slight soil surface loss and degradation (9) observed in plant interspaces.

Site 24 is located in the western portion of the South Unit. A moderate departure rating for Hydrologic Function was due to the presence of active gullies (5) and increased litter (14). Gullies had significant depth and width and were present throughout the site, with headcuts mainly on slopes, intermittent vegetation observed along banks, and moderate bottom erosion. Site 24 is classified as part of the Badlands Fan (R058CY070ND) ecological site, which was in draft status during the time of the assessment. For sites with draft reference sheets, crews used Plant Community Phase (PCP) 1.1 as the default for comparison due to the lack of a state-and-transition (STM) model or PCP narrative for comparison. The draft reference sheet for this ecological site indicates that gullies are not to be expected in PCP 1.1; however, active gullies greater than 3.6-m in length with signs of active erosion are expected in PCP 1.2. Gullies were rated as moderate to extreme, but without an STM and PCP narrative, we could not differentiate PCP 1.1 from PCP 1.2 as being the proper community phase for comparison at this site.

Litter was another primary driver of the overall Hydrologic Function rating at Site 24. The draft reference sheet for this ecological site states that in PCP 1.1 litter cover is expected to be between 50–70% with a depth of 0.6- to 1.2-cm. At the time of assessment, litter cover was observed at 94% with depths ranging from 0- to 7.6-cm. The increase in both litter percent cover and depth (14) lead to an indicator rating of moderate. Unlike with gullies, PCP 1.2 has an expected litter cover of 1–30% with a depth of less than 0.6-cm, meaning that the indicator rating for litter cover and depth (14) is departed from reference, regardless of PCP.

Site 30 is located on the southeastern boundary of the South Unit. The moderate departure for Biotic Integrity of this site is due to the prevalence of Kentucky bluegrass (*Poa pratensis*) throughout the site (16) and shifts in functional/structural groups (12). Though not always considered invasive, this introduced grass is listed as invasive in the Loamy (R054XY031ND) ecological site reference sheet and was assessed as such. Functional/structural groups (12) were rated as moderate due to an unexpected functional group appearing at the site (i.e., Kentucky bluegrass). It should be noted that while the Loamy reference sheet states Kentucky bluegrass is not a suitable alternative for reference plant communities, relative dominance is calculated using annual production estimates and all grasses were pooled during estimation at this site making it impossible to differentiate the proportion of production attributed to Kentucky bluegrass compared to native grasses.

4. Discussion and Recommendations

Overall rangeland health looked relatively good across sites, with most attributes receiving ratings of either none to slight or slight to moderate departure from reference. While the rangeland health assessment protocol is such that extrapolation beyond individual sites is tenuous, there are several points that warrant further discussion. An example is the consistently poor ratings for Biotic Integrity across sites at the Elkhorn Ranch Unit. At all three sites, the expected dominant function group had shifted to subdominant, and at two sites, an unexpected functional group had become the dominant component. Additionally, all sites in the South Unit received reduced ratings for Biotic Integrity due to the presence of smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*). The same is true for two of the three assessment sites in the North Unit. Given the proportion of sites where these grasses were present, closely tracking spread into areas throughout each management unit where they have not previously been observed should be a priority to increase the likelihood of successful detection and eradication at newly invaded sites.

Theodore Roosevelt National Park has been in a drought for several years prior to this assessment, and at the time of this assessment, THRO was experiencing above average precipitation. Despite previous prolonged drought conditions, the herbaceous component across all assessment sites seems to have not lost vigor and most individuals were capable of producing seed, expanding via rhizome and tiller, and accumulating biomass at a rate that estimates annual production to be relatively similar to expected values in representative years for most sites. Although vegetation across assessment sites seemed vigorous, it is important to note that grasses were pooled for production estimation and we could not differentiate the proportion of production attributed to native grasses compared to introduced grasses.

IIRH assessments are primarily qualitative, point-in-time assessments of site condition. As such, findings are not intended to be used to imply causal relationships and should not be independently used to make management decisions. If the decision to take management action is influenced by findings in this report, we recommend that additional information be compiled to support an appropriate course of action, including, but not limited to, NPS Inventory and Monitoring data, Fire Effects monitoring data, NPS Invasive Plant Management Team data, and outside research.

4.1 Sites with Plant Communities Dominated by Introduced Grasses

At several assessment locations introduced grass prevalence resulted in greater departure ratings for the Biotic Integrity attribute. Smooth brome and Kentucky bluegrass are cool-season, sod-forming grasses with the ability to reproduce and spread via rhizomes as well as by seed (ND Department of Agriculture -Kentucky bluegrass Full Description; Salesman and Thomsen 2011), though Kentucky bluegrass predominantly spreads via rhizomes and tillers (ND Department of Agriculture -Kentucky bluegrass Full Description). Both grasses have a history of being planted as forage crops and for soil stabilization in restoration and reclamation settings making them widespread in much of the United States (ND Department of Agriculture -Kentucky bluegrass Full Description; Salesman and Thomsen 2011). In North Dakota, smooth brome was widely used in both contexts and currently occurs in most if not all counties in the state (ND Department of Agriculture -Smooth Brome Full

Description). Both species are relatively disturbance tolerant and can be aggressive competitors, becoming invasive and displacing desirable native vegetation.

Although not always considered invasive, the introduced grasses smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) can behave as invaders under favorable conditions, and many of the reference sheets for this area specify that these grasses are to be considered invasive and are not suitable replacements for native grass in terms of their effects on infiltration and when considering relative dominance of functional/structural groups. Stotz et al. (2019) found the smooth brome invasion led to biotic homogenization within and among eight grasslands in Alberta Canada. Specifically, the authors show that smooth brome alters species composition on short timescales, reduces light availability, and acts as a filter likely able to exclude similar functional groups (Stotz et al. 2019). The effects of biotic homogenization can be problematic for conservation (e.g., increased species extinction risks, reduced ecosystem functionality, lower ecosystem resilience), making the short amount of time required for this transition in smooth brome invaded areas a potential management concern (Stotz et al. 2019). Monitoring of moderately invaded sites and sites adjacent to smooth brome infestations at THRO could increase the effectiveness of early detection rapid response (EDRR) efforts aimed at reducing smooth brome presence early in the stages of invasion.

While smooth brome is more likely to be found closer to roads and areas adjacent to agricultural operations, Kentucky bluegrass is commonly found in large expanses of grassland farther away from obvious disturbance sites (Grant et al. 2020). This distribution phenomenon was observed in our assessment as well, with smooth brome dominating Site 1, Site 2, and Site 3, and Kentucky bluegrass dominating Site 24, Site 26, and Site 30. Similar to smooth brome, Kentucky bluegrass can shift the structure and function of invaded sites by excluding native vegetation. One study found an increase from 13–34% in Kentucky bluegrass cover, a 66 – 44% reduction in native grass cover, and a 24 – 12% reduction in native forb cover on a loamy ecological site in North Dakota (DeKeyser et al. 2009). It is important to note however that little is known as to whether Kentucky bluegrass is the primary driver of reduced native species richness or whether Kentucky bluegrass simply occupies the newly available niches left as native vegetation declines due to an unrelated stressor (Toledo et al. 2014).

Due to their relative tolerance to disturbance and similarity in life history to native cool-season grasses, controlling these species, once they are established, is difficult and full eradication later in the invasion process may be an unrealistic management goal (Hendrickson and Lund 2010; ND Department of Agriculture -Kentucky bluegrass Full Description; ND Department of Agriculture - Smooth Brome Full Description; Rejmánek and Pitcairn 2002). Toledo et al. (2014) state that for Kentucky bluegrass specifically, an invaded site cannot be returned to a native grassland state, and the North Dakota Department of Agriculture suggests that actions focused on reducing the vigor and spread of Kentucky bluegrass might be a more feasible management goal (ND Department of Agriculture -Kentucky bluegrass Full Description). As with any management strategy for an invasive species, an understanding of extant native vegetation at the restoration site is imperative. As mentioned above, control measures utilized to reduce these grasses could also negatively impact other species of similar life form in the area. In other cases, if there is not a healthy native component

at the treatment site, additional care should be taken to ensure effective native plant revegetation following introduced grass removal.

The primary means of attempting to control both introduced species are successive defoliation via mowing or grazing and repeated prescribed fire (ND Department of Agriculture -Kentucky bluegrass Full Description; ND Department of Agriculture -Smooth Brome Full Description). The differential responses to management actions between these two species could result in a reduction of one and subsequent replacement with the other, especially when either fire or grazing is the only defoliation tactic employed (Murphy and Grant 2005). Annual prescribed burns for smooth brome reduction in mid to late spring, at the tiller elongation and heading growth stages, and in mid-June during the flowering stage, were effective at reducing tiller density (ND Department of Agriculture -Smooth Brome Full Description). Fire has been shown to yield varied results for Kentucky bluegrass reduction and grazing is not a recommended tactic (ND Department of Agriculture -Kentucky bluegrass Full Description). Most research on the effects of prescribed burning on Kentucky bluegrass has been focused on tallgrass systems, where warm-season grasses are dominant, making it difficult to generalize results to cool-season dominated, mix-grass prairies such as those found at THRO. Studies have shown success at reducing Kentucky bluegrass through repeated early spring burns, and a dormant season burn at the Konza Prairie reduced Kentucky bluegrass and increased native cool-season grasses over time. Conversely, Kentucky bluegrass increased following a fall burn in a North Dakota mixed-grass prairie (ND Department of Agriculture -Kentucky bluegrass Full Description). Herbicides, such as glyphosate and imazapyr, have been used for control of both species, but the non-selective nature of these products can result in non-target injury to native grasses. Biological control does not exist for either smooth brome or Kentucky bluegrass (ND Department of Agriculture -Kentucky bluegrass Full Description; ND Department of Agriculture -Smooth Brome Full Description).

4.2 Sites Lacking Disturbance

Site 11 at the Elkhorn Ranch occurs within the Sandy Terrace ecological site (R054XY042ND; Draft). The team observed the plant community had departed from reference due to shifts in relative dominance between shrubs and tall-statured, rhizomatous grasses. The crew determined the appropriate state, according to the ESD, to be State 3.1 Excessive Litter, Shrub, which can develop after 10–20 years of non-use and/or exclusion from fire. The ESD indicates that introduction of fire, herbivory, or a combination of the disturbance regimes can redirect this ecosite towards a desirable condition.

Sites 12 and 13 within the Loamy Terrace ecological site (R058CY091ND) on the Elkhorn Ranch Unit. Due again to departures in relative dominance, the crew determined the appropriate state to be State 1.3 Non-Use Plant Community. This shift is also likely the result of a lack of disturbance (i.e., prescribed fire and/or grazing). The 1.3 Non-Use Plant Community is characterized by high litter levels, enough to reduce native grass vigor, density, and diversity. Non-native grasses may invade and become the dominate plant community. Shrubs such as western snowberry (*Symphoricarpus occidentalis*), silver sage (*Salvia argentea*), buffaloberry (*Shepherdia argentea*), and chokecherry (*Prunus virginiana*) are all likely to increase in density and cover, followed by an increased density

of tree species. It is recommended that managers consider assessing other data sources to determine trends in plant community composition through time to determine whether reintroducing disturbance to the Elkhorn Ranch Unit is feasible.

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Appendix A. Attribute Result Maps

Attribute result maps are provided in figures A1 to A3.

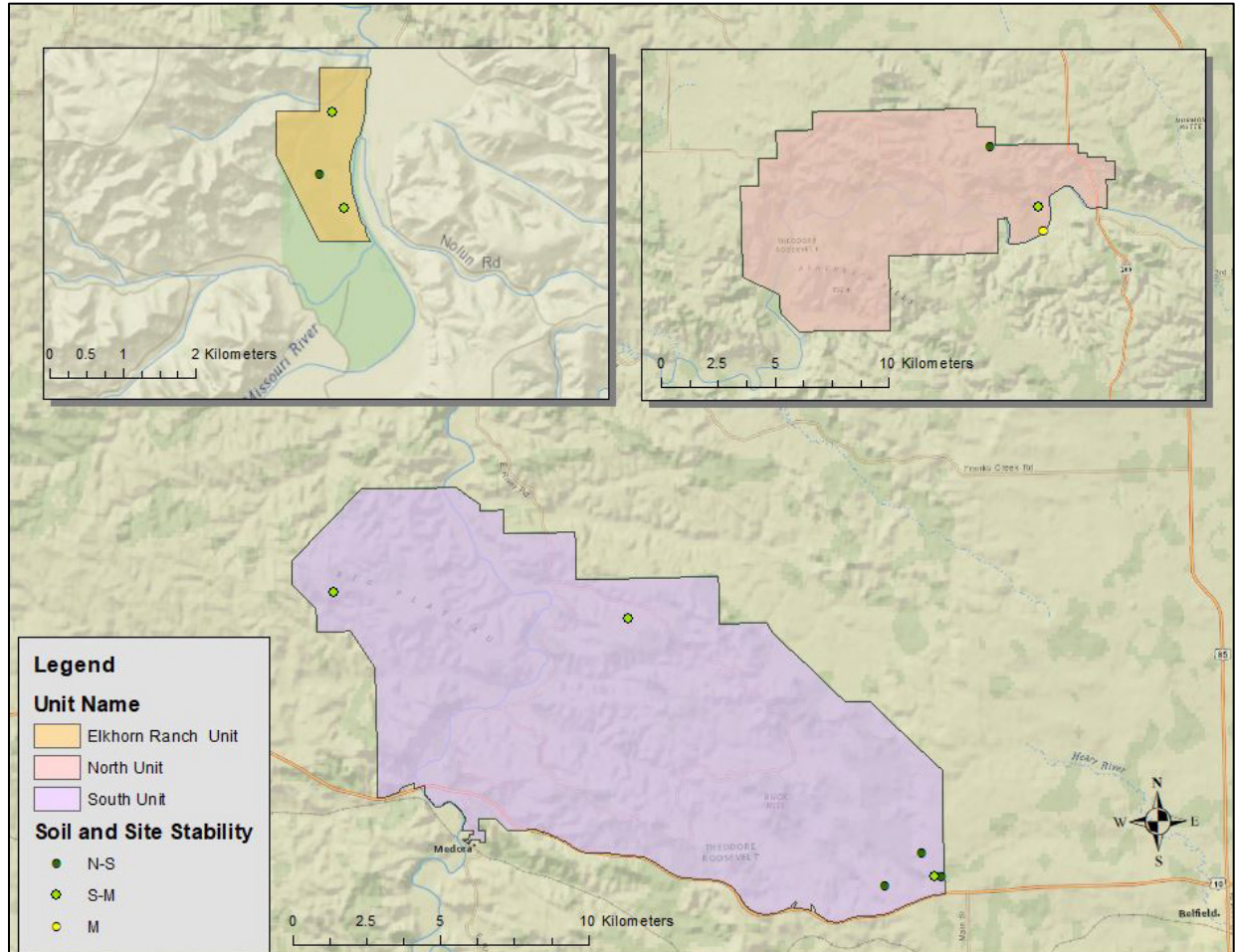


Figure A1. IIRH assessment ratings for the attribute Soil and Site Stability. Rating: N-S = None to slight; S-M = Slight to moderate; M = Moderate.

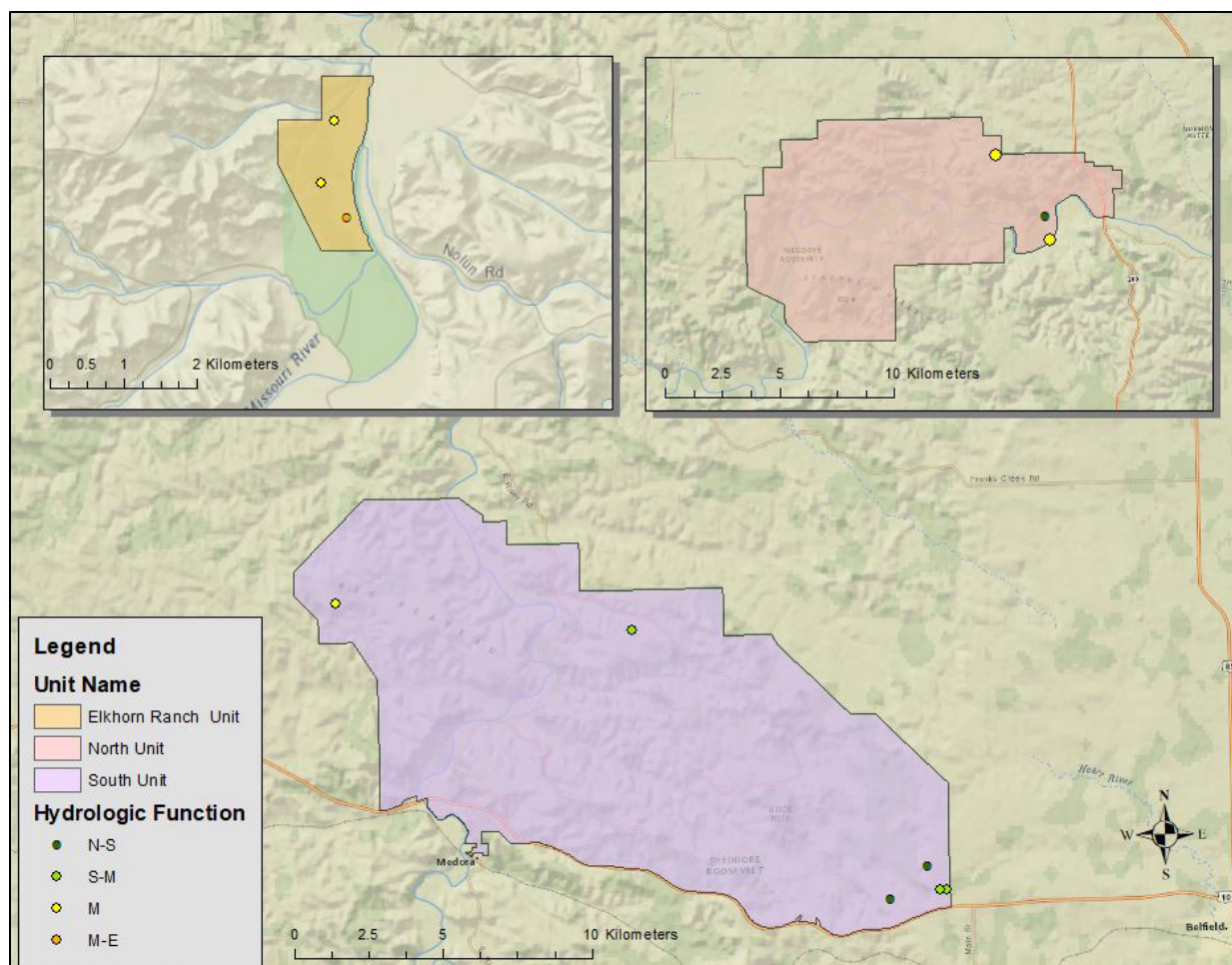


Figure A2. IIRH assessment ratings for the attribute Hydrologic Function. Rating: N-S = None to slight; S-M = Slight to moderate; M = Moderate; M-E = Moderate to extreme.

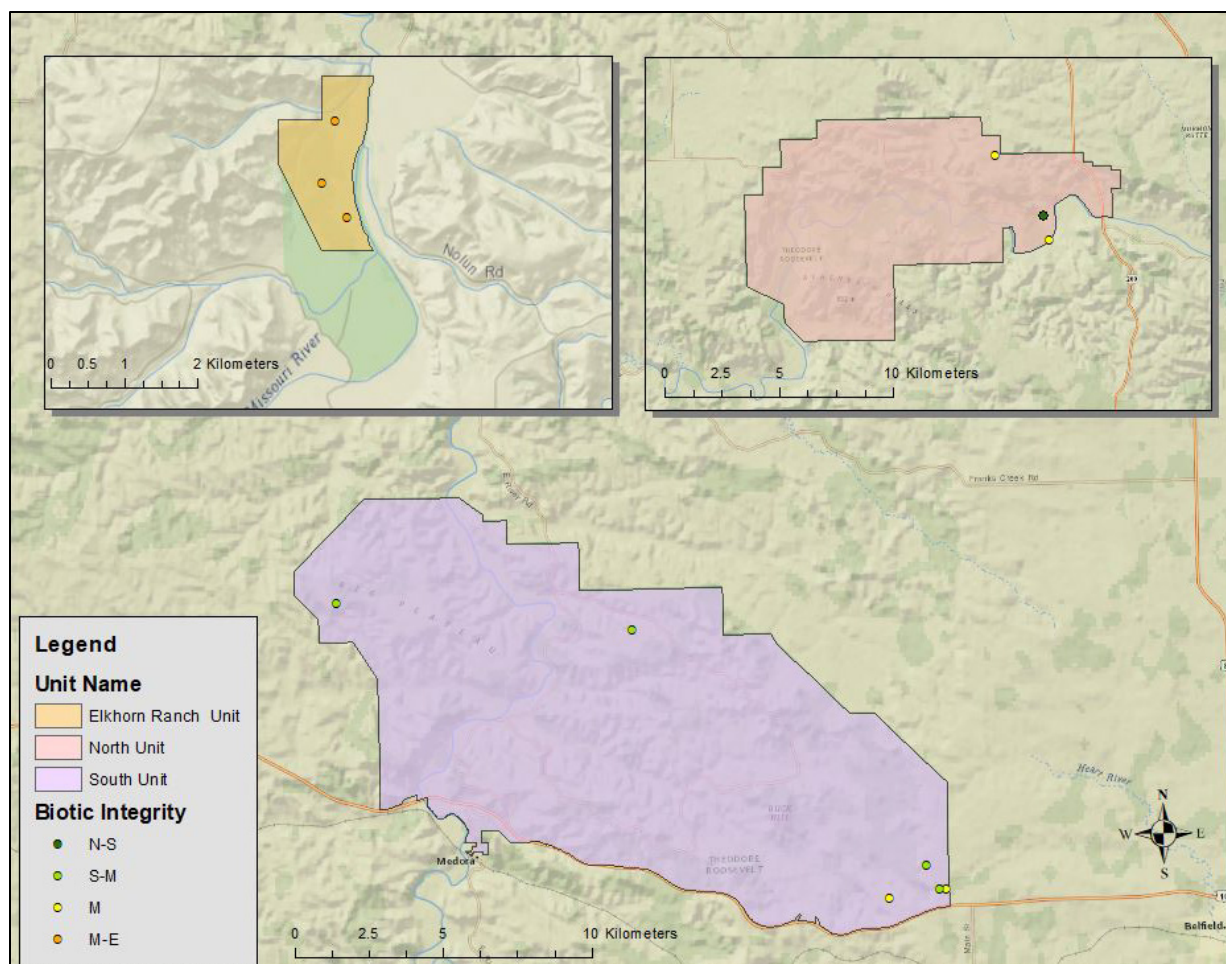


Figure A3. IIRH assessment ratings for the attribute Biotic Integrity. Rating: N-S = None to slight; S-M = Slight to moderate; M = Moderate; M-E = Moderate to extreme.

Appendix B. Summary Data

Summary data are provided in tables B1 to B4.

Table B1. Metadata for assessment sites.

Site ID	Date	X	Y	Unit	ESD code
1	6/14/2022	-103.32557	46.325578	South Unit	R054XY031ND
2	6/14/2022	-103.31704	46.901602	South Unit	R054XY033ND
3	6/14/2022	-103.32015	46.901503	South Unit	R054XY020ND
8	6/17/2022	-103.28541	47.582740	North Unit	R054XY042ND
9	6/17/2022	-103.28785	47.592104	North Unit	R054XY033ND
11	6/16/2022	-103.62228	47.235408	Elkhorn Ranch Unit	R054XY042ND
12	6/16/2022	-103.62385	47.243494	Elkhorn Ranch Unit	R058CY091ND
13	6/16/2022	-103.62540	47.238299	Elkhorn Ranch Unit	R058CY091ND
19	6/17/2022	-103.31527	47.616513	North Unit	R054XY031ND
24	6/18/2022	-103.58483	46.991600	South Unit	R058CY070ND
26	6/18/2022	-103.45429	46.982234	South Unit	R058CY079ND
30	6/15/2022	-103.34209	46.899015	South Unit	R054XY031ND

Table B2. Attribute ratings for sites assessed using IIRH.

Site ID	Attribute ^{a,b}		
	S	H	B
1	N-S	N-S	S-M
2	N-S	S-M	M
3	S-M	S-M	S-M
8	M	M	M
9	S-M	N-S	N-S
11	S-M	M-E	M-E
12	S-M	M	M-E
13	N-S	M	M-E
19	N-S	M	M
24	S-M	M	S-M
26	S-M	S-M	S-M
30	N-S	N-S	M

^a Attributes: S = Soil and Site Stability; H = Hydrologic Function; B = Biotic Integrity.

^b Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate; M-E = Moderate to extreme; E-T = Extreme to total.

Table B3. IIRH indicator (#1–9) ratings for assessment sites.

Site ID	Indicator ^{a,b}								
	1	2	3	4	5	6	7	8	9
1	N-S	S-M	N-S	N-S	N-S	N-S	S-M	S-M	S-M
2	N-S	M	N-S	N-S	N-S	N-S	N-S	N-S	S-M
3	N-S	S-M	S-M	S-M	N-S	N-S	N-S	N-S	S-M
8	M	S-M	S-M	N-S	N-S	N-S	S-M	N-S	M-E
9	N-S	M	S-M	N-S	N-S	N-S	N-S	N-S	N-S
11	N-S	S-M	N-S	N-S	N-S	N-S	S-M	M	N-S
12	S-M	S-M	S-M	N-S	N-S	N-S	N-S	M	N-S
13	N-S	M	N-S	N-S	N-S	N-S	N-S	–	S-M
19	N-S	S-M	S-M	S-M	N-S	N-S	N-S	M	S-M
24	S-M	S-M	S-M	N-S	M-E	N-S	S-M	N-S	S-M
26	N-S	S-M	M	N-S	S-M	N-S	M	N-S	S-M
30	N-S	S-M	N-S	N-S	N-S	N-S	S-M	S-M	N-S

^a See Table 1 for indicator references.

^b Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate; M-E = Moderate to extreme; E-T = Extreme to total; dashes represent locations where indicator was omitted from consideration when determining attribute ratings.

Table B4. IIRH indicator (#10–17) ratings for sites.

Site ID	Indicator ^{a,b}							
	10	11	12	13	14	15	16	17
1	N-S	N-S	N-S	N-S	N-S	S-M	M-E	N-S
2	N-S	N-S	S-M	N-S	N-S	N-S	E-T	N-S
3	S-M	N-S	S-M	N-S	N-S	S-M	E-T	N-S
8	M	S-M	S-M	S-M	M	M	M-E	S-M
9	N-S	N-S	M	N-S	N-S	N-S	N-S	N-S
11	M-E	S-M	M	S-M	M-E	M-E	M	N-S
12	M-E	S-M	M-E	S-M	M-E	–	M	N-S
13	M	N-S	M-E	N-S	N-S	N-S	E-T	N-S
19	M	S-M	M-E	N-S	N-S	S-M	E-T	N-S
24	S-M	N-S	S-M	N-S	M	N-S	M	N-S
26	S-M	N-S	S-M	N-S	M	N-S	S-M	S-M
30	S-M	N-S	M	N-S	N-S	N-S	M-E	N-S

^a See Table 1 for indicator references.

^b Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate; M-E = Moderate to extreme; E-T = Extreme to total; dashes represent locations where indicator was omitted from consideration when determining attribute ratings.

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NPS 387/191377, October 2023

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