National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

# Bent's Old Fort National Historic Site

## *Natural Resource Condition Assessment*

Natural Resource Report NPS/SOPN/NRR—2015/998



**ON THE COVER**

Misty day at Bent's Old Fort NHS. NPS Photo

# Bent's Old Fort National Historic Site

## *Natural Resource Condition Assessment*

Natural Resource Report NPS/SOPN/NRR—2015/998

**Authors**

Kimberly Struthers
Utah State University
Department of Environment and Society
Logan, Utah

Robert E. Bennetts
National Park Service
Southern Plains Inventory and Monitoring Network
Model, Colorado

Patricia Valentine-Darby
University of West Florida
Pensacola, Florida

Nina Chambers
Northern Rockies Conservation Cooperative
Jackson, Wyoming

Tomye Folts-Zettner
National Park Service
Southern Plains Inventory and Monitoring Network
Johnson City, Texas

**Editing and Design**

Heidi Sosinski
National Park Service
Southern Plains Inventory and Monitoring Network
Johnson City, Texas

July 2015

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from Southern Plains Inventory and Monitoring Network (http://science.nature.nps.gov/im/units/sopn/) and the Natural Resource Publications Management Web site (http://www.nature.nps.gov/publications/nrpm/) on the Internet. To receive this report in a format optimized for screen readers, please email irma@nps.gov.

Please cite this publication as:

Struthers, K., R. E. Bennetts, P. Valentine-Darby, N. Chambers, T. Folts-Zettner, and H. Sosinski. 2015. Bent's Old Fort National Historic Site: Natural resource condition assessment. Natural Resource Report NPS/SOPN/NRR—2015/998. National Park Service, Fort Collins, Colorado.

NPS 417/129324, July 2015

# Contents

Page

Executive Summary ..... xv

Acknowledgements ..... xvii

Chapter 1: NRCA Background Information ..... 1

Chapter 2: Introduction and Resource Setting ..... 5
2.1. Introduction ..... 5
2.1.1. Enabling Legislation/Executive Orders ..... 5
2.1.2. Geographic Setting ..... 6
2.1.3. Visitation Statistics ..... 6
2.2. Natural Resources ..... 6
2.2.1. Ecological Units and Watersheds ..... 7
2.2.2. Resource Descriptions ..... 7
2.2.3. Resource Issues Overview ..... 10
2.3. Resource Stewardship ..... 10
2.3.1. Management Directives and Planning Guidance ..... 10
2.3.2. Status of Supporting Science ..... 11
2.4. Literature Cited ..... 11

Chapter 3: Study Scoping and Design ..... 13
3.1. Preliminary Scoping ..... 13
3.2. Study Design ..... 14
3.2.1. Indicator Framework, Focal Study Resources and Indicators ..... 14
3.2.2. Reporting Areas ..... 15
3.2.3. General Approach and Methods ..... 15
3.3. Literature Cited ..... 18

Chapter 4: Natural Resource Conditions ..... 19
4.1. Viewshed ..... 21
4.1.1. Background and Importance ..... 21
4.1.2. Data and Methods ..... 22
4.1.3. Reference Conditions ..... 28
4.1.4. Condition and Trend ..... 29
4.1.5. Sources of Expertise ..... 31
4.1.6. Literature Cited ..... 32
4.2. Night Sky ..... 35
4.2.1. Background and Importance ..... 35
4.2.2. Data and Methods ..... 36
4.2.3. Reference Conditions ..... 39
4.2.4. Condition and Trend ..... 39
4.2.5. Sources of Expertise ..... 40
4.2.6. Literature Cited ..... 40
4.3. Soundscape ..... 43
4.3.1. Background and Importance ..... 43
4.3.2. Data and Methods ..... 44
4.3.3. Reference Conditions ..... 47
4.3.4. Condition and Trend ..... 49

# Contents (continued)

Page


4.3.5. Sources of Expertise ..... 55
4.3.6. Literature Cited ..... 55
**4.4. Air Quality ..... 57**
4.4.1. Background and Importance ..... 57
4.4.2. Data and Methods ..... 59
4.4.3. Reference Conditions ..... 60
4.4.4. Condition and Trend ..... 61
4.4.5. Sources of Expertise ..... 64
4.4.6. Literature Cited ..... 64
**4.5. Geology ..... 67**
4.5.1. Background and Importance ..... 67
4.5.2. Data and Methods ..... 68
4.5.3. Reference Conditions ..... 68
4.5.4. Condition and Trend ..... 69
4.5.5. Sources of Expertise ..... 73
4.5.6. Literature Cited ..... 73
**4.6. Surface Water Quality ..... 75**
4.6.1. Background and Importance ..... 75
4.6.2. Data and Methods ..... 77
4.6.3. Reference Conditions ..... 80
4.6.4. Condition and Trend ..... 80
4.6.5. Sources of Expertise ..... 85
4.6.6. Literature Cited ..... 85
**4.7. Groundwater ..... 89**
4.7.1. Background and Importance ..... 89
4.7.2. Data and Methods ..... 91
4.7.3. Reference Conditions ..... 93
4.7.4. Condition and Trend ..... 93
4.7.5. Source of Expertise ..... 95
4.7.6. Literature Cited ..... 95
**4.8. Riparian Habitat ..... 97**
4.8.1. Background and Importance ..... 97
4.8.2. Data and Methods ..... 100
4.8.3. Reference Conditions ..... 102
4.8.4. Condition and Trend ..... 103
4.8.5. Sources of Expertise ..... 110
4.8.6. Literature Cited ..... 111
**4.9. Grasslands ..... 113**
4.9.1. Background and Importance ..... 113
4.9.2. Data and Methods ..... 117
4.9.3. Reference Conditions ..... 120
4.9.4. Condition and Trend ..... 123
4.9.5. Sources of Expertise ..... 131
4.9.6. Literature Cited ..... 131
**4.10. Exotic Plants ..... 135**
4.10.1. Background and Importance ..... 135
4.10.2. Data and Methods ..... 136
4.10.3. Reference Conditions ..... 142
4.10.4. Condition and Trend ..... 143

# Contents (continued)

Page

4.10.5. Sources of Expertise ..... 146
4.10.6. Literature Cited ..... 146
4.11. Breeding Landbirds ..... 149
4.11.1. Background and Importance ..... 149
4.11.2. Data and Methods ..... 150
4.11.3. Reference Conditions ..... 155
4.11.4. Condition and Trend ..... 156
4.11.5. Sources of Expertise ..... 164
4.11.6. Literature Cited ..... 164
4.12. Black-tailed Prairie Dog (*Cynomys ludovicianus*) ..... 167
4.12.1. Background and Importance ..... 167
4.12.2. Data and Methods ..... 170
4.12.3. Reference Conditions ..... 171
4.12.4. Condition and Trend ..... 171
4.12.5. Sources of Expertise ..... 175
4.12.6. Literature Cited ..... 175
4.13. Fish ..... 177
4.13.1. Background and Importance ..... 177
4.13.2. Data and Methods ..... 177
4.13.3. Reference Conditions ..... 178
4.13.4. Condition and Trend ..... 178
4.13.5. Sources of Expertise ..... 179
4.13.6. Literature Cited ..... 180

Chapter 5: Discussion of Natural Resource Condition Assessment Findings and Considerations for Park Planning ..... 181
5.1. Introduction ..... 181
5.2. Connecting Natural Resource Condition Assessment Findings to Park Purpose, Significance, and Fundamental Resources & Values ..... 181
***5.3. State of the Park* Reporting** ..... 182
5.4. Viewshed Resource Brief and Narrative ..... 185
5.4.1. Noteworthy Highlights ..... 185
5.4.2. Condition Rationale ..... 185
5.4.3. Management and Project Considerations and Narrative ..... 185
5.5. Night Sky Resource Brief and Narrative ..... 190
5.5.1. Condition Rationale ..... 190
5.5.2. Management and Project Considerations and Narrative ..... 190
5.6. Soundscape Resource Brief and Narrative ..... 192
5.6.1. Noteworthy Highlights ..... 192
5.6.2. Condition Rationale ..... 192
5.6.3. Management and Project Considerations and Narrative ..... 192
5.7. Air Quality Resource Brief and Narrative ..... 195
5.7.1. Condition Rationale ..... 195
5.7.2. Management and Project Considerations and Narrative ..... 196
5.8. Geology Resource Brief and Narrative ..... 197
5.8.1. Condition Rationale ..... 197
5.8.2. Management and Project Considerations and Narrative ..... 197
5.9. Surface Water Resource Brief and Narrative ..... 199

# Contents (continued)

Page

5.9.1. Condition Rationale ..... 199
5.9.2. Management and Project Considerations and Narrative ..... 200
5.10. Groundwater Resource Brief and Narrative ..... 201
5.10.1. Condition Rationale ..... 201
5.10.2. Management and Project Considerations and Narrative ..... 201
5.11. Riparian Habitat Resource Brief and Narrative ..... 204
5.11.1. Condition Rationale ..... 204
5.11.2. Management and Project Considerations and Narrative ..... 206
5.12. Grasslands Resource Brief and Narrative ..... 208
5.12.1. Noteworthy Highlights ..... 208
5.12.2. Condition Rationale ..... 208
5.12.3. Management and Project Considerations and Narrative ..... 210
5.13. Exotic Plants Resource Brief and Narrative ..... 211
5.13.1. Noteworthy Highlights ..... 211
5.13.2. Condition Rationale ..... 211
5.13.3. Management and Project Considerations and Narrative ..... 212
5.14. Landbirds Resource Brief and Narrative ..... 213
5.14.1. Noteworthy Highlights: ..... 213
5.14.2. Condition Rationale ..... 213
5.14.3. Management and Project Considerations and Narrative ..... 214
5.15. Prairie Dog Resource Brief and Narrative ..... 215
5.15.1. Noteworthy Highlights ..... 215
5.15.2. Condition Rationale ..... 215
5.15.3. Management and Project Considerations and Narrative ..... 216
5.16. Fish Resource Brief and Narrative ..... 217
5.16.1. Condition Rationale ..... 217
5.16.2. Management and Project Considerations and Narrative ..... 217
5.17. Resource Action Item Summary ..... 219
5.18. Literature Cited ..... 219

Appendix A: Team Members and Subject Matter Experts ..... 223
Appendix B: Viewshed Analysis Steps ..... 225
Appendix C: Bortle Dark-Sky Scale ..... 227
Appendix D: Listening Session Reports ..... 229
Appendix E: Grassland and Soil Assessment - June 3 and 4, 2013 ..... 235
Appendix F: Maps of the Known Distribution of Exotic Plant Species At Bent's Old Fort NHS ..... 239
Appendix G: Additional Exotic Plant Species at Bent's Old Fort NHS ..... 249
Appendix H: Background on Bird Species of Conservation Concern Lists ..... 251
Appendix I: Bent's Old Fort NHS Bird Lists ..... 255

# Figures

Page

Figure 2.1.2-1. Setting of Bent's Old Fort NHS. ..... 6
Figure 2.1.3-1. Average number of visitors to Bent's Old Fort NHS by month, 1979-2013. ..... 6
Figure 2.2.1-1. Bent's Old Fort NHS is within the Anderson Arroyo-Arkansas River watershed of the Upper Arkansas- Lake Meredith subbasin. ..... 7
Figure 3.2.3-1. Condition, trend, and level of confidence key used in the Bent's Old Fort NHS NRCA. ..... 17
Figure 3.2.3-2. An example of a good condition, unchanging trend, and high confidence level in the assessment graphic used in NRCAs. ..... 17
Figure 4.1.1-1. View to the South, from the Southwest Bastion of Bent's Old Fort National Historic Site. ..... 21
Figure 4.1.1-2. One of the values of a viewshed, particularly one with such historic significance, is the potential to visualize that site as it once might have been to gain a "sense of place" in that historic context. ..... 22
Figure 4.1.2-1. The two Fort bastion vantage points used in this assessment . ..... 23
Figure 4.1.2-2. View of the Fort from the Arch. ..... 24
Figure 4.1.2-3. View approaching the Fort from the parking lot. ..... 24
Figure 4.1.2-4. View of the Fort from the surrounding cottonwoods have been enhanced by the removal of Tamarisk. ..... 24
Figure 4.1.2-5. The GigaPan system takes a series of images that are stitched together to create a single panoramic image. ..... 25
Figure 4.1.2-6. An example of approximate distance classes used in this assessment. ..... 26
Figure 4.1.2-7. Graphic illustration of how color (left) and shape (right) can influence whether features are in harmony with the environment, or are in contrast. ..... 27
Figure 4.1.2-8. Conceptual framework for hierarchical relationship of characteristics that influence the conspicuousness of features within a viewshed. ..... 28
Figure 4.1.4-1. Panoramic views in each direction from the Fort bastion vantage points. ..... 30
Figure 4.1.4-2. Views of the Fort from the surrounding area help to maintain the historic context and sense of place ..... 31
Figure 4.1.4-3. Area visible and not visible from the Bent's Old Fort Bastions based on GIS analysis. . 31
Figure 4.1.4-4. The Spanish Peaks can be seen from the Fort's back bastion on clear days. ..... 32
Figure 4.2.1-1. The Leonid meteor shower of 1833 became known as "the night the sky fell" and was an important and formative event in the history of Bent's Fort and relationships with the Cheyenne and Pawnee people. ..... 35
Figure 4.2.2-1. Composite image illustrating the range of night sky conditions based on the Bortle Dark Sky Scale. ..... 37
Figure 4.2.4-1. Artificial brightness in North America and the location of Bent's Old Fort NHS (Cinzano et al. 2001) ..... 40
Figure 4.2.4-2. Panoramic all-sky ALR output at Bent's Old Fort NHS (February 2008) from the NPS Night Skies and Natural Sounds Division. Notice that the Historic Site is relatively dark, but influenced by light domes of nearby towns and cities. ..... 40
Figure 4.3.1-1. Natural sounds, such as the cicada seen here, as well as Bent's Old Fort cultural sounds all contribute to the Historic Site's soundscape ..... 43
Figure 4.3.1-2. A 6 dBA reduction in sound would produce a 4x increase in listening area (NSNSD 2014). ..... 44
Figure 4.3.2-1. On-site listening locations. ..... 45

# Figures (continued)

Page


Figure 4.3.2-2. Appropriate sounds at Bent's Old Fort include the cultural sounds of the historic context, such as the blacksmiths seen here, as well as the natural sounds of the Fort's setting. ..... 47

Figure 4.3.3-1. Designated management zones at Bent's Old Fort NHS. ..... 49

Figure 4.3.4-1. Surrounding developments and land uses that contribute to the noises heard throughout the Historic Site. ..... 51

Figure 4.3.4-2. Sound sources heard and percent time audible at on-site monitoring locations. ..... 52

Figure 4.3.4-3. No sounds were heard from these school groups touring Bent's Old Fort while conducting the on-site listening session along the Nature Trail. ..... 53

Figure 4.3.4-4. Approximate sound levels for sounds heard at the Historic Site (at specified distances), and modeled sound levels for Bent's Old Fort NHS (Mennitt et al. 2013). ..... 54

Figure 4.4.1-1. Bent's Old Fort National Historic Site is a Class II airshed. ..... 57

Figure 4.4.1-2. A cloudy fall day at Bent's Old Fort National Historic Site. ..... 58

Figure 4.4.4-1. Change in wet deposition levels From 1988-2008 throughout the United States. ..... 62

Figure 4.5.1-1. Bent's Old Fort National Historic Site has mostly flat to gently rolling surfaces surrounded at a distance by hogback ridges. ..... 67

Figure 4.5.1-2. The Great Plains Physiographic Province and location of Bent's Old Fort NHS in the Colorado Piedmont section (KellerLynn 2005). ..... 68

Figure 4.5.4-1. Topographic map (1953) of Bent's Old Fort NHS location on the northern edge of the Arkansas River floodplain. Source: USGS Hadley, Colorado, quadrangle 1953, in KellerLynn 2005. ..... 70

Figure 4.6.1-1 Water quality sampling in the Arkansas River along Bent's Old Fort National Historic Site. ..... 75

Figure 4.6.1-2 Bent's Fort is located in the Thompson Arroyo-Arkansas River subwatershed and drains an area of 1,890 square miles. ..... 76

Figure 4.6.1-3 Major surface water features surrounding and located within Bent's Old Fort NHS ..... 76

Figure 4.7.1-1. Flood damage in the Fort's well room at Bent's Old Fort NHS. ..... 89

Figure 4.7.1-2. Overview of the Arkansas River Basin with alluvial aquifers identified in green (http://geosurvey.state.co.us/apps/wateratlas/chapter5_2page1.asp 2003). ..... 90

Figure 4.7.2-1. Groundwater well locations at Bent's Old Fort NHS. ..... 92

Figure 4.8.1-1. Overview of the Arkansas River Basin with alluvial aquifers identified in green. ..... 97

Figure 4.8.1-2. Topographic overview of the Arkansas River Valley and some of the adjacent uplands (USGS quadrangle, Hadley, Colorado 1953). ..... 98

Figure 4.8.1-3. Major surface water features surrounding and located within Bent's Old Fort NHS ..... 99

Figure 4.8.4-1 Annual peak flow record from USGS gage #07123000, Arkansas River at La Junta (USGS 2013). ..... 105

Figure 4.8.4-2. The Arkansas River was near bankfull during the 2013 riparian habitat assessment. 106

Figure 4.9.1-1 . Grassland at Bent's Old Fort NHS. ..... 113

Figure 4.9.1-2. The 13 map classes identified by Stevens et al. (2007) including the six plant alliances used by the National Vegetation Classification (NVC) system. ..... 114

Figure 4.9.1-3. One of the values of grasslands, is the importance that they played in the historic context. The ability for visitors to imagine the historic setting can dramatically add to their sense of place in that historic context. ..... 115

# Figures (continued)

Page

Figure 4.9.1-4. The Palmer Modified Drought Index for each of the four years for which data from Bent's Old Fort NHS were available. Also shown to the right of each map are photos taken from a monitoring transect (LT02_0-50T) for the corresponding time period. ..... 116

Figure 4.9.2-1. Location of Soil Rapid Assessment points and grassland monitoring plots at Bent's Old Fort NHS. ..... 117

Figure 4.9.4-1. Several measures of grassland resource condition can be dramatically influenced by the extreme drought conditions during the time of this assessment. ..... 124

Figure 4.9.4-2. The distribution of soil types based on NRCS (2012), ecological sites based on NRCS (2007) and plant communities based on Stevens et al. (2007). ..... 125

Figure 4.9.4-3. The percentage of native and exotic grasses and forbs for each ecological site samples in 2010-2013 at Bents' Old Fort NHS. ..... 126

Figure 4.9.4-4. The percentage of annual, biennial, and perennial grasses and forbs for each ecological site and each years sampled. ..... 127

Figure 4.9.4-5. The percentage of life forms for each ecological site samples in 2010-2013 at Bent's Old Fort NHS. ..... 128

Figure 4.9.4-6. The percentage of C3 and C4 grasses for each ecological site samples in 2010-2013 at Bent's Old Fort NHS. ..... 129

Figure 4.10.1-1. Cheatgrass (***Bromus tectorum***) can form dense, nearly single-species communities in grasslands. ..... 135

Figure 4.10.2-1. Fifty meter blocks are sampled on each side of a high-risk vector (e.g., roads and trails) ..... 136

Figure 4.10.2-2. Annual high priority blocks sampled in 2010 -2013 and one time rapid assessment Historic Site grid plots sampled in 2013 only. ..... 137

Figure 4.10.2-3. ***Acroptilon repens*** plant density based on surveys conducted by SOPN monitoring efforts and 2013 rapid assessment. ..... 138

Figure 4.10.2-4. ***Bromus tectorum*** plant density based on surveys conducted by SOPN monitoring efforts and 2013 rapid assessment. ..... 138

Figure 4.10.2-5. ***Convolvulus arvensis*** plant density based on surveys conducted by SOPN monitoring efforts and 2013 rapid assessment. ..... 139

Figure 4.10.2-6. ***Tamarix ramosissima*** plant density based on surveys conducted by SOPN monitoring efforts and 2013 rapid assessment. ..... 139

Figure 4.10.2-7. ***Cirsium arvense*** plant density based on surveys conducted by SOPN monitoring efforts and 2013 rapid assessment. ..... 140

Figure 4.10.2-8. ***Kochia scoparia*** plant density based on surveys conducted by SOPN monitoring efforts and 2013 rapid assessment. ..... 140

Figure 4.10.2-9. ***Sorghum halepense*** plant density based on surveys conducted by SOPN monitoring efforts and 2013 rapid assessment. ..... 141

Figure 4.11.1-1 Blue Grosbeak, found in both grassland and riparian habitat at Bent's Old Fort NHS. ..... 149

Figure 4.11.2-1. Bird Conservation Regions in North America. ..... 152

Figure 4.11.2-2. Bird Conservation Regions in the vicinity of Bent's Old Fort NHS. ..... 153

Figure 4.11.2-3. Survey points sampled by the Rocky Mountain Bird Observatory at Bent's Old Fort NHS in 2009-2012 ..... 154

# Figures (continued)

Page


Figure 4.11.2-4. Five IMBCR sampling sites (in yellow; primary data source) and four BBS routes (in purple; secondary data source) used for the regional comparison of landbird species occurrence. ..... 155

Figure 4.12.1-1 Black-tailed Prairie Dog (***Cynomys ludovicianus***), the most abundant and widespread of the prairie dog species. ..... 167

Figure 4.12.1-2 Species that benefit from black-tailed prairie dogs,clockwise from top left: Burrowing Owl (***Athene cunicularia***); Coyote (***Canis latrans***); Ferruginous Hawk (***Buteo regalis***); and American badger (***Taxidea taxus***). ..... 168

Figure 4.12.1-3 Areal coverage of Black-tailed prairie dog colony in 2011, prior to the sylvatic plague event. (Source: annual surveys at the Historic Site.) Digital data from NPS Intermountain Region; collected in 2011 by Kansas State University. ..... 169

Figure 4.13.1-1. The Arkansas River reach where Foutz et al. (2012) conducted fish sampling within the Historic Site..... 177

Figure 5.6.3-1. Sounds from a crackling wood fire enhance the Historic Site's soundscape..... 193

Figure D-1. Existing CONUS soundscape model zoomed to Bent's Old Fort NHS..... 233

Figure D-2. Impact between existing and natural CONUS soundscape models zoomed to Bent's Old Fort NHS. ..... 233

Figure D-3. Natural CONUS soundscape model zoomed to Bent's Old Fort NHS. ..... 234

Figure F-1. Garden Asparagus (*Asparagus officinalis)* ..... 239

Figure F-2. Smooth brome (*Bromus inermis)*..... 239

Figure F-3. Whitetop (*Cardaria draba)* ..... 240

Figure F-4. Common lambsquarters (*Chenopodium album)* ..... 240

Figure F-5. Bermudagrass (*Cynodon dactylon)* ..... 241

Figure F-6. Stinkgrass (*Eragrostis cilianensis)* ..... 241

Figure F-7. Prickly lettuce (*Lactuca serriola)* ..... 242

Figure F-8. Blue Lettuce (*Lactuca tatarica)* ..... 242

Figure F-9. Alfalfa (*Medicago sativa)*..... 243

Figure F-10. Yellow Sweetclover (*Melilotus officinalis)* ..... 243

Figure F-11. Curly dock (*Rumex crispus)* ..... 244

Figure F-12. Prickly Russian thistle (*Salsola tragus)*..... 244

Figure F-13. Dandelion (*Taraxacum officinale)* ..... 245

Figure F-14. Intermediate Wheatgrass (*Thinopyrum intermedium)*..... 245

Figure F-15. Rush Wheatgrass (*Thinopyrum ponticum)* ..... 246

Figure F-16. Western Salsify (*Tragopogon dubius)* ..... 246

Figure F-17. Puncturevine (*Tribulus terrestris)*..... 247

Figure F-18. Narrowleaf Cattail (*Typha angustifolia)* ..... 247

Figure F-19. Siberian Elm (*Ulmus pumila)*..... 248

# Tables

Page


Table 3.2.1-1. Bent's Old Fort NHS Natural Resource Condition Assessment Framework....15

Table 4-1. Page numbers where the description, methods, and condition for each indicator(s) are presented within this chapter. ....19

Table 4.1.2-1. Indicators and measures of viewshed and why these are important to the resource condition. ....22

Table 4.1.2-2. Characteristics that influence how less conspicuous human-made features are within a viewshed and the general effect. ....25

Table 4.1.2-3. A matrix describing the six size classes used for visible human-made features. ....27

Table 4.1.3-1. Qualitative reference condition classes used for scenic and historic integrity within the viewshed at Bent's Old Fort NHS. ....29

Table 4.1.4-1. Indicator and measures of viewshed condition, their corresponding assigned condition class, and the rationale for assigning condition class. ....29

Table 4.2.2-1. Indicators and measures of the night sky and why they are important to resource condition. ....36

Table 4.2.2-2. Bortle Dark Sky Scale.* ....38

Table 4.2.3-1. Night sky condition class summary. ....39

Table 4.2.4-1. Summary of night sky indicators and measures and assessment of night sky condition at Bent's Old Fort National Historic Site. ....41

Table 4.3.2-1. Summary of on-site listening sessions at Bent's Old Fort NHS. ....45

Table 4.3.2-2. Indicators and measures used to assess the soundscape at Bent's Old Fort NHS. ....46

Table 4.3.2-3. Types of sounds expected at Bent's Old Fort NHS. ....48

Table 4.3.3-1. Activities and associated sounds expected within each management zone (NPS 1994b) that influence the reference condition within that zone. ....50

Table 4.3.3-2. Reference conditions used to assess soundscape condition at Bent's Old Fort NHS. ....50

Table 4.3.4-1. Summary of the soundscape indicators/measures and their contribution to the overall soundscape condition assessment. ....55

Table 4.4.3-1. Reference conditions for air quality indicators. ....60

Table 4.4.4-1. Condition results for air quality indicators at Bent's Old Fort NHS. ....61

Table 4.4.4-2. Ozone sensitive plants found at Bent's Old Fort NHS (NPS-ARD 2006). ....61

Table 4.4.4-3. Summary of the air quality indicators/measures and their contributions to the overall air quality Natural Resource Condition Assessment. ....63

Table 4.5.3-1. Qualitative description for determining condition of geologic resources. ....69

Table 4.5.4-1. Indicator, measure, and rationale of geology condition. ....73

Table 4.6.2-1. Core water quality results from discrete sampling at Bent's Old Fort NHS ....78

Table 4.6.2-2. Core water quality results from continuous sampling from 10/08/2012 – 10/23/2012 ....78

Table 4.6.2-3. Core water quality results from continuous sampling from 4/24/2013 – 5/07/2013. ....78

Table 4.6.2-4. Alkalinity results from sampling at Bent's Old Fort NHS ....79

Table 4.6.2-5. Metals results from sampling at Bent's Old Fort NHS ....79

Table 4.6.2-6. Primary nutrient results from sampling at Bent's Old Fort NHS. ....80

Table 4.6.2-7. Biological condition results from sampling at Bent's Old Fort NHS ....80

# Tables (continued)

Page


Table 4.6.2-8. Emerging contaminant results from discrete sampling at Bent's Old Fort NHS 10/07/2012. ..... 80

Table 4.6.3-1. Core water quality reference conditions ..... 81

Table 4.6.3-2. Reference conditions for metals ..... 81

Table 4.6.4-1. Summary of the surface water quality indicators and their contributions to the overall condition at Bent's Old Fort NHS. ..... 84

Table 4.6.4-2. Arkansas River 303(d) history report summaries for the area including Bent's Old Fort NHS (EPA 2013). ..... 84

Table 4.7.3-1. Reference condition classes for assessing groundwater condition from an ecological condition, however, there is concern for flooding of historic structures at Bent's Old Fort National Historic Site. ..... 93

Table 4.7.4-1. Indicator, measure, and rationale of groundwater condition. ..... 95

Table 4.8.3-1. The reference conditions used to determine whether the condition of the riparian habitat at Bent's Old Fort NHS is good, moderate, or of significant concern as adapted from Prichard et al. 1998. ..... 103

Table 4.8.4-1. Results for the riparian wetland condition assessment at Bent's Old Fort NHS (Wagner and Martin 2014-Appendix). ..... 104

Table 4.8.4-2. Summary of the riparian habitat indicators/measures categories and their contributions to the overall riparian habitat resource condition assessment ..... 110

Table 4.9.1-1. The eight different National Vegetation Classification (NVC) plant associations identified by the Colorado Natural Heritage Program and their corresponding area occupied. ..... 115

Table 4.9.2-1. Indicators and measures used to assess grasslands at Bent's Old Fort NHS. ..... 119

Table 4.9.3-1. Reference conditions for soil/site stability/hydrologic function measures. ..... 121

Table 4.9.3-2. Reference conditions used to assess the current condition for measures of grassland biotic integrity. ..... 122

Table 4.9.4-1. The assessment of measures used to assess soil/site stability/hydrologic function at each of six rapid-assessment points at Bent's Old Fort NHS. ..... 123

Table 4.9.4-2. The number and percentage of native and exotic species of each life form found on Bent's Old Fort NHS during the 2010-2012 grassland monitoring sampling. ..... 124

Table 4.9.4-3. The number and percentage of perennial grass and forb species observed at each ecological site on Bent's Old Fort NHS during the 2010-2013 grassland monitoring sampling. ..... 127

Table 4.9.4-4. The number and percentage cover of each life form observed at each ecological site on Bent's Old Fort NHS during the 2010-2013 grassland monitoring sampling. ..... 128

Table 4.9.4-5. Summary of the grassland indicators and measures and their contributions to the overall assessment of grassland condition ..... 131

Table 4.10.2-1. Number and percentage of exotic plant species detected in SOPN high priority monitoring blocks sampled in 2011 - 2013 at Bent's Old Fort NHS ..... 137

Table 4.10.2-2. Number and percentage of exotic plant species detected throughout the Historic Site grid plots sampled in 2013. ..... 141

Table 4.10.2-3. Ecological impact rank and management difficulty rank according to NatureServe (2013). ..... 142

Table 4.10.4-1. Exotic species found within Bent's Old Fort National Historic Site that are considered to have the most impact to native habitats throughout the Historic Site based upon combined measures. ..... 144

# Tables (continued)

Page

Table 4.10.4-2. Indicator, measures, and their contributions to the overall exotic plants condition rationale. ..... 145

Table 4.11.2-1. Breeding habitat classes assigned to each species that has been reported to occur at Bent's Old Fort NHS and is within or near its reported breeding range. ..... 151

Table 4.11.2-2. Classes assigned to species of concern regarding the potential for Bent's Old Fort NHS to play a role in their conservation. ..... 151

Table 4.11.3-1. Reference conditions used to assess the current condition of breeding landbird species occurrence in temporal and spatial contexts. ..... 156

Table 4.11.4-1 Species reported in 2001 and/or 2002 by CNHP (Gionfriddo et al. 2002, Gionfriddo and Stevens 2003) at Bent's Old Fort NHS that were not observed during the 2009-2012 RMBO surveys. Also shown is the range status based on Birds of North America species accounts, and breeding habitat class for birds within (or within 100 miles of) their normal breeding range. ..... 157

Table 4.11.4-2 Birds species detected in 2008-2012 IMBCR regional surveys by RMBO in the vicinity of Bent's Old Fort NHS that were not detected at the Historic Site during the 2009-2012 RMBO point-count surveys. Species that were detected during surveys by CNHP in 2001 and/or 2002 are noted (with a "1"). ..... 158

Table 4.11.4-3. Summary of species detected during 2009-2012 RMBO surveys (or 2001/2002 inventories only*) (excluding the exotic Ring-necked Pheasant) at Bent's Old Fort NHS of conservation concern, as listed by government agencies and non-governmental organizations. ..... 160

Table 4.11.4-4. Species detected at Bent's Old Fort NHS during 2009-2012 surveys (and/or 2001 or 2002 CNHP inventories) that have also been identified as species of concern on one or more watch list. Species are organized by whether they have high, moderate, or low potential for the Historic Site to contribute to their conservation. ..... 162

Table 4.11.4-5. The number of individuals of species with highest conservation potential detected at Bent's Old Fort NHS during recent RMBO surveys. ..... 163

Table 4.11.4-6. Summary of the breeding landbirds indicator/measures and their contributions to the overall landbirds condition. ..... 163

Table 4.12.4-1. Area occupied, estimated densities, and number of burrows of black-tailed prairie dogs at Bent's Old Fort NHS from various studies and surveys. ..... 172

Table 4.12.4-2. Indicators and measures of black-tailed prairie dog condition, their corresponding assigned condition class(es), and the rationale for assigning the condition class(es). 173

Table 4.13.2-1. Fish species detected during inventories. ..... 178

Table 4.13.4-1. Indicator and measure of fish condition ..... 179

Table 5.2-1. Summary of natural resource topic relevance (denoted by black dots) as it relates to Bent's Old Fort National Historic Site's purpose, significance, and fundamental resources and values as identified in NPS (2013). ..... 182

Table 5.3-1 *State of the Park* Natural Resource Summary Table ..... 183

Table 5.4.2-1. Summary of overall viewshed condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site. ..... 185

Table 5.5.1-1. Summary of overall night sky condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site. ..... 190

Table 5.6.2-1. Summary of overall soundscape condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site. ..... 193

Table 5.7.1-1. Summary of overall air quality condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site. ..... 195

# Tables (continued)

Page

Table 5.8.1-1. Summary of overall geology condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site. ..... 197

Table 5.9.1-1. Summary of overall surface water quality condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site. ..... 199

Table 5.10.1-1. Summary of overall groundwater condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site. ..... 201

Table 5.11.1-1. Summary of overall riparian habitat condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site. ..... 204

Table 5.12.2-1. Summary of overall grasslands condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site. ..... 208

Table 5.13.2-1. Summary of overall exotic plants condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site. ..... 211

Table 5.14.2-1. Summary of overall landbirds condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site. ..... 213

Table 5.15.2-1. Summary of overall prairie dog condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site. ..... 215

Table 5.16.1-1. Summary of overall fish condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site. ..... 217

Table 5.17.1-1. Summary of action items for each resource ..... 219

Table A.1. Bent's Old Fort National Historic Site NRCA Project Team Members ..... 223

Table A.2. Bent's Old Fort NHS NRCA Subject Matter Experts ..... 223

# Executive Summary

The Natural Resource Condition Assessment (NRCA) Program, administered by National Park Service's (NPS) Water Resources Division, aims to provide documentation about current conditions of important park natural resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. The NRCA for Bent's Old Fort National Historic Site began in 2013, and 13 focal study natural resources were chosen for the Historic Site's NRCA. These resources were organized into three categories that ranged in contexts from broader to narrower including landscape-scale, supporting environment (i.e., physical resources), and biological integrity, which included wildlife and vegetation topics.

Bent's Old Fort NHS was established on June 3, 1960 ([Public Law 86-487]). The Historic Site was set aside by Congress to commemorate the historic role this trading post played in the opening of the West. As identified in the parks recently completed Foundation document the park's purpose is to develop, maintain and preserve the National Historic Site for visitor education and enjoyment; and interpret the significance of the Santa Fe Trail and the impact it had on the U.S., Mexico and Southern Plains tribes.

The landscape scale resources chosen for this assessment included viewshed, night sky, and soundscape. Overall, these resources are in moderate condition. The area surrounding the Historic Site is rural to moderately developed, contributing to issues impacting these resources including road and housing developments as well as train and overflight traffic.

The Historic Site's supporting physical environment resource topics included air quality, geology, surface water quality, and groundwater. The condition for each of these topics ranged between good, moderate, and significant concern.

The resource topics related to vegetation include grasslands, riparian habitat, and exotic plants. The riparian habitat is considered to be in good condition, whereas exotic plants and grasslands are in moderate condition. However, the Historic Site's prairie restoration efforts have contributed to an improving trend for grassland condition.

Finally, the wildlife resource topics included breeding landbirds, prairie dogs, and fish. Condition for landbirds is good. In early 2010 the sylvatic plague decimated the prairie dog colony in and adjacent to the Historic Site. Data gaps exist for the fish resource at the Historic Site.

# Acknowledgements

We wish to thank Jeff Albright, program lead of the Natural Resource Condition Assessment Program, Water Resources Program Center, National Park Service, who provided programmatic insight and guidance on project development and review and Donna Shorrock, Intermountain Region Natural Resource Condition Assessment Coordinator for her guidance and review. The authors are grateful to the staff at the National Park Service Natural Resource Stewardship and Science Directorate for their technical expertise, guidance, and reviews of their respective subjects, with a special thanks to Michael Martin for researching and writing the groundwater section. We are extremely grateful to all subject matter experts who provided valuable information pertaining to their respective areas of research and expertise. Their input helped to create a relevant, scientifically based document that provided new insights into the communities and processes found and occurring throughout the Historic Site. Finally, we would like to express our gratitude and thanks to Bent's Old Fort and Sand Creek Massacre NHS staffs, whose input and reviews were very informative and helpful. To all those remaining who reviewed and commented on this report, thank you. Your contributions have increased its professional value.


NPS

# Chapter 1: NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement — not replace — traditional issue- and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- are multi-disciplinary in scope;[1]
- employ hierarchical indicator frameworks;[2]
- identify or develop reference conditions/values for comparison against current conditions;[3]
- emphasize spatial evaluation of conditions and GIS (map) products;[4]
- summarize key findings by park areas; and[5]
- follow national NRCA guidelines and standards for study design and reporting products.

**NRCAs Strive to Provide…**

- Credible condition reporting for a subset of important park natural resources and indicators
- Useful condition summaries by broader resource categories or topics, and by park areas

1. The breadth of natural resources and number/type of indicators evaluated will vary by park.
2. Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures [ conditions for indicators ] condition summaries by broader topics and park areas
3. NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers").
4. As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.
5. In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

### Important NRCA Success Factors

- Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline
- Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures / indicators) broader resource topics, and park areas
- Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.

Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators;



NPS

**A NRCA is intended to provide useful science-based information products in support of all levels of park planning.**

recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions, but in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decision making, planning, and partnership activities.

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What a NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

**NRCA Reporting Products…**

- Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:
- Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations (near-term operational planning and management)
- Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values (longer-term strategic planning)
- Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public ("resource condition status" reporting)

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference

6. An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

7. While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

8. The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.



NPS

**A NRCA uses a variety of data to assess the condition of a park's natural resources.**

conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

Over the next several years, the NPS plans to fund a NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information on the NRCA program, visit http://www.nature.nps.gov/water/nrca/.


NPS

**Encampment at Bent's Old Fort National Historic Site, located in the Plains cottonwood gallery.**

# Chapter 2: Introduction and Resource Setting

## 2.1. Introduction

### *2.1.1. Enabling Legislation/Executive Orders*

Bent's Old Fort National Historic Site was established on June 3, 1960 under Public Law 86-487. The purpose of the Historic Site is to:

- Commemorate the historic role this trading post played in the opening of the West.
- Develop, maintain and preserve the national historic site for visitor education and enjoyment.
- Interpret the significance of the Santa Fe Trail and the impact it had on the U.S., Mexico and Southern Plains tribes (NPS 2012).

*"For much of its 16-year history, the Fort was the only major permanent settlement on the Santa Fe Trail between Missouri and Santa Fe. William and Charles Bent, along with Ceran St. Vrain, built the original adobe fort in 1833 to trade for buffalo robes with the Southern Cheyenne and Arapaho Indians. The fort became the center of the Bent, St. Vrain Company's expanding trade empire that included Fort St. Vrain to the north and Fort Adobe to the south, along with company stores in Mexico, Taos and Santa Fe. Situated along the Mountain Branch of the Santa Fe Trail, the fort provided explorers, adventurers, and the U.S. Army a place to get needed supplies, wagon repairs, livestock, good food, water and company, rest and protection in this vast "Great American Desert." During the war with Mexico in 1846, the fort became a staging area for Colonel Stephen Watts Kearny's "Army of the West". Disasters and disease caused the fort's abandonment in 1849.*

*Today, Bent's Old Fort National Historic Site features a reconstructed version of the 1840's adobe fur trading post. Archeological excavations and original sketches, paintings and diaries were used to replicate the features of the Fort, which was reconstructed during the country's bicentennial and the state's centennial in 1976. Living history programs recreate the sights, sounds, and smells of the past with guided tours, demonstrations and special events" (NPS 2012).*

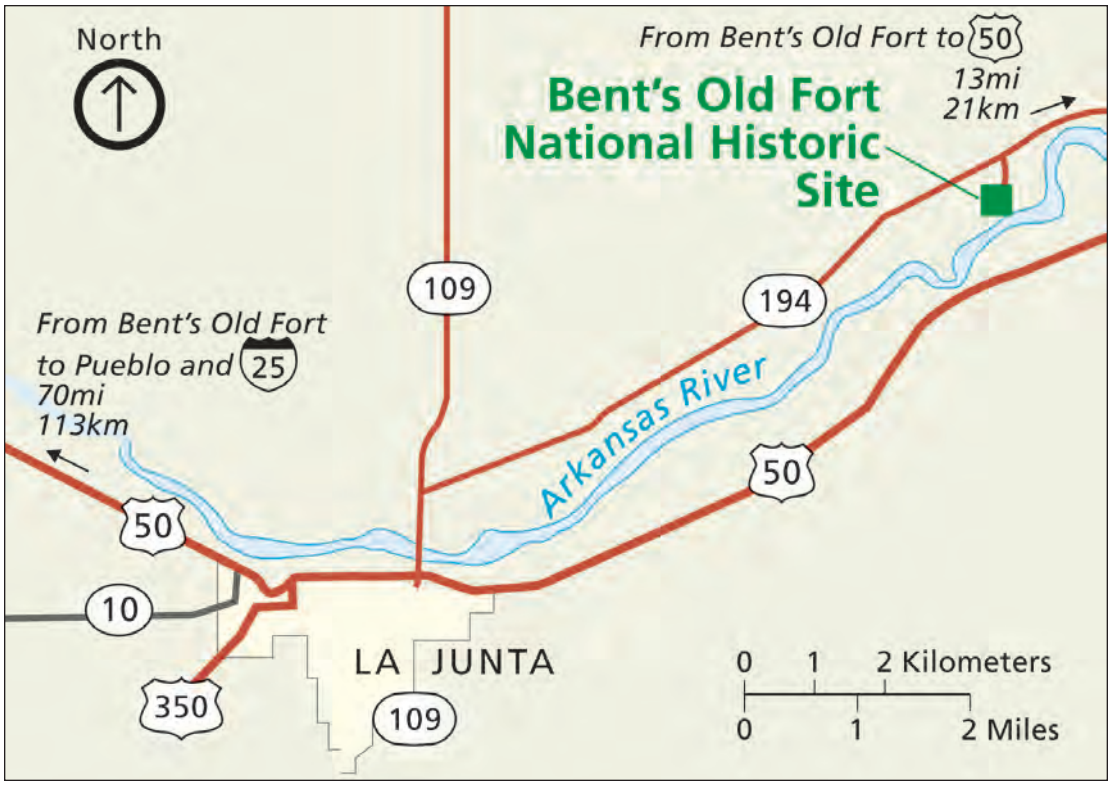



**Figure 2.1.2-1. Setting of Bent's Old Fort NHS.**

### *2.1.2. Geographic Setting*

Bent's Old Fort National Historic Site contains 800 acres (324 hectares). The Historic Site is located along the Mountain Route of the Santa Fe Trail in Otero County in southeastern Colorado. It is 8 miles northeast of La Junta, Colorado on State Highway 194 and 75 miles southeast of Pueblo, Colorado. (Figure 2.1.2-1). The Arkansas River runs though and bisects the Historic Site, and shortgrass prairie and riparian habitat along the river characterize the landscape. The Historic Site is located on the western edge of the Great Plains shortgrass prairie at an elevation of 4,035 feet (1,230 meters). This area is short grass prairie, classified as the Kuchler Vegetation Type, as grama and buffalo grasses predominate on the high benches. The river bottoms encompass mixed grasses, riparian, and wetland plant species (NPS 2013).

### *2.1.3. Visitation Statistics*

Monthly visitation data for Bent's Old Fort NHS are available for 1979-2012, although annual visitation data date back to 1964. The total number of visitors each year ranged from 15,700 (in 1964) to 109,300 (in 1975). The number of visitors in 2013 was 23,324. Visitation data by month are available for 1979-2013. Although there has been substantial monthly variation by year, the months receiving the greatest average number of visitors over the recording period were May, June, July, and August (Figure 2.1.3-1) (NPS Public Use Statistics Office 2014).

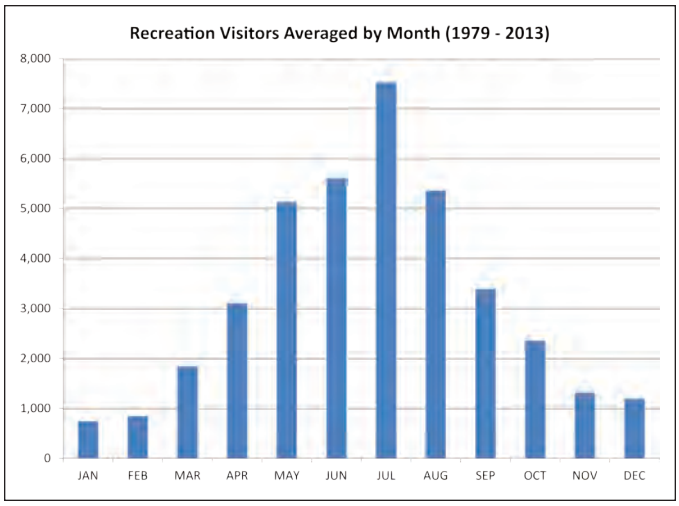



**Figure 2.1.3-1. Average number of visitors to Bent's Old Fort NHS by month, 1979-2013.**

## 2.2. Natural Resources

A summary of the natural resources at Bent's Old Fort NHS

is presented in this section and represents information known prior to the completion of this condition assessment. New data were gathered and compiled throughout this assessment process as a result of meetings, consultations, and literature reviews pertaining to each natural resource topic. Therefore, some of the information presented in section 2.2 may have been included in subsequent chapters or omitted depending upon new findings.

### 2.2.1. Ecological Units and Watersheds

Bent's Old Fort NHS falls within the Great Plains-Palouse Dry Steppe and the short-grass prairie ecoregion. Annual precipitation averages between 11 and 15 inches, of which roughly 70 percent falls during April through August and about 10 percent falls during November through February (USDI NPS 2008).

Excerpted from Vana-Miller et al. 2010

*The NHS is in the Upper Arkansas Lake Meredith watershed (HUC 1102000, as defined by the U.S. Geological Survey; Figure 12). In this case 'Upper Arkansas' refers to the upper part of the overall Arkansas River watershed. Within this watershed there are approximately 1,413,670 acres of land utilized for farming or ranching. The population of this watershed is slightly greater than 100,000.*(Figure 2.2.1-1).




**Figure 2.2.1-1. Bent's Old Fort NHS is within the Anderson Arroyo-Arkansas River watershed of the Upper Arkansas-Lake Meredith subbasin.**

### 2.2.2. Resource Descriptions

(Italicized text in the following section are excerpts from resource descriptions in Stevens et al. 2007, describing some key resources of the Historic Site.)

Topography

*The topography of the Historic Site site is dominated by the hydro-geomorphic influence of the Arkansas River and nearby tributaries. It is located on the banks of the Arkansas River and includes area of active floodplain and a series of stepped river terraces. The alluvial plain is about a mile wide at the park and is marked by a river bluff to the north, and low hills to the south. The Fort itself is located within the 100-year floodplain on a low terrace north of the river (NPS 2007).*

Geology

*The Historic Site is within the Colorado Piedmont section of the Great Plains Physiographic province (Fenneman and Johnson 1946 as cited in Stevens et al. 2007). The surficial geology of the site consists of sedimentary deposits ranging in age from the Late Jurassic (Morrison Formation) to Recent Quaternary alluvial and aeolian deposits. The Arkansas River channel and alluvial plain are the central geomorphic features at the park. The river meanders widely throughout this stretch, with a grade of 5 feet per mile (KellerLynn 2005). An investigation on the movement of the main channel revealed that the meanders have migrated downstream little since the construction of the Fort (KellerLynn 2005). However, beginning in the late 1930's the river has become more braided in character, with more sandbars and islands. It is believed that this change has taken place due to increased drawdown in the dry summer months for irrigation (KellerLynn 2005). The National Park Service has investigated the geology of the site and produced a detailed study of its characteristics (KellerLynn 2005).*

Soils

*The soils at the Historic Site belong to the Rocky Ford – Numa – Kornman soil association, a type which occupies much of the Arkansas River valley in Otero County (SCS 1972).*

*They originate from a combination of alluvial and aeolian deposition. Bankard Sand occurs nearest to the river, where it has been deposited by flood waters. This sand is excessively drained and has low fertility, supporting cottonwoods, willows and tamarisk. Some areas of the floodplain have salt deposits from intermittent flooding. On the first terrace and to the north of the Fort, the soils include fertile loams which have been utilized for agriculture. The other soils present in the Park include Glenberg-Bankard sandy loam, Rocky Ford silty clay loam, Bloom loam, and Las Animas soils (SCS 1972).*

Hydrology

*The Arkansas River has dams and diversions along most of its length, the majority of which are concentrated in Oklahoma. Seventy-five miles upstream from the park is the Pueblo dam and reservoir west of Pueblo, Colorado. The John Martin Reservoir begins about 20 miles downstream from the Historic Site. The Fort Lyon Canal, which is used for irrigation, diverts water near La Junta, and runs parallel to the river in the broad alluvial plain. At the park, the canal is roughly a mile north of the river. Fountain Creek, a tributary of the Arkansas River entering downstream from Pueblo, drains south from Colorado Springs. Urban runoff from this area has had high levels of Escherichia coli bacteria from untreated sewage. Urban development in a watershed also can affect the hydrograph of a stream by increasing the intensity and speed with which runoff occurs. A concentrated area of impervious surfaces effectively funnels precipitation out of the city as fast as possible. This makes the peak flow of a river both larger in magnitude and shorter in duration.*

*Floods along this stretch of the Arkansas River often happen due to a combination of snowmelt and spring rainstorms. This was the case in June of 1921, when heavy rains in the upper watershed contributed to the largest flood ever recorded in Pueblo. This flood washed away part of the ruins of the old Fort at the park. Other regionally significant flood events occurred in 1935, 1942, 1955 and 1965. Park personnel reported high waters during the summers of 1995 and 1999. During both of these years the water level reached the second bench of the floodplain.*

*The groundwater along the floodplain of the Arkansas River is commonly within 10 feet of the land surface, and it has been measured at 11 and 13 feet below the surface in the vicinity of the Fort (KellerLynn 2005). It is thought that seepage from the Fort Lyon Canal contributes to the level of the water table in the vicinity of the Fort (KellerLynn 2005). Water diversion into the Canal may also contribute to daily fluctuations in the river level at the Historic Site.*

*According to USGS gage data (1974 to 2005), the discharge of the Arkansas River at gage number 07123000 at La Junta (8 miles upstream) has been highest in the early summer months, with peak discharge occurring between May and July. The average monthly discharge from La Junta for June during this time period is 842 cubic feet per second. During the flood of 1921, peak discharge reached 200,000 cubic feet per second (USGS 2007).*

Air Quality

Bent's Old Fort NHS is designated as a Class II air quality area. No on-site monitoring or air quality monitoring stations within the required distances to be representative of Historic Site conditions exist, therefore, air quality trends cannot be determined.

Wildlife

*Common mammal species at the Historic Site include white-tailed deer (Odocoileus virginianus), mule deer (Odocoileus virginianus), raccoons (Procyon lotor), coyotes (Canis latrans), black-tailed prairie dogs (Cynomys ludovicianus), and many small mammals (Gionfriddo et al. 2002). Also, the park is home to numerous reptiles, amphibians and fish.*

*The Historic Site's bird list contains 99 documented species, roughly half of which are known to breed at the site.. Common bird species include Red-tailed Hawks, Wild Turkeys, Mallards, Great Blue Herons, and Great Horned Owls, to name a few. The Colorado Field Ornithologists website lists Bent's Old*

*Fort as having the "marsh where Black Rail was first found in the state" (CFO 2007).*

Fish (excerpted from Vana-Miller et al. 2010)

*Two fish surveys have been performed within the NHS in 2001 (Gionfriddo et al. 2002) and 2005 (Tisdale-Hein 2006). Based on these studies, 13 species of fish have been collected thus far in NHS waters. Gionfriddo et al. sampled via dip nets, seines and direct observation; however, sampling of fishes occurred only at the Day Pond and Arch Wetland. Because of the limited, sampling only four species of fish were collected. The only fish species of concern present at BEOL is the flathead chub. It is not known how abundant the flathead chub population is in the vicinity of the park. Tisdale-Hein collected a total of 12 species of fish; nine species from the Arkansas River and three species from the Arch wetland.*

Vegetation

*The vegetation at the Historic Site is typical for the lower Arkansas River valley, and is influenced by several natural and anthropogenic processes. The Arkansas River has a direct effect on the vegetation of much of the site through the level of the water table, the shape of the channel and floodplain, and periodic flooding. The lower Arkansas River has been impacted by the activities of humans in many ways, and this has probably influenced the ecology of the region. Alterations in hydrology, the introduction of non-native species, and changes in land use, such as grazing and cultivation all have noticeable effects at Bent's Old Fort.*

*In the park, the banks of the river are lined with narrow bands of coyote willow (Salix exigua). The rest of the floodplain supports plains cottonwood (Populus deltoides) gallery forests with an understory of inland saltgrass (Distichlis spicata) and alkali sacaton (Sporobolus airoides). In some areas, the cottonwoods are sparse and grade into meadows composed of these grasses. Along the terraces, the vegetation transitions to shortgrass prairie. North of the Fort, alfalfa fields have ceased to be irrigated and have been seeded with native grasses with the intention of restoring the fields to native shortgrass prairie. These areas are now dominated by buffalograss (Buchloe dactyloides) and grama grass (Bouteloua gracilis). Sand sagebrush (Artemisia filifolia) shrublands cover the high ground on the south side of the river. The southeast corner of the park supported a large black-tailed prairie dog colony until the winter of 2011-2012. In this area the vegetation is dominated by bindweed (Convolvulus arvensis).*

*The Arch Wetland is a 55-acre [54.7 acres] perennial natural wetland dominated by cattails (Typha latifolia). It is located to the northeast of the Fort and is likely fed in part by irrigation water seeping from the Fort Lyon Canal (Gionfriddo et al. 2002). Several smaller wetlands exist along the floodplain, and are either old gravel pits or abandoned river sloughs which likely flood during high water events.*

*The lower Arkansas River basin widely supports tamarisk (Tamarix ramosissima), a non-native invasive tree. Efforts have been taken to eradicate this species within the park property boundary. In March of 2002, more than 500 acres of land, including the areas cleared of tamarisk, burned in a fire caused by high winds sparking an agricultural ditch burn that occurred several days earlier. Annual weeds, including Russian thistle (Salsola spp.) and kochia (Kochia scoparia), form dense patches in these recently disturbed areas. Along*



NPS

**Alkali sacaton (*Sporobolus airoides*) at the Historic Site.**

*the plains cottonwood gallery forest, many of the mature cottonwoods were killed in the fire and are now resprouting.*

Night Sky and Soundscape

A formal night sky study was conducted at the Historic Site in 2008 by the Natural Sounds and Night Skies Division. Results showed a Bortle Dark-Sky Class of 4, which is considered to be a rural to suburban transition night sky. No soundscape study has been conducted at the Historic Site. Activities on land surrounding the Historic Site (e.g., highway traffic, local development and operations) have the potential to influence the condition of the landscape-scale resources.

### *2.2.3. Resource Issues Overview*

The natural environment and availability of resources has impacted the lifestyles of humans who have used the area for the past thousands of years. The site and surrounding area have been affected by hunting, grazing, cultivation, water diversion, development, introduction of non-native species, and extirpation (local extinction) of native species such as bison. The spread of exotic plant species, alterations in the vegetation community resulting from climate change, changing hydrologic patterns, disease, natural disturbance (e.g., fire and flooding), and succession all are likely to influence the wildlife and vegetation communities of the Historic Site. Bent's Old Fort NHS is a small national park and, even though it is protected, land cover and land use changes around the Historic Site and in the region would be expected to influence the various species found in the Historic Site and impact the Arkansas River. Water resources also face numerous and varied threats, including impacts from climate change, atmospheric deposition, altered hydrology, acid mine drainage, agriculture, pollution from boats, non-native species, erosion, improper sewage plant or drain field operations, and storm water runoff, and the Arkansas River is no exception to these potential threats.

## 2.3. Resource Stewardship

### *2.3.1. Management Directives and Planning Guidance*

In addition to NPS staff recommendations, the Washington (WASO) level programs guided the selection of key natural resources for this condition assessment. This included Southern Plains Inventory and Monitoring Network (SOPN) Program, Air Resources Division for air quality, Water Resources Division for riparian habitat, and the Natural Sounds and Night Skies Program for the soundscape and night sky sections. In addition, NPScape data, developed by the Inventory & Monitoring's Washington Office, were used in the viewshed analysis.

SOPN Program

In an effort to improve overall national park management through expanded use of scientific knowledge, the Inventory & Monitoring (I&M) Program was established to collect, organize, and provide natural resource data as well as information derived from data through analysis, synthesis, and modeling (NPS 2011). The primary goals of the I&M Program are to:

- inventory the natural resources under NPS stewardship to determine their nature and status;
- monitor park ecosystems to better understand their dynamic nature and condition and to provide reference points for comparisons with other altered environments;
- establish natural resource inventory and monitoring as a standard practice throughout the National Park System that transcends traditional program, activity, and funding boundaries;
- integrate natural resource inventory and monitoring information into NPS planning, management, and decision making; and
- share NPS accomplishments and information with other natural resource organizations and form partnerships for attaining common goals and objectives (NPS 2011).

To facilitate this effort, 270 parks with significant natural resources were organized into 32 regional networks. Bent's Old Fort is part of the SOPN, which also includes ten additional parks. Through a rigorous

multi-year, interdisciplinary scoping process, each network selected a number of important physical, chemical, and/or biological elements and processes for long-term monitoring. These ecosystem elements and processes are referred to as 'vital signs', and their respective monitoring programs are intended to provide high-quality, long-term information on the status and trends of those resources. For the SOPN, notable core vital signs were identified. Inventories on a wide variety of natural resource topics have been completed, and long-term monitoring programs are currently underway.

Resource Stewardship Strategy

National Parks are encouraged to develop a Resource Stewardship Strategy (RSS) as part of the park management planning process. Indicators of resource condition, both natural and cultural, are selected by the park. After each indicator is chosen, a target value is determined and the current condition is compared to the desired condition. An RSS has not yet been started for the Historic Site. The NRCA will provide valuable information for the RSS process. Management plans may then be developed based upon information from the RSS and NRCA to outline actions to be taken over the next 15 to 20 years that will help achieve or maintain the desired condition(s) for each indicator.

### *2.3.2. Status of Supporting Science*

Available data and reports varied significantly depending upon the resource topic. The existing data used for each indicator to assess condition or to develop reference conditions are described in each indicator summary in Chapter 4. Part of SOPN's mission is to collect, manage, analyze, and report long term ecological data to support each park in determining the status, condition, and trend of important natural resources (USDI NPS 2008). In addition to data from the SOPN Program and research by other scientists and programs, subject matter experts provided significant information pertaining to riparian habitat, grassland ecology, and exotic plants. Washington level programs, including night sky, soundscape, riparian habitat, and air quality also provided a wealth of information for this NRCA.

## 2.4. Literature Cited

CFO. 2007. Colorado Field Ornithologists (CFO) website. Birding by County, Otero County. Online (http://www.coloradocountybirding.com/county/bird_a_county.php?name=Otero) Accessed 25 January 2007.

Gionfriddo, J.P., D. Culver, and J. Stevens. 2002. Biological Survey of Bent's Old Fort National Historic Site, Otero County, Colorado. Report submitted to the National Park Service by the Colorado Natural Heritage Program. Fort Collins, Colorado.

KellerLynn. 2005. Bent's Old Fort National Historic Site Geologic Resource Evaluation Report NPS D-74. United States Department of Interior, National Park Service, Geologic Resources Division. Denver, Colorado.

NPS. 2007. Bent's Old Fort National Historic Site website. United States Department of Interior, National Park Service (NPS). Online (http://www.nps.gov/beol/). Accessed 24 January 2007.

National Park Service. 2011. Program brief: Inventory and monitoring program. U.S. Department of the Interior, National Park Service, Natural Resource Program Center, Inventory and Monitoring Division, Fort Collins, Colorado.

National Park Service (NPS). 2013. Foundation Document: Bent's Old Fort National Historic Site. National Park Service, Denver, Colorado. 40pp.

National Park Service. 2013. Bent's Old Fort nature and science. Available at http://www.nps.gov/beol/naturescience/index.htm (accessed May 6, 2013).

National Park Service Public Use Statistics Office. 2013. NPS visitor use statistics. Annual park visitation (all years) and visitation by month and year. Available at https://irma.nps.gov/Stats/Reports/ReportList (accessed May 19, 2014).

SCS. 1972, Soil survey of Otero County, Colorado. United States Department of Agriculture. Soil Conservation Service. Washington D.C.

Stevens, J.E., K. Forrest, S. Neid, and M. Fink. 2007. Bent's Old Fort National Historic Site: Vegetation Classification and Mapping. Natural Resource Technical Report NPS/SOPN/NRTR—2007/049. National Park Service, Fort Collins, Colorado. Tisdale-Hein, Rinda E. 2006. Survey of fish and plant species in Arch Wetland and Arkansas River at Bent's Old National Historic Site. Unpublished Report. Bent's Old Fort National Historic Site, La Junta, CO.

U.S.D.I. National Park Service, Southern Plains Inventory and Monitoring Network. 2008. Southern Plains Network Vital Signs Monitoring Plan. Natural Resource Report NPS/SOPN/ NRR-2008/028. National Park Service, Fort Collins, Colorado.

USGS. 2007. United States Geological Survey Water Resources Website. Peak stream flows for Colorado, USGS gage 07123000 Arkansas River at La Junta, CO. Online (http://nwis.waterdata.usgs.gov/co/nwis/peak?site_no=07123000&agency_cd=USGS&format=gif). Accessed 25 January 2007.

Vana-Miller, D., C. Moore, J. Hughes and K. Noon. 2010. Water resources information and issues overview report: Bent's Old Fort National Historic Site. Natural Resource Report NPS/NRPC/WRD/NRR—2010/258. National Park Service, Fort Collins, Colorado.



KIM STRUTHERS

**Field meeting at Bent's Old Fort NHS.**

# Chapter 3: Study Scoping and Design

This NRCA is a collaborative project between the Bent's Old Fort NHS staff and the SOPN, both of the NPS. Stakeholders in this project include the Historic Site's natural resource managers and management staff and SOPN staff. The purpose of the condition assessment is to provide a "snapshot-in-time" evaluation of the condition of a select set of Historic Site natural resources that were identified and agreed upon by the project team. Project findings will aid Historic Site staff in the following objectives:

- Develop near-term management priorities.
- Engage in watershed or landscape scale partnership and education efforts.
- Conduct park planning [e.g., General Management Plan (GMP), compliance, Resource Stewardship Strategy, resource management plans].

The approach we used to select natural resources was to assess the fundamental and important values of the Historic Site as well as to consider broader natural resources as identified by the NPS' Natural Resource Program Center. The resources assessed are limited to natural-based topics, but cultural resources were also taken into consideration within the context of the chosen natural resources.

## 3.1. Preliminary Scoping

The selection of resources to assess resulted from meetings and subsequent discussions. For a complete list of team members, please refer to Appendix A.

These meetings and discussions focused on:

1. Confirming the purpose of the Historic Site and its related significance statements and related values.
2. Identifying important natural and cultural resources and concerns for each topic.
3. Identifying data sources and gaps for each resource topic.

Certain constraints were placed on this NRCA, including the following:

- Condition assessments are conducted using existing data and information.
- Identification of data needs and gaps is driven by the project framework categories.

- A preliminary study framework was developed as a result of the meetings and discussions, which listed the chosen resources and the degree of assessment (e.g., full or limited) based upon existing data and information.

Specific project expectations and outcomes included the following:

- For key natural resource components, consolidate available Historic Site data, reports, and spatial information from appropriate sources including: Historic Site resource staff, scientific literature, NatureBib, NPSpecies, Inventory and Monitoring data, and available third-party sources. Enlist the help of subject matter experts for each resource topic when appropriate and feasible (refer to Appendix A for subject matter expert list).
- Define an appropriate description of reference condition for each of the key natural resource components and indicators so statements of current condition can be developed for the NRCA report.
- Where applicable, develop GIS products and graphic illustrations that provide spatial representation of resource data, ecological processes, resource stressors, trends, or other valuable information that can be better interpreted visually.
- Conduct analysis of specific existing data sets to develop descriptive statistics about key natural resource indicators.
- Discuss the issue of key natural resource indicators that are not contained within the Historic Site or controlled directly by Historic Site management activities (e.g., viewshed condition). There are important stressors that impact key natural resource components in the Historic Site but are not under NPS jurisdiction.

Historic Site natural resource staff participated in on-site meetings. Historic Site staff reviewed interim and final products. Historic Site staff, I&M staff, and additional writer/editors data mined information for each assigned resource topic.

## 3.2. Study Design

### *3.2.1. Indicator Framework, Focal Study Resources and Indicators*

The Historic Site's NRCA utilizes an assessment framework adapted from "The State of the Nation's Ecosystems 2008: Measuring the Lands, Waters, and Living Resources of the United States", by the H. John Heinz III Center for Science, Economics and the Environment. This framework was endorsed by the National NRCA Program as an appropriate framework for listing resource components, indicators/measures, and resource conditions.

Each NRCA project represents a unique assessment of key natural resource components that are important to the specific park that is being assessed. As a result, the project framework is developed by the project participants to reflect the key resources of the park. For the purpose of this NRCA, 13 key Historic Site resources were identified and are listed under the "Resource" column in Table 3.2.1-1. This list of focal study resources is not all inclusive of every natural resource at the Historic Site, but it includes natural resources and processes that were of greatest concern at the time of this assessment.

Reference conditions were identified with the intent of providing a benchmark to which the current condition of each indicator/measure could be compared. Generally, this condition represents a historical reference in which modern human activity and disturbance were not major drivers of population and ecological processes. Attempts were made to utilize existing research and documentation to identify reference conditions; however, many of the indicators lack a quantifiable reference condition according to literature and data reviewed for this project. When a specific reference condition for the Historic Site resources was unknown, an attempt was made to include state and federal standards or data from other relevant locations in order

**Table 3.2.1-1. Bent's Old Fort NHS Natural Resource Condition Assessment Framework**

| Resource | Assessment Level | Indicators and Measures |
|---|---|---|
| I. Landscape Condition Context | | |
| Viewshed | Full Assessment | • Scenic and Historic Integrity (Intactness and Conspicuousness of noncontributing features) |
| Night Sky | Full Assessment | • Sky brightness (Anthropogenic light ratio)<br>• Sky Quality (Bortle dark-sky scale) |
| Soundscape | Full Assessment | • Audibility (Percent time audible)<br>• Sound Level (Amplitude-qualitative and quantitative) |
| II. Supporting Environment | | |
| Air Quality | Full Assessment | • Visibility (Visibility Haze Index)<br>• Level of Ozone (Annual 4th-Highest 8-hour Concentration)<br>• Atmospheric Wet Deposition (Total N and Total S in kg/ha/yr) |
| Geology | Limited Assessment | • Geologic Resource Integrity |
| Surface Water | Full Assessment | • Core water Quality Parameters (7 measures)<br>• Alkalinity (3 measures)<br>• Pollutant Metals (15 metals)<br>• Primary Nutrients (11 measures)<br>• Biological Conditions (Biological Oxygen Demand)<br>• Emerging Contaminants (Presence/Absence) |
| Groundwater | Full Assessment | • Groundwater Elevation (Change in groundwater elevation) |
| III. Biological Integrity | | |
| Vegetation | | |
| Riparian Habitat | Full Assessment | • Hydrology (5 indicators)<br>• Vegetation (7 indicators)<br>• Erosion/Deposition (5 indicators) |
| Grasslands | Full Assessment | • Hydrology soil/site stability and hydrologic function (10 indicators)<br>• Biotic integrity (5 indicators) |
| Exotic Plants | Full Assessment | • Prevalence of Exotic Plants (2 measures)<br>• Potential to Alter Native Plant Communities (2 measures) |
| Wildlife | | |
| Landbirds | Full Assessment | • Species Occurrence (Temporal. Spatial, and Conservation Context) |
| Prairie Dog | Limited Assessment | • Prairie Dog Occurrence (Area Occupied and Prairie Dog Density) |
| Vertebrates-Fish | Limited Assessment | • Species Occurrence |

to provide some context for interpreting condition.

### *3.2.2. Reporting Areas*

The reporting area was treated as one unit and encompassed the entire acreage within the Historic Site's boundary. Due to the nature of some of the focal study resources, areas outside of the Historic Site's boundary were assessed to determine overall condition within the Historic Site (e.g., viewshed, air quality).

### *3.2.3. General Approach and Methods*

This study involved reviewing existing literature and data for each of the resources listed, and, where appropriate, analyzing the data to provide summaries or to create new spatial representations. After gathering data regarding current condition

of indicators and measures, a qualitative statement was developed comparing the current condition(s) at the Historic Site to the reference condition(s) when possible.

Data Mining

Data and literature were found in multiple forms: NPS reports and monitoring plans (Historic Site, regional, and national level), other reports from various state and federal agencies, published and unpublished research documents, non-governmental organization reports, databases, and tabular data. Spatial data were provided by the Historic Site, the SOPN, and by the Natural Resource Program Center. Data and literature acquired throughout the data mining process were inventoried and analyzed for thoroughness, relevancy, and quality pertaining to the indicators identified in the project framework. All reasonably accessible and relevant data were used to conduct this assessment.

Subject Matter Experts

Several researchers and subject matter experts were consulted while developing this assessment. Consultations ranged from on-site visits to personal communication, and reviews of resource sections. A full list of the team of experts can be found in Appendix A.

Data Analyses and Development

Data analysis and development/writing tasks were performed for specific resources based on the data mining process and recommendations provided by NPS staff. Data analyses and development were resource specific, and the methodology for individual analyses can be found within each section of chapter four.

Geographic Information System (GIS) technology was utilized to graphically depict the status and distribution of considered resources when possible.

Final Assessments

Final assessments were made by incorporating comments provided by subject matter experts, reviewers, and Historic Site staff during the review of draft chapters. Additionally, continued contact with Historic Site staff to address questions and comments pertaining to each resource topic was maintained throughout the data analysis and report writing phase to ensure accurate representation of staff knowledge. The final assessments represent the most relevant and timely data available for each resource topic based on the recommendations and insight provided by Historic Site staff, researchers, subject matter experts, and assessment writers.

Indicator/Measures Assessment Format

Indicator assessments are presented in a standard format that is consistent with *State of the Park* reporting (NPS 2012). The major components are as follows:

The condition/trend/level of confidence graphic provides a visual representation for each resource indicator and is intended to give readers a quick interpretation of the authors' assessments of condition. The level of confidence ranges from high-low and indicates how confident we are with the data used to determine condition. The written statements of condition, located under the "*Condition and Trend*" heading in each resource topic section, provides a more in-depth description of each indicator and associated measure(s)' condition. Figure 3.2.3-1 shows the condition/trend/confidence level scorecard used to describe each indicator/measure.

Circle colors provide indication of condition based upon the chosen indicators/measures and reference conditions. Red circles signify that a resource is of significant concern; yellow circles signify that a resource is in moderate condition; and green circles denote that an indicator is currently in good condition. A circle without any color, (which is almost always associated with the low confidence symbol-dashed line), signifies that there is insufficient information to make a statement about condition of the indicator, therefore, condition is unknown.

We include an indicator condition and overall rationale summary table at the end of each resource topic's section.

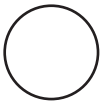
| Condition Status | | Trend in Condition | | Confidence in Assessment | |
|---|---|---|---|---|---|
|  | Warrants Significant Concern |  | Condition is Improving |  | High |
|  | Warrants Moderate Concern |  | Condition is Unchanging |  | Medium |
|  | Resource is in Good Condition |  | Condition is Deteriorating |  | Low |
|  | An open (uncolored) circle indicates that current condition is unknown or indeterminate; this condition status is typically associated with unknown trend and low confidence | | | | |

**Figure 3.2.3-1. Condition, trend, and level of confidence key used in the Bent's Old Fort NHS NRCA.**

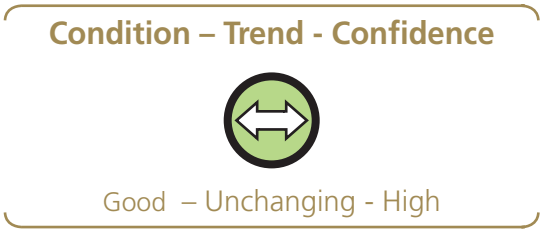



**Figure 3.2.3-2. An example of a good condition, unchanging trend, and high confidence level in the assessment graphic used in NRCAs.**

Arrows inside the circles signify the trend of the indicator/measure condition. Upward pointing arrows signify that the indicator is improving; right pointing arrows signify that the indicator's condition is currently unchanging; downward pointing arrows indicate that the indicator's condition is deteriorating. No arrow denotes that the trend of the indicator's condition is currently unknown. Figure 3.2.3-2 is an example of a final condition graphic used in the indicator assessments.

Background and Importance

This section provides information regarding the relevance of the resource to the Historic Site. This section also explains the characteristics of the resource that help the reader understand subsequent sections of the document.

Data and Methods

This section describes the existing datasets used for evaluating the indicators/measures. Methods used for processing or evaluating the data are also discussed where applicable. The indicators/measures are listed in this section as well, describing how we measured or qualitatively assessed the natural resource topic.

Reference Conditions

This section explains the reference conditions that were used to evaluate the current condition for each indicator. Additionally, explanations of available data and literature that describe the reference conditions are located in this section.

Condition and Trend

This section provides a summary of the condition and trend of the indicator/measure at the Historic Site based on available literature, data, and expert opinions. This section highlights the key elements used in defining the condition and trend designation, represented by the condition/trend graphic, located at the beginning of each resource topic.

The level of confidence and key uncertainties are also included in the condition and trend section. This provides a summary of the unknown information and uncertainties due to lack of data, literature, and expert opinion, as well as our level of confidence about the presented information.

Sources of Expertise

Individuals who were consulted for the focal study resources are listed in this section. A short paragraph describing their background is also included.

Literature Cited

This section lists all of the referenced sources. A DVD is included in the final report with copies of all literature cited unless the citation was from a book. When possible, links to websites are also included.

## 3.3. Literature Cited

The H. John Heinz III Center for Science, Economics and the Environment. 2008. The State of the Nation's Ecosystems 2008: Measuring the Lands, Waters, and Living Resources of the United States. Washington, D.C.

National Park Service. 2012. A Call to Action: Preparing for a Second Century of Stewardship and Engagement. Washington, D.C. 28pp

# Chapter 4: Natural Resource Conditions

In this chapter, we present the background and importance, methods, and condition assessment for each focal study resource that we considered for Bent's Old Fort NHS. In many cases, we did not have a quantitative measure for the indicators but tried to present meaningful categorical measures qualitatively that reflect the condition. We also explained why each indicator was chosen and what we considered as a good, moderate or significant concern reference condition for each indicator. We provide a summary of all focal study resource indicators and their page numbers for explanations of our methods and natural resource conditions in Table 4.1.

**Table 4-1. Page numbers where the description, methods, and condition for each indicator(s) are presented within this chapter.**

| Resource | Indicator | Description/ Methods | Condition |
|---|---|---|---|
| I. Landscape Condition Context | | | |
| Viewshed | Scenic and Historic Integrity | 22 | 29 |
| Night Sky | Sky Brightness | 37 | 39 |
| | Sky Quality | 37 | 39 |
| Soundscape | Audibility | 46 | 50 |
| | Sound Level | 46 | 51 |
| Air Quality | Visibility | 61 | 63 |
| | Level of Ozone | 62 | 63 |
| | Atmospheric Wet Deposition in Total N and Total S | 62 | 63 |
| Geology | Geologic Resource Integrity | 70 | 71 |
| Surface Water | Core Water Quality Parameters | 79 | 82 |
| | Alkalinity | 80 | 84 |
| | Metals | 80 | 84 |
| | Primary Nutrients | 81 | 84 |
| | Biological Conditions | 81 | 85 |
| | Emerging Contaminants | 81 | 85 |
| Groundwater | Change in Groundwater Level | 91 | 93 |
| III. Biological Integrity | | | |
| Vegetation | | | |
| Riparian Habitat | Hydrology | 100 | 103 |
| | Vegetation | 101 | 107 |
| | Erosion/Deposition | 102 | 109 |
| Grasslands | Hydrology Soil/Site Stability and Hydrologic Function | 117 | 120 |
| | Biotic Integrity | 118 | 120 |
| Exotic Plants | Prevalence of Exotic Plant | 136 | 143 |
| | Potential to Alter Native Plant Communities | 141 | 143 |

***Table 4.1. Page numbers where the description, methods, and condition for each indicator are presented within this chapter (cont.).***

| Resource | Indicator | Description/ Methods | Condition |
|---|---|---|---|
| Wildlife | | | |
| Landbirds | Species Occurrence | 150 | 155 |
| Prairie Dog | Prairie Dog Occurrence | 170 | 171 |
| Rare Vertebrates | Species Occurrence | 177 | 178 |

## 4.1. Viewshed

**Indicators/Measures**

- Scenic and Historic Integrity (2 Measures)

**Condition – Trend - Confidence**



Moderate – Unchanging - High

### *4.1.1. Background and Importance*

The conservation of scenery is established in the National Park Service (NPS) Organic Act ("… to conserve the scenery and the wildlife therein…"), reaffirmed by the General Authorities Act, as amended, and addressed generally in the NPS Management Policies (Section 1.4.6 and 4.0) (Johnson et al. 2008). Although no management policy currently exists exclusively for scenic or viewshed management and preservation, parks are still required to protect scenic and viewshed quality as one of their most fundamental resources. According to Biel (2005), aesthetic conservation, interchangeably used with scenic preservation, has been practiced in the NPS since the early twentieth century. Aesthetic conservation strove to protect scenic beauty for park visitors to better experience the values of the park. The need for scenic preservation management is as relevant today as ever, particularly with the pervasive development pressures that challenge park stewards to conserve scenery today and for future generations.

Bent's Old Fort National Historic Site was established to commemorate the historic role played by the Fort in the opening of the American West. The original adobe Fort was opened in 1833 by William and Charles Bent, along with Ceran St. Vrain to trade for buffalo robes with the Cheyenne and Arapaho Tribes (NPS 2013). The Fort was abandoned in 1849 due to disasters and disease, but was reconstructed during the 1976 United States bicentennial and the Colorado centennial based on archeological excavations, sketches, and diaries. The reconstructed Fort and its historic setting preserves the interconnection between the natural and cultural environments. Within this context, the viewshed was identified as one of the fundamental resources and values for the site (NPS 2013) (Figure 4.1.1-1).

The Fort was situated along the Mountain Branch of the Santa Fe Trail and was initially the only permanent settlement along the



NPS PHOTO

**Figure 4.1.1-1. View to the South, from the Southwest Bastion of Bent's Old Fort National Historic Site.**



PHOTO CREDIT: NINA CHAMBERS

**Figure 4.1.1-2. One of the values of a viewshed, particularly one with such historic significance, is the potential to visualize that site as it once might have been to gain a "sense of place" in that historic context.**

Santa Fe Trail between Missouri and Santa Fe, New Mexico (NPS 2013).

Visitor Experience

Inherent in virtually every aspect of this assessment is how features on the visible landscape influence the enjoyment, appreciation, and understanding of the Historic Site by visitors. The indicators we use for condition of the viewshed are based on studies related to perceptions people hold toward various features and attributes of the viewsheds. We also focus on how the historic integrity of the viewshed enhances the opportunity for visitors to better understand the historical significance that the Fort had in shaping our country.

From a cultural and historical perspective, the views are not just about the scenery, but an important way to better understand the connection between natural and cultural resources at Bent's Old Fort NHS. Visualizing this connection as part of the landscape is a critical part of the visitor experience (Figure 4.1.1-2). The first visual intrusion when visitors leave the parking lot is the trail's patchwork asphalt.

### *4.1.2. Data and Methods*

Viewsheds are considered in this assessment within two interrelated contexts: natural scenic integrity and historic integrity. Impacts that degrade one aspect likely degrade the other as well. For example, modern structures or roadways visible on the landscape may detract from the natural scenic integrity of the viewshed as well as the sense of place that a historically authentic landscape evokes. Depending on the context, scenic and historic integrity may be distinct, or there may be so little practical difference that they are the same. In the case of Bent's Old Fort National Historic Site, there is so much overlap that we treat them together. We qualitatively assess how features on the landscape contribute (or not) to the scenic and historic integrity of the site.

**Indicator**

Scenic and Historic Integrity

The overall indicator of viewshed condition we use in this assessment is a combination of scenic and historic integrity. For this overall indictor we used two measures (intactness and conspicuousness) from key vantage points (Table 4.1.2-1). Each of these measures are described in greater detail below.

**Table 4.1.2-1. Indicators and measures of viewshed and why these are important to the resource condition.**

| Indicators of Condition | Measures | Why are these indicators/measures important to resource condition? |
|---|---|---|
| Scenic and Historic Integrity | Intactness of View | Intactness represents how much the viewshed has been altered from its reference state, which in turn influences scenic quality as well as the sense of place in an historic context. |
| | Conspicuousness of non-contributing features | Non-contributing features that are more conspicuous tend to detract more from the scenic quality and/or the sense of place in an historic context. |

Scenic integrity is defined as, the state of naturalness or, conversely, the state of disturbance created by human activities or alteration (USFS 1995). This focuses on the features of the landscape related to non-contributing (in an historic context) human alteration.

Historic integrity is the authenticity of a site's historic identity, evidenced by the survival of physical characteristics that existed during its historic period. Historic integrity is based on those features of the cultural and natural landscape, from the perspective of an observer, that contribute to the sense of place and enhance the visitor experience. In this assessment, we focus on those features that have a visual impact and contribute to the story of Bent's Old Fort NHS. We evaluate features as contributing (i.e., enhancing the scenic and historic features of the landscape) or noncontributing (i.e., detracting from the scenic and historic integrity).

We assess scenic and historic integrity by evaluating specific human-made features that can be seen from key vantage points and whether or not those features are contributing or noncontributing to the scenic and/or historic integrity of the view. For noncontributing features, we further assess the characteristics that make them more or less conspicuous; which influences the level of impact that they might have. We then supplement this assessment with a GIS-based map showing areas that are or are not visible from key vantage points. The GIS analysis provides spatial orientation of key features.

*Viewshed Vantage Points*

For this assessment we focused primarily on the views visible from the Fort, and used two vantage points from which to assess those views. The vantage points we used were the two bastions of the Fort (Figure 4.1.2-1). These bastions are the highest points within the Fort, receive high visitation, and represent the points from which most visitors view the surrounding landscape. As such, the views from these bastions play a major role in how visitors perceive the Fort within the context of its surrounding landscape.




**Figure 4.1.2-1. The two Fort bastion vantage points used in this assessment .**

*Ancillary Views*

The area immediately surrounding the Fort is relatively flat and the views from the Fort really represent the best views within the site of the surrounding landscape. There are however additional views that may contribute to the story of Bent's Old Fort NHS. For example, views looking toward the Fort from the surrounding landscape may have been a welcomed site for weary travelers and traders coming to the Fort. One such view might be aproaching the Fort from what is now the Arch or from the parking lot walking to the Fort (Figures 4.1.2-2, -3).

Similarly, views of the Fort from various sites in the surrounding landscape (e.g. hiking trail) help evoke the sense of connectedness between the Fort and its surroundings (Figure 4.1.2-4). These views have been enhanced by



NPS PHOTO

**Figure 4.1.2-2. View of the Fort from the Arch.**


NPS PHOTO

**Figure 4.1.2-3. View approaching the Fort from the parking lot.**


NPS PHOTO

**Figure 4.1.2-4. View of the Fort from the surrounding cottonwoods have been enhanced by the removal of Tamarisk.**

the removal of Tamarisk from the cottonwood understory.

These additional views were not included in the assessment with respect to applying our full measures of integrity, but still may have important implications to Historic Site management.

## Measure
### Intactness

The extent of intactness provides a measure of the degree to which the viewshed is unaltered from its original (reference) state, particularly the extent to which intrusive or disruptive elements may diminish the character of the scene (USFS 1995, Johnson et al. 2008).

We used a series of panoramic images to portray the viewshed from an observer's perspective. These images were taken using a Canon PowerShot digital camera and the GigaPan Epic 100 system, a robotic camera mount coupled with stitching software (Figure 4.1.2-5). A series of images are automatically captured and the individual photographs are stitched into a single high-resolution panoramic image. These photographs provided a means of illustrating the features on the landscape related to viewshed integrity.

We recognize that visitor perceptions of an altered landscape are highly subjective, and there is no completely objective way to measure this. Research has shown, however, that there are certain landscape types and characteristics that people tend to prefer over others. In general, there is a wealth of research demonstrating that people tend to prefer natural over human-modified landscapes (Zube et al. 1982, Kaplan and Kaplan 1989, Sheppard 2001, Kearny et al. 2008, Han 2010). However, in the case of parks set aside for their historical significance, human-made structures that have historical significance add value to the historical context and contribute to the sense of place. Therefore, human-made features that are consistent with the historical context of the Historic Site are likewise considered consistent with the goals of scenic and historic integrity. Human-altered components of the landscape (e.g., roads,



**Figure 4.1.2-5. The GigaPan system takes a series of images that are stitched together to create a single panoramic image.**

buildings, powerlines, and other features) that do not contribute to the historic context are often perceived as detracting from the scenic and historic character of the viewshed.

Despite this generalization for natural landscape preferences, studies have also shown that not all human-made structures or features have the same impact on visitor preferences. Visitor preferences can be influenced by a variety of factors including cultural background, familiarity with the landscape, and their environmental values (Kaplan and Kaplan 1989, Virden and Walker 1999, Kaltenborn and Bjerke 2002, Kearney et al. 2008).

## Measure
### Conspicuousness of Noncontributing Features

Substantial research has demonstrated that human-made features on a landscape are perceived more positively when they are considered in harmony with the landscape (e.g., Kaplan and Kaplan 1989, Gobster 1999, Kearney et al. 2008). For example, Kearney et al. (2008) showed that survey respondents tended to prefer development that blended with the natural setting through use of colors, smaller scale, and vegetative screening. For this measure, we focused on four characteristics, or groups of characteristics, that have been demonstrated to contribute to the conspicuousness of man-made features: (1) distance from a given vantage point, (2) size, (3) color and shape, and (4) movement and noise. A general relationship between these characteristics and their influence on conspicuousness is presented in Table 4.1.2-2 and more detailed descriptions of these human-made features are presented below.

*Distance*-- The impact that individual human-made features have on perception is substantially influenced by the distance from the observer to the feature(s). Viewshed assessments using distance zones or classes often define three classes: foreground, middle ground, and background (Figure 4.1.2-6). For this assessment, we have used the distance classes that have been recently used by the National Park Service:

- Foreground = 0-½ mile from vantage point
- Middle ground = ½-3 miles from vantage point
- Background = 3-60 miles from vantage point. Over time, different agencies have

**Table 4.1.2-2. Characteristics that influence how less conspicuous human-made features are within a viewshed and the general effect.**

| Characteristic | Less Conspicuous | More Conspicuous |
|---|---|---|
| Distance | Distant from the vantage point | Close to the vantage point |
| Size | Small relative to the landscape | Large relative to the landscape |
| Color and Shape | Colors and shapes that blend into the landscape | Colors and shapes that contrast with the landscape |
| Movement and Noise | Lacking movement or noise | Exhibits obvious movement or noise |




NPS PHOTO

**Figure 4.1.2-6. An example of approximate distance classes used in this assessment.**

adopted minor variations in the different specific distances use to define these zones, but the overall logic and intent has been consistent.

The foreground is the zone where visitors should be able to distinguish variation in texture and color, such as the relatively subtle variation among vegetation patches, or some level of distinguishing clusters of tree boughs. Large birds and mammals would likely be visible throughout this distance class, as would small or medium-sized animals at the closer end of this distance class (USFS 1995). Within the middle ground there is often sufficient texture or color to distinguish individual trees or other large plants (USFS 1995). It is also possible to still distinguish larger patches within major plant community types (such as grasslands), provided there is sufficient difference in color shades at the farther distance. Within the closer portion of this distance class, it still may be possible to see large birds when contrasted against the sky, but other wildlife would be difficult to see without the aid of binoculars or telescopes. The background distance class is where texture tends to disappear and colors flatten. Depending on the actual distance, it is sometimes possible to distinguish among major vegetation types with highly contrasting colors (for example, forest and grassland), but any subtle differences within these broad land cover classes would not be apparent without the use of binoculars or telescopes, and even then may be difficult.

*Size*

Size is another characteristic that may influence how conspicuous a given feature dominates the landscape, and how it is perceived. For example, Kearney et al. (2008) found human preferences were lower for human-made developments that tended to dominate the view, such as large, multi-storied buildings) and were more favorable toward smaller, single family dwellings. In another study, Brush and Palmer (1979) found that farms tended to be viewed more favorably than views of towns or industrial sites, which ranked very low on visual preference. This is consistent with other studies that have reported rural family dwellings, such as farms or ranches, as quaint and contributing to rural character (Schauman 1979, Sheppard 2001, Ryan 2006), or as symbolizing good stewardship (Sheppard 2001).

We considered the features on the landscape surrounding Bent's Old Fort NHS as belonging to one of six size classes (Table 4.1.2-3), which reflect the preference groups reported by studies. Using some categories of perhaps mixed measures, we considered size

**Table 4.1.2-3. A matrix describing the six size classes used for visible human-made features.**

| | Low Volume | Substantial Volume |
|---|---|---|
| Low Height | Single family dwelling (home, ranch house) | Small towns, complexes |
| Substantial Height | Radio and cell phone towers | Wind farms, oil derecks |
| Substantial Length | Small roads, wooden power lines, fence lines | Utility corridors, highways, railroads |

classes within the context of height, volume, and length.

*Color and Shape*

Studies have shown that how people perceive a human-made feature in a rural scene depends greatly on how well it seems to fit or blend in with the environment (Kearney et al. 2008, Ryan 2006). For example, Kearney et al. (2008) found preferences for homes that exhibit lower contrast with their surroundings as a result of color, screening vegetation, or other blending factors (see Figure 4.1.2-7). It has been shown that colors lighter in tone or higher in saturation relative to their surroundings have a tendency to attract attention (contrast with their surroundings), whereas darker colors (relative to their surroundings) tend to fade into the background (Ratcliff 1972), O'Connor 2008). This is consistent with the findings of Kearney et al. (2008) who found that darker color was one of the factors contributing to a feature blending in with its environment and therefore preferred. Some research has indicated that color can be used to offset other factors, such as size, that may evoke a more negative perception (O'Connor 2009). Similarly, shapes of features that contrast sharply with their surroundings may also have an influence on how they are perceived. This has been a dominant focus within visual resource programs of land management agencies (Ribe 2005). In forest management, negative perceptions related to the contrasting shapes of forest harvest with their surroundings (for example, clear cuts) was so strong that it was explicitly addressed in the National Forest Management Act of 1976 calling for "cuts shaped and blended to the extent practicable with the natural terrain" (16 USCA 1604g3Fiii). The Visual Resource Management Program of the BLM (BLM 1980) similarly places considerable focus on design techniques that minimize visual conflicts with features such as roads and power lines by aligning them with the natural contours of the landscape. Based on these characteristics of contrast, we considered the color of a feature in relative harmony with the landscape if it closely matched the surrounding environment, or

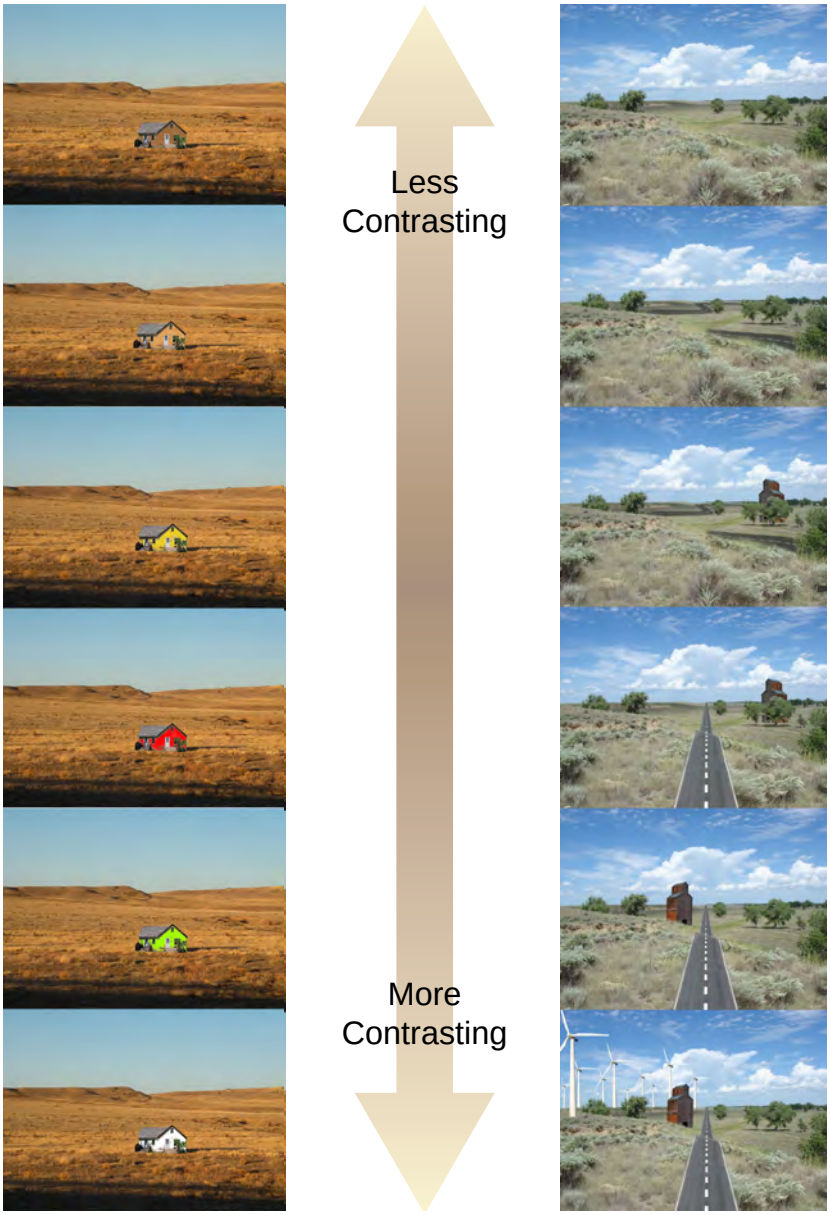



**Figure 4.1.2-7. Graphic illustration of how color (left) and shape (right) can influence whether features are in harmony with the environment, or are in contrast.**

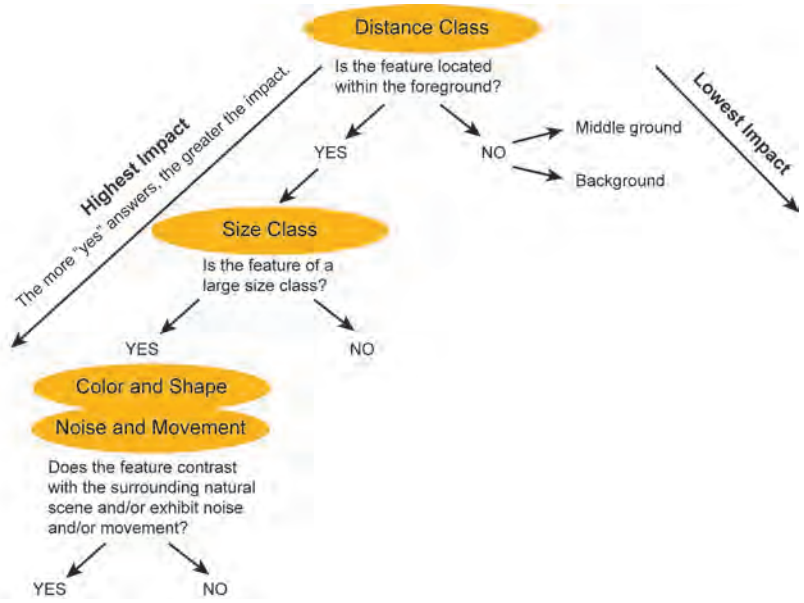



**Figure 4.1.2-8. Conceptual framework for hierarchical relationship of characteristics that influence the conspicuousness of features within a viewshed.**

if the color tended to be darker relative to the environment. We considered the shape of a feature in relative harmony with the landscape if it was not in marked contrast to the environment.

Movement and Noise

Motion and sound can both have an influence on how a landscape is perceived (Hetherington et al. 1993), particularly by attracting attention to a particular area of a viewshed. Movement and noise parameters can be perceived either positively or negatively, depending on the source and context. For example, the motion of running water generally has a very positive influence on perception of the environment (Carles et al. 1999), whereas noise from vehicles on a highway may be perceived negatively. In Carles et al.'s 1999 study, sounds were perceived negatively when they clashed with aspirations for a given site, such as tranquility. We considered the conspicuousness of the impact of movement and noise to be consistent with the amount present (that is, little movement or noise was inconspicuous, obvious movement or noise was conspicuous).

Hierarchical Relationship among Conspicuousness Measures

The above-described characteristics do not act independently with respect to their influence on the conspicuousness of features; rather, they tend to have a hierarchical effect. For example, the color and shape of a house would not be important to the integrity of the Historic Site's viewshed if the house was located too far away from the vantage point. Thus, distance becomes the primary characteristic that affects the potential conspicuousness. Therefore, we considered potential influences on conspicuousness in the context of a hierarchy based on the distance characteristics having the most impact on the integrity of the viewshed, followed by the size characteristic, then both the color and shape, and movement and noise characteristic (Figure 4.1.2-8).

GIS Viewshed Analyses

We supplement our assessment with a Geographic Information System (GIS) analysis to provide spatial context for these measures.

Viewshed analyses were conducted to depict the total visible area seen from each of the two key vantage points. Aerial maps of each of the vantage points were generated based on digital elevation models (DEMs) to predict the area visible from a given vantage point taking into account changes in elevation and other obstructions such as tree, mountain, or building heights. We limited this approach to an area of 30 km from Historic Site since features at greater distances have relatively less impact on scenic or historic integrity than those in greater proximity.

Ground verification indicated that the initial viewshed analyses tended to underestimate the visible area. Consequently, we adjusted the analyses by experimenting with different offsets that adjust the height of the observer or the surrounding landscape. After several iterations, we found that a 10 m offset for the surrounding landscape provided the best depiction of the visible area from each vantage point. Complete details of the viewshed analysis process are listed in Appendix B.

### *4.1.3. Reference Conditions*

The indicators and measures of viewshed condition at Bent's Old Fort NHS are all inter-related and are intended to provide

**Table 4.1.3-1. Qualitative reference condition classes used for scenic and historic integrity within the viewshed at Bent's Old Fort NHS.**

| Class | Scenic & Historic Integrity |
|---|---|
| High Integrity *(Good Condition)* | Some noncontributing features or developments may be visible, but the vast majority of the landscape is dominated by natural or historic features. The integrity of the historic context is well preserved such that an observer can easily visualize the historic aspect of the viewshed. As such, the features that contribute to the historic integrity are well preserved (even as ruins) and the noncontributing features are generally absent or are sufficiently inconspicuous so as to not detract from the historic sense of place. |
| Moderate Integrity *(Moderate Concern)* | Noncontributing features or developments occupy a moderate portion of the landscape and/or are moderately conspicuous, but sufficient intactness retains much of its integrity. The integrity of the historic context is also largely preserved such that an observer can visualize the historic aspect of the viewshed. |
| Low Integrity *(Significant Concern)* | The vast majority of the landscape is dominated by noncontributing features or developments that are conspicuous enough that little integrity or "sense of place" remains. The integrity of the historic context is essentially lost either from the contributing factors not being well preserved or the noncontributing features overwhelming the potential to visualize the historic aspect of the viewshed. |

information about how well the views maintain their scenic quality and their ability to evoke a sense of place in an historic context. As previously discussed, the scenic and historic integrity at Bent's Old Fort NHS overlap considerably. From the historic perspective, the reference state is based on a particular period relevant to the site—in this case, the time that the Fort was active (1833-1849).

The basis for determining condition in an assessment such as this is a comparison between current condition and a reference condition, in this case the period between 1833 and 1849. Based on this reference period, we used a qualitative reference state for the scenic and historic integrity of the viewshed (Table 4.1.3-1). Embedded within these reference conditions is both the intactness and conspicuousness of features that do not contribute to the scenic and historic integrity relative to that period.

### *4.1.4. Condition and Trend*

Overall, the scenic and historic integrity of the viewsheds at Bent's Old Fort NHS ranges from fair to good condition. The landscape surrounding site remains largely intact to the south and to the east, but has a moderate degree of conspicuous agricultural and rural development to the west and north (Table 4.1.4-1) (Figure 4.1.4-1).

**Table 4.1.4-1. Indicator and measures of viewshed condition, their corresponding assigned condition class, and the rationale for assigning condition class.**

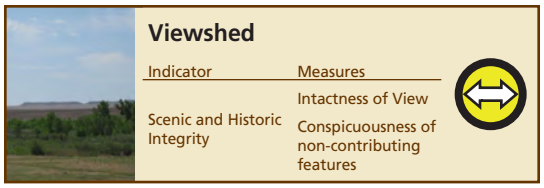
| Indicator of Condition | Measures | Condition | Rationale for Condition |
|---|---|---|---|
| Scenic and Historic Integrity | Intactness of View | Moderate | Views to the south and east are relatively intact with few non-contributing features; whereas, to the west and north, there is a moderate degree of development. The moderate ranking for this measure reflects these differing conditions. |
| | Conspicuousness of non-contributing features | Moderate | Non-contributing features to the west and north are relatively conspicuous; whereas, the limited development within view to the south and east are relatively inconspicuous. The moderate ranking for this measure reflecting these differing conditions |




**Figure 4.1.4-1. Panoramic views in each direction from the Fort bastion vantage points.**

Non-contributing features visible from the Fort bastions include both NPS and external features. From these vantage points, one of the prominent non-contributing NPS features is the Historic Site administrative and maintenance facilities. In addition, the prairie in between the Fort and the administration is in a somewhat degraded condition along with drought conditions at the time of this assessment; together these probably detract from the view in that direction. It should be noted however, that the Historic Site is actively engaged in restoring native prairies. Other prominent non-contributing features external to the Historic Site include houses along Highway 194 as well as agricultural development. Most of this development (both NPS and external are within the foreground and middle ground of the viewshed, thus adding to their conspicuousness. Because of the relatively flat terrain and shielding from vegetation, only a small area of the viewshed would be considered in the background. Additionally, the impact from the railroad, including noise and movement, impacts the historic setting. The highways (US 150, CO 194) both negetivly impact the viewshed due to noise and especially movement of vehicles, both of which catches a visitor's attention as they look out from the Fort. Other intrusions include crop dusters and non-native plants.

Despite any noncontributing development, the natural and historic integrity remain sufficiently intact that a sense of place is largely retained. The Fort itself helps to maintain this sense of place for ancillary views toward the Fort (Figure 4.1.4-2). This sense is also enhanced in views from the Fort due to the living history emphasis of the Historic Site, where visitors have already been "transported" back in time such that they might better be able to visualize the historic context of the Fort within its surroundings.




Overall Condition

Based on this assessment, we considered the viewshed condition at Bent's Old Fort NHS to be moderate. This condition represents a balance between views to the west and north that have a moderate amount of relatively conspicuous agricultural and rural development and views to the south and east which have very little conspicuous development. Non-contributing development both within and outside Historic Site can detract from the scenic and historic integrity, but is not so extensive so as to lose the sense of place of this historic site.

GIS-based Assessment

For our GIS-based analysis, we estimated the areas visible or not visible from the Fort bastion vantage points. Distant views to the north and west are limited by topography, whereas views to the south and east are limited by riparian vegetation along the Arkansas River (Figure 4.1.4-3). The Spanish Peaks, which are 110 miles to the southwest, can be seen when not obscured by clouds, dust, or Front Range smog. The Peaks were landmarks on the Santa Fe Trail and help to interpret the routes to the west (Figure 4.1.4-4).

It is important to keep in mind that these estimates of visible area are approximations based on Digital evaluation models. Although, we have checked them on the ground to verify that they are approximately correct, it should not be assumed that they are exactly correct for the purposes of planning specific projects. Such cases may require further verification, and adjustment if necessary, for the specific context intended.

### *4.1.5. Sources of Expertise*

For assessing the condition of this resource, we relied primary on literature on this topic. Heidi Sosinski provided GIS expertise.




**Figure 4.1.4-2. Views of the Fort from the surrounding area help to maintain the historic context and sense of place.**

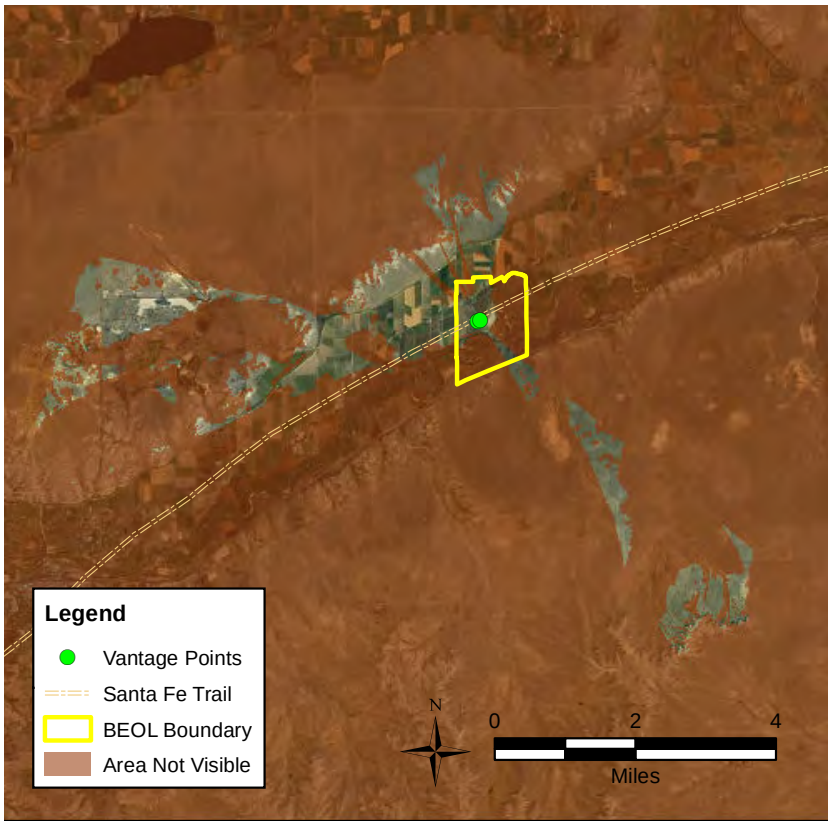



**Figure 4.1.4-3. Area visible and not visible from the Bent's Old Fort Bastions based on GIS analysis.**

Key Uncertainties

How a view is perceived is quite subjective and will always have an element of uncertainty. We have tried to base our assessment on the findings of an extensive body of literature, and have tried to be transparent with our assessment, such that those that disagree can make an argument based on our approach.



NPS PHOTO

**Figure 4.1.4-4. The Spanish Peaks can be seen from the Fort's back bastion on clear days.**

Another element of uncertainty is our GIS analysis. This analysis is based on digital elevation models and does not take into account visibility limitations from vegetation, etc. Also, our field verification of our initial analysis indicated that we were underestimating the visible area, which we accounted for using an offset. Further field checks indicated that our final analysis was closer, but undoubtedly still has some error due to the process. Thus, as stated previously, it should not be assumed that our analysis is exactly correct for the purposes of planning specific projects. Such cases may require further verification, and adjustment if necessary, for the specific context intended.

### *4.1.6. Literature Cited*


Biel, A. 2005. Aesthetic conservation and the National Park Service. Yellowstone Science 13(3): pages?.

Brush, R. 0. And J. F. Palmer. 1979. Measuring the impact of urbanization on scenic quality: Land use changes in the northeast. In Proceedings of Our National Landscape Conference. U.S. Department of Agriculture. Location?

Bureau of Land Management (BLM). 1980. Visual Resource Management. U.S. Department of the Interior, Bureau of Land Management. Washington, DC. http://www.blm.gov/nstc/vrm/8400. html

Carles, L. J., I. L. Barrio, and J. Vicente de Lucio. 1999. Sound influence on landscape values. Landscape and Urban Planning 43:191-200.

Gobster, P. H. 1999. An ecological aesthetic for forest landscape management. Landscape Journal. 18: 54-64.

Han, K. T. 2010. An exploration of relationships among responses to natural scenes: Scenic beauty, preference and restoration. Environment and Behavior 42(2):243-270.

Hetherington, J., T.C. Daniel. and T.C. Brown. 1993. Is motion more important than it sounds?: The medium of presentation in environmental perception research. J. Environmental Psychology. 13: 283-291.

Johnson, G. W., J. D. Anderson, and D. Godwin. 2008. A guidebook for the Blue Ridge Parkway Scenery Conservation System. Draft. National Park Service, Asheville, North Carolina.

Kaltenborn, B. P. and T. Bjerke. 2002. Associations between environmental

value orientations and landscape preferences. *Landscape and Urban Planning* 59:1-11.

Kaplan, R. and S. Kaplan. 1989. The Experience of Nature: A Psychological Perspective. Cambridge University Press, Cambridge, UK.

Kearney, A. R., G. A. Bradley, C. H. Petrich, R. Kaplan, S. Kaplan, and D. Simpson-Colebank. 2008. Public perception as support for scenic quality regulation in a nationally treasured landscape. *Landscape and Urban Planning* 87:117-128.

National Park Service (NPS). 2013. Foundation Document, Bent's Old Fort National Historic Site. 40pp.

O'Connor, Z. 2008. Facade Colour and Aesthetic Response: Examining Patterns of Response within the Context of Urban Design and Planning in Sydney, University of Sydney: Sydney, Austraila.

O'Connor, Z. 2009. Facade colour and judgements about building size. In D. Smith, P. Green-Armytage, M. A. Pope, and N. Harkness (Eds.) AIC 2009: Proceedings of the 11th Congress of the International Colour Association, Sydney.

Ratcliff, F. 1972. Contour and contrast. *Scientific American* 226: 91-101.

Ribe, R. G. 2005. Aesthetic perceptions of green-tree retention harvests in vista views: The interaction of cut level, retention pattern, and harvest shape. *Landscape and Urban Planning* 73:277-293.

Ryan, R. L. 2006. Comparing the attitudes of local residents, planners, and developers about preserving rural character in New England. *Landscape and Urban Planning* 75: 5-22.

Schauman, S. 1979. The Countryside Visual Resource. In Proceedings of Our National Landscape: A Conference on Applied Techniques for Analysis and Management of the Visual Resource, General Technical Report PSW-35, Pacific Southwest Forest and Range Experiment Station, Forest Service, USDA, Berkely, California.

Sheppard, S. R. J. 2001. Beyond visual resource management: Emerging theories of an ecological aesthetic and visible stewardship. In Sheppard, S. R. J. and H. W. Harshaw, Eds., Forests and Landscapes: Linking Ecology, Sustainability and Aesthetics. CABI Publishing, New York.

U.S. Forest Service (USFS). 1995. Landscape Aesthetics: A Handbook for Scenery Management. Agricultural Handbook 710.

Virden, R. J. and G. J. Walker. 1999. Ethnic/racial and gender variations among meanings given to, and preferences for, the natural environment. *Leisure Sciences* 21:219-239.

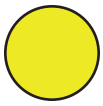
Zube, E. H., J. L. Sell, and J. G. Taylor. 1982. Landscape perception: Research, application, and theory. *Landscape Planning* 9:1-33.

## 4.2. Night Sky

**Indicators/Measures**

- Sky Brightness (Anthropogenic Light Ratio)
- Sky Quality (Bortle Dark-Sky Scale)

**Condition – Trend – Confidence**



Moderate - Insufficient Data - Medium

### *4.2.1. Background and Importance*

Natural dark skies are a valued resource within the NPS, reflected in NPS management policies (NPS 2006) which highlight the importance of a natural photic environment to ecosystem function, and the importance of the natural lightscape for aesthetics. The NPS Natural Sounds and Night Skies Division makes a distinction between a *lightscape*—which is the human perception of the nighttime scene, including both the night sky and the faintly illuminated terrain, and the *photoic environment*—which is the totality of the pattern of light at night at all wavelengths (Moore et al. 2013).

Lightscapes are an aesthetic and experiential quality that are integral to natural and cultural resources (Moore et al. 2013). A 2007 visitor survey conducted throughout Utah national parks found that 86% of visitors thought the quality of park night skies was "somewhat important" or "very important" to their visit. Additionally, in an estimated 20 national parks, stargazing events are the most popular ranger-led program (NPS 2010).

The values of night skies goes far beyond visitor experience and scenery. The photic environment affects a broad range of species, is integral to ecosystems, and is a natural physical process (Moore et al. 2013). Natural light intensity varies during the day-night (diurnal) cycle, the lunar cycle, and the seasonal cycle. Organisms have evolved to respond to these periodic changes in light levels in ways that control or modulate movement, feeding, mating, emergence, seasonal breeding, migration, hibernation, and dormancy. Plants also respond to light levels by flowering, vegetative growth, and their direction of growth (Royal Commission on Environmental Pollution 2009). Given the effects of light on living organisms, it is likely that the introduction of artificial light into the natural light/darkness regime will disturb the normal routines of many plants and animals (Royal Commission on Environmental Pollution 2009), as well as diminish stargazing recreational opportunities offered to national park visitors.

Bent's Old Fort National Historic Site (NHS) is primarily a cultural resource park, and the cultural significance of dark night skies should be recognized as part of the cultural landscape. The night sky played a critical role in the history of Bent's Fort. In November 1833, William Bent met with Cheyenne Chief White Thunder. As they talked, a meteor shower (Figure 4.2.1-1) lit up the sky over the



IMAGE FROM HTTP://STAR.ARM.AC.UK/LEONIDMETEOR-SHOWER.JPG

**Figure 4.2.1-1. The Leonid meteor shower of 1833 became known as "the night the sky fell" and was an important and formative event in the history of Bent's Fort and relationships with the Cheyenne and Pawnee people. The most famous depiction of the 1833 Leonid meteor shower is this engraving produced in 1889 by Adolf Vollmy based on an original painting by the Swiss artist Karl Jauslin.**

**Table 4.2.2-1. Indicators and measures of the night sky and why they are important to resource condition.**

| Indicator | Measure | Description |
|---|---|---|
| Sky Brightness | Anthropogenic Light Ratio | The all-sky anthropogenic light ratio describes light due to man-made sources compared to light from a natural dark sky. Understanding the lightscape and sources of light is helpful to managers to maintain dark skies for the benefit of wildlife and people alike. |
| Sky Quality | Bortle Scale Class | The Bortle Dark Sky classification system describes the quality of the dark night sky by the celestial bodies and night sky features an observer can see. Observing the stars has been an enjoyable human pastime for centuries. |

plains, and that event changed the course of history.

The spectacular Leonid meteor shower of 1833 was very intense, with descriptions comparing the falling stars to falling snowflakes in a snowstorm, hundreds to thousands an hour (e.g., Olmstead 1833). Although the Leonid meteor showers had been documented since 902 AD, the 1833 event led to the first formulation of a theory on the origin of meteors (NASA 2013). The event also became known as "the night the sky fell" among Native American Tribes throughout the Western U.S. (Kronk 2013). Many believed the meteor shower signaled the end of the world.

> And now, on November 12, 1833, the very firmament was cracking open, tumbling down the stars. While the skies dripped fire, while William Bent and other traders watched from the fort's unfinished walls, the visiting warriors decked themselves in full battle regalia of feather and paint, lance and shield. They could not fight this fearful thing. But at least they could die like men. They mounted their horses. Women cried and children shrieked; in the fort the dogs howled back at the chorusing wolves. Chanting their death dirges above the din, the warriors rode in single file around the tepees, under the shadow of the great mud bastions (Lavender 1954:153).

Chief White Thunder saw the event as an opportunity for a new beginning. Soon after, he sought a truce with the Pawnee. The evenings he spent with William Bent during the meteor shower formented their friendship, and White Thunder arranged a formal marital alliance between his daughter Owl Woman and William Bent. He believed that through their children would be another element of a new beginning, of peace for the Cheyenne and the region (Hyde 2011).

Protecting the night sky resources at Bent's Old Fort NHS benefits the natural resources, is important for visitor experience, has cultural and historical significance, and is important within the cultural context of the Historic Site.

### *4.2.2. Data and Methods*

The NPS Natural Sounds and Night Skies Division goals of measuring night sky brightness are to describe the quality of the lightscape, quantify how much it deviates from natural conditions, and how it changes with time due to changes in natural conditions, as well as artificial lighting in areas within and outside of the national parks (Duriscoe et al. 2007).

Based on new guidance (Moore et al. 2013), the NPS Natural Sounds and Night Skies Division recommends that the all-sky Anthropogenic Light Ratio (ALR) is the best single parameter for characterizing the overall sky condition. Additional indicators and measures may be considered in an assessment of night sky condition, but the ALR measure is the primary data source for condition assessment (see Table 4.2.2-1).

We conducted a supplemental rapid assessment of the Historic Site's night sky condition on June 6, 2013 using the Bortle

Dark Sky Scale, a qualitative assessment commonly used by amateur astronomers to evaluate the potential quality for star gazing. This rapid assessment is supplementary and is intended only to illustrate the night sky condition.

## Measure
### Anthropogenic Light Ratio

The anthropogenic light ratio (ALR) is the average anthropogenic sky luminance presented as a ratio over natural conditions. It is a useful metric to average the light flux over the entire sky (measuring all that is above the horizon and omitting the terrain). Recent advances in modeling of the natural components of the night sky allow the separation of anthropogenic light from natural features, such as the Milky Way. This metric is a convenient and robust measure. It is most accurately obtained from ground-based measurements with the NPS Night Skies Program's photometric system, however, it can also be modeled with moderate confidence when such measurements are not available. No ground-based measures were taken for Bent's Old Fort NHS; modeling data are reported here.

CCD camera images assess brightness, including maximum sky brightness, minimum sky brightness, and two measures of integrated sky brightness. The maximum sky brightness is typically found in the core of urban light domes (i.e., the semicircular-shaped light along the horizon caused by the scattering of urban light). The minimum sky brightness is typically found at or near the zenith (i.e., straight overhead). The integrated night sky brightness is calculated from both the entire celestial hemisphere as well as a measure of the integrated brightness masked below 20° altitude to avoid site-to-site variations introduced by terrain and vegetation blocking.

## Measure
### Bortle Dark Sky Scale

The Bortle Dark Sky Scale (Appendix C) was proposed by John Bortle (Bortle 2001) based on 50 years of astronomical observations. Bortle's qualitative approach uses a nine-class scale that requires a basic knowledge of the night sky and no special equipment (Bortle 2001, Moore 2001, White et al. 2012, Table 4.2.2-2). The Bortle scale uses both stellar objects and familiar descriptors to distinguish among the different classes. Another advantage of the Bortle scale is that

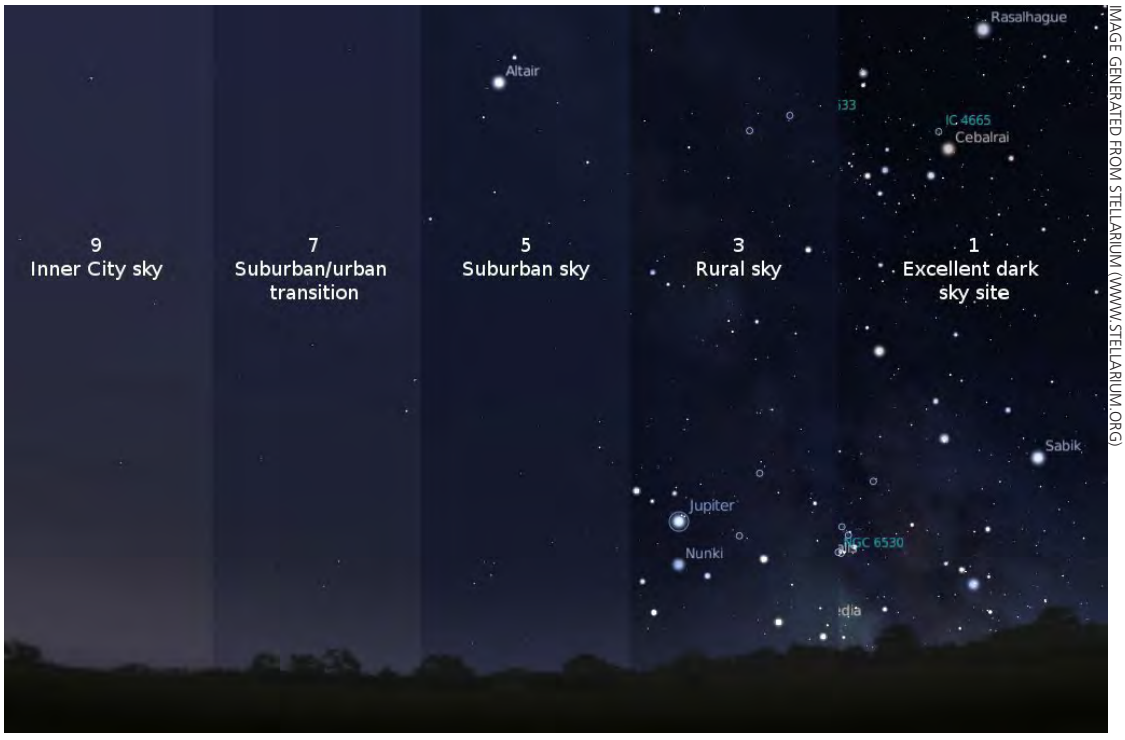



**Figure 4.2.2-1. Composite image illustrating the range of night sky conditions based on the Bortle Dark Sky Scale.**

**Table 4.2.2-2. Bortle Dark Sky Scale.***

| Bortle Scale | Milky Way (MW) | Astronomical Objects | Zodiacal Constellations | Airglow and Clouds | Nighttime Scene |
|---|---|---|---|---|---|
| Class 1 Excellent Dark Sky Site | MW shows great detail, and appears 40° wide in some parts; Scorpio-Sagittarius region casts an obvious shadow | Spiral galaxies (M33 and M81) are obvious objects; the Helix nebula is visible with the naked eye | Zodiacal light is striking as a complete band, and can stretch across entire sky | The horizon is completely free of light domes, very low airglow | Jupiter and Venus annoy night vision, ground objects are barely lit, trees and hills are dark |
| Class 2 Typical Dark Site | MW shows great detail and cast barely visible shadows | The rift in Cygnus star cloud is visible; the Prancing Horse in Sagittarius and Fingers of Ophiuchus dark nebulae are visible, extending to Antares | Zodiacal band and gegenschein are visible | Very few light domes are visible, with none above 5° and fainter than the MW; airglow may be weakly apparent, and clouds still appear as dark voids | Ground is mostly dark, but object projecting into the sky are discernible |
| Class 3 Rural Sky | MW still appears complex; dark voids and bright patches and a meandering outline are visible | Brightest globular clusters are distinct, pinwheel galaxy visible with averted vision | Zodiacal light is easily seen, but band of gegenschein is difficult to see or absent | Airglow is not visible, and clouds are faintly illuminated except at zenith | Some light domes evident along horizon, ground objects are vaguely apparent |
| Class 4 Rural-Suburban Transition | MW is evident from horizon to horizon, but fine details are lost | Pinwheel galaxy is a difficult object to see; deep sky objects such as M13 globular cluster, Northern Coalsack dark nebula, and Andromeda galaxy are visible | Zodiacal light is evident, but extends less than 45° after dusk | Clouds are just brighter than the sky, but appear dark at zenith | Light domes are evident in several directions (up to 15° above the horizon), sky is noticeably brighter than terrain |
| Class 5 Suburban Sky | MW is faintly present, but may have gaps | The oval of Andromeda galaxy is detectable, as is the glow in the Orion nebula, Great rift in Cygnus | Only hints of zodiacal light may be glimpsed | Clouds are noticeably brighter than sky | Light domes are obvious to casual observers, ground objects are easily seen |
| Class 6 Bright Suburban Sky | MW only apparent overhead, and appears broken as fainter parts are lost to sky glow | Cygnus, Scutum, and Sagittarius star fields just visible | Zodiacal light is not visible; constellations are seen, and not lost against a starry sky | Clouds appear illuminated and reflect light | Sky from horizon to 35° glows with grayish color, ground is well lit |
| Class 7 Suburban-Urban Transition | MW may be just barely seen near the zenith | Andromeda galaxy (M31) and Beehive cluster (M44) are rarely glimpsed | Zodiacal light is not visible, and brighter constellations are easily seen | Clouds are brilliantly lit | Entire sky background appears washed out, with a grayish or yellowish color |
| Class 8 City Sky | MW not visible | Pleiades are easily seen, but few other objects are visible | Zodiacal light not visible, constellations are visible but lack key stars | Clouds are brilliantly lit | Entire sky background has uniform washed out glow, with light domes reaching 60° above the horizon |
| Class 9 Inner City Sky | MW not visible | Only the Pleiades are visible to all but the most experienced observers | Only the brightest constellations are discernible | Clouds are brilliantly lit | Entire sky background has a bright glow, ground is illuminated |

*Table 4.2.2-1 also incorporates the Bortle Dark Sky Scale Key for the Summer Sky for Latitudes 30° to 50° N, White et al. 2012.

**Table 4.2.3-1. Night sky condition class summary.**

| Condition Class | ALR* | Bortle Scale |
|---|---|---|
| Good | ALR <0.33 (<26 nL average anthropogenic light in sky) | 1-3 |
| Moderate | 0.33-2.0 (26-156 nL average anthropogenic light in sky) | 4 |
| Significant concern | ALR >2.0 (>156 nL average anthropogenic light in sky) | 5-9 |

*at least half of the Historic Site's geographic area should meet the standard described

it is suitable for conditions ranging from the darkest skies to the brightest urban areas (Moore 2001, Figure 4.2.2-1).

### *4.2.3. Reference Conditions*

The ideal night sky reference condition, regardless of how it's measured, is one devoid of any light pollution. However, results from night sky data collection throughout more than 90 national parks suggest that a pristine night sky is very rare (NPS 2010). A natural night sky has an average brightness across the entire sky of 80 nL (nanolamberts, a measure of luminance), and includes features such as the Milky Way, Zodiacal light, airglow, and other starlight. This is figured into the ratio, so that an ALR reading of 0.0 would indicate pristine natural conditions where the anthropogenic component was 0 nL. A ratio of 1.0 would indicate that anthropogenic light was 100% brighter than the natural light from the night sky. For a summary of condition assessment categories for all night sky indicators, see Table 4.2.3-1.

Anthropogenic Light Ratio

The threshold for night skies in good condition is an ALR <0.33 and the threshold for a moderate condition is ALR 0.33-2.0. An ALR >2.0 suggests significant concern (Moore et al. 2013).

Bortle Dark Sky Scale

A night sky with a Bortle Dark Sky Scale class 1 is considered in the best possible condition (Bortle 2001); unfortunately, a sky that dark is so rare that few observers have ever witnessed it (Moore 2001). Non-urban park skies with a Bortle class 3 or darker are considered to be in good condition, class 4 of moderate condition, and class 5 are considered poor condition. At class 4 and higher, many night-sky features are obscured from view due to artificial lights (either within or outside the park). Skies class 7 and higher have a significantly degraded aesthetic quality that may introduce ecological disruption (Moore et al. 2013). It is important to note that such degraded conditions may be restored toward a more natural state by modifying outdoor lighting, depending on the surrounding conditions that exist outside the Historic Site.

### *4.2.4. Condition and Trend*

Modeling data provided by the NPS Night Skies Program show an ALR of 0.78 indicating moderate condition (the models have an error of $\pm$0.1 ALR).

The qualitative Bortle Scale assessment estimated the night sky quality to class 3, consistent with a rural sky, which indicates good condition.

Local and Regional Context

Bent's Old Fort NHS is located just 12 miles from La Junta and 18 miles from Las Animas, Colorado and approximately 65 miles from Pueblo, Colorado (Figure 4.2.4-1). La Junta has a population of approximately 7,077, within Otero County (population 18,831). Pueblo, Colorado is a city of 106,595 people (U.S. Census Bureau 2010). The light domes from these population centers, as well as the cities of Denver and Colorado Springs, do impact the night sky (Figure 4.2.4-2). Other sources of artificial light include homes and ranch buildings near the Historic Site. The Historic Site does include night sky interpretive programs, and the some of the

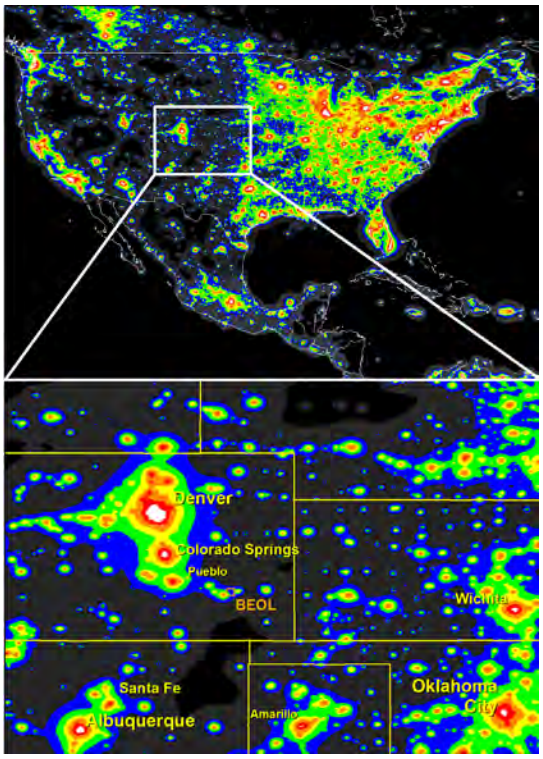
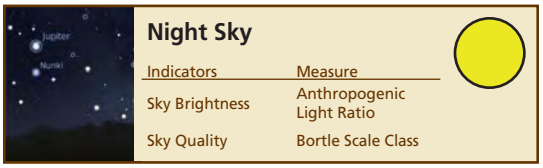



**Figure 4.2.4-1. Artificial brightness in North America and the location of Bent's Old Fort NHS (Cinzano et al. 2001).**

light is buffered by the riparian vegetation and topography of the site.




Overall Condition

Quantitative modeling of sky brightness (all-sky anthropogenic light ratio) and a qualitative assessment of sky quality (the Bortle Dark Sky Scale) were used to assess the condition of the night sky. These indicators are summarized and interpreted in Table 4.2.4-1. The overall condition of the Historic Site's night sky is moderate, based on the more reliable ALR reading and the significant influence from nearby light domes.

Uncertainties

The Bortle Dark Sky Scale estimates have inherent uncertainties and error. The principle drawback of the Bortle Scale is that it relies upon human visual observers. Differences in visual acuity, experience and knowledge, as well as time and effort expended can influence the estimates (Bortle 2001, Moore 2001). This assessment should be interpreted as interim until ground-based measures of all-sky ALR are taken (C. Moore, NPS, pers. comm.).

### *4.2.5. Sources of Expertise*

Chad Moore, Natural Sounds and Night Skies Division, part of the NPS Natural Resource Stewardship & Science Directorate provided information pertaining to night sky data collection methodology and interpretation of results. Moore earned a master's degree in earth science in 1996 and began working for the NPS shortly thereafter. Moore is the Night Skies Program manager, a small team of scientists that measure, restore, and promote the proper management of the night sky resource. He and team member Dan Duriscoe have developed an automated all-sky camera capable of precise measurement of light pollution. Since 2001 the team has collected sky quality inventories at over 110 U.S. national parks.

### *4.2.6. Literature Cited*

Bortle, J. E. 2001. Introducing the Bortle DarkSky Scale. *Sky and Telescope* February:126-129.

Cinzano, P., F. Falchi, C. D. Elvidge. 2001. The first world atlas of the artificial night sky brightness. Monthly Notices of the Royal Astronomical Society 328:689-707. Available from http://www.lightpollution.

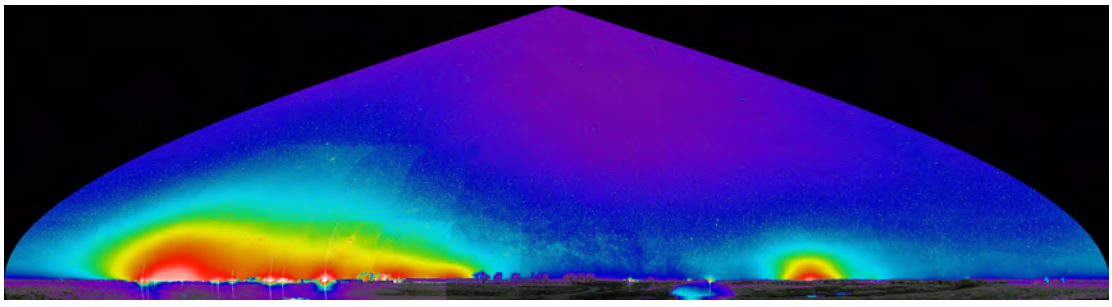


**Figure 4.2.4-2. Panoramic all-sky ALR output at Bent's Old Fort NHS (February 2008) from the NPS Night Skies and Natural Sounds Division. Notice that the Historic Site is relatively dark, but influenced by light domes of nearby towns and cities.**

**Table 4.2.4-1. Summary of night sky indicators and measures and assessment of night sky condition at Bent's Old Fort National Historic Site.**

| Indicator | Measure | Condition | Condition Rationale |
|---|---|---|---|
| Sky Brightness | Anthropogenic Light Ratio (0.78) | Moderate | This measure results from modeling data provided by the NPS Night Sky Program. Specific thresholds for condition classes have been set by the NPS. In this case, the moderate condition likely resulted from the significant light domes of nearby cities. No ground-based measurement has been collected, therefore, the confidence level in this assessment is medium. |
| Sky Quality | Bortle Scale Class (3) | Good | Although star gazing at Bent's Old Fort NHS can be quite good as far as seeing constellations, the Milky Way, and other celestial bodies, the light dome from nearby La Junta was quite visible; and point sources for homes, farm buildings and roads were also evident. Inside the Historic Site, the interfering light sources are mostly shielded by the topography and riparian vegetation, which results in this qualitative assessment of good condition. Because this measure is qualitative, it has a low confidence level. |

it/dmsp/artbri.html (accessed 27 September 2012).

Duriscoe, D., C. B. Luginbuhl, and C. A. Moore. 2007. Measuring night sky brightness with a wide-field CCD camera. *Publications of the Astronomical Society of the Pacific* 119:192-213.

Hyde, A. F. 2011. Empires, nations, and families: a history of the North American West, 1800-1860. University of Nebraska Press. Available at http://books.google.com/books?id=dxFJMMqVobQC. (accessed 26 August 2013)

Kronk, Gary W. 2013. Observing the Leonids web page. Available at http://meteorshowersonline.com/leonids.html. (accessed 26 August 2013)

Lavender, D. S. 1954. Bent's Fort. University of Nebraska Press. Available at http://books.google.com/books?id=XaZ9Lq6A4jYC&dq=the+night+the+sky+fell,+Bent's+Old+Fort&source=gbs_navlinks_s. (accessed 26 August 2013)

Moore, C. A. 2001. Visual estimations of night brightness. *George Wright Forum* 18:4655.

Moore, C. A., J. M. White, and F. Turina. 2013. Recommended indicators of nightskyquality for NPS state of the park reports, interim guidance. Natural Sounds and Night Skies Division, WASO-Natural Resource Stewarship and Science. April 10, 2013.

National Park Service. 2006. Management Policies 2006: The guide to managing the National Park System. Washington, DC. 180 pp.

National Park Service. 2010. Stargazing in parks. NPS Natural Resource Program Center Air Resources Division Night Sky Program. Available from http://www.nature.nps.gov/air/lightscapes (accessed 29 July 2012).

National Aeronautics and Space Administration (NASA). 2013. A brief history of the Leonid shower. Available from http://leonid.arc.nasa.gov/history.html (accessed 26 August 2013).

Olmsted, Denison. 1833. Observations on the Meteors of November 13th, 1833. *The American Journal of Science and Arts* 25: 363–411. Available at http://www.biodiversitylibrary.org/page/30964366#page/383/mode/1up (accessed 26 August 2013).

Royal Commission on Environmental Pollution. 2009. Artificial light in the

environment. The Stationery Office Limited, London.

U.S. Census Bureau. 2010. Profile of general population and housing characteristics. Available at http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk (accessed 26 August 2013).

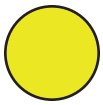
White, J., D. Duriscoe, and C. Moore. 2012. Bortle Dark-Sky Scale: Key for the summer sky, latitudes 30° to 50° North. NPS Natural Sounds and Night Skies Division.

## 4.3. Soundscape

**Indicators/Measures**

- Audibility (% Time Audible)
- Sound Level (2 Measures)

**Condition – Trend – Confidence**



Moderate - Insufficient Data - Medium

### *4.3.1. Background and Importance*

Our ability to see is a powerful tool for experiencing our world, but sound adds a richness that sight alone cannot provide. In many cases, hearing is the only option for experiencing certain aspects of our environment. An unimpaired acoustical environment is an important part of overall NPS visitor experience and enjoyment as well as vitally important to overall ecosystem health.

Visitors to national parks often indicate that an important reason for visiting the parks is to enjoy the relative quiet they can offer. In a 1998 survey of the American public, 72% of respondents identified opportunities to experience natural quiet and the sounds of nature as an important reason for having national parks (Haas and Wakefield 1998) (Figure 4.3.1-1). Additionally, 91% of NPS visitors "consider enjoyment of natural quiet and the sounds of nature as compelling reasons for visiting national parks" (McDonald et al. 1995). Despite this desire for quiet environments, anthropogenic noise continues to intrude upon natural areas and has become a source of concern in national parks (Lynch et al. 2011).

Sound also plays a critical role in intraspecies communication, courtship and mating, predation and predator avoidance, and effective use of habitat. Studies have shown that wildlife can be adversely affected by sounds that intrude on their habitats. While the severity of the impacts varies depending on the species being studied and other conditions, research strongly supports the fact that wildlife can suffer adverse behavioral and physiological changes from intrusive sounds (noise) and other human disturbances. Documented responses of wildlife to noise include increased heart rate, startle responses,



NPS

**Figure 4.3.1-1. Natural sounds, such as the cicada seen here, as well as Bent's Old Fort cultural sounds all contribute to the Historic Site's soundscape.**

flight, disruption of behavior, and separation of mothers and young (Selye 1956, Clough 1982, USDA 1992, Anderssen et al. 1993, NPS 1994a).

A park's natural soundscape is an inherent component of "the scenery and the natural and historic objects and the wildlife" protected by the Organic Act of 1916. NPS Management Policies (§ 4.9) (2006) require preservation of parks' natural soundscapes and restoration of degraded soundscapes to natural conditions wherever possible. Additionally, NPS is required to prevent or minimize degradation of the natural soundscapes from noise (i.e., any unwanted sound). Although the management policies currently refer to the term soundscape as the aggregate of all natural sounds that occur in a park, differences exist between the physical sound sources and human perceptions of those sound sources. The physical sound resources (i.e., wildlife, waterfalls, wind, rain, and cultural or historical sounds), regardless of their audibility, at a particular location, as the acoustical environment, while the human perception of that acoustical environment is defined as the soundscape. Clarifying this distinction will allow managers to create objectives for safeguarding both the acoustical environment and the visitor experience.

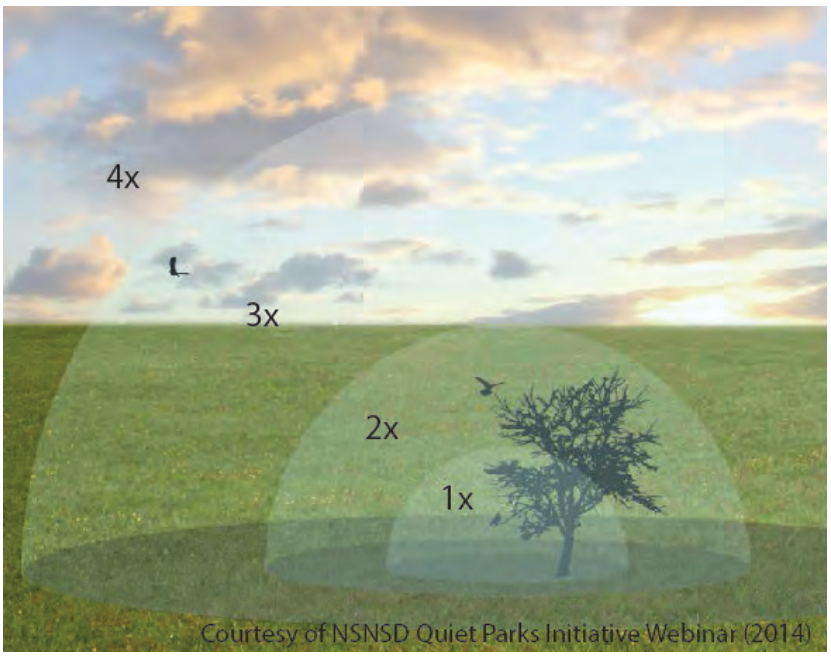



**Figure 4.3.1-2. A 6 dBA reduction in sound would produce a 4x increase in listening area (NSNSD 2014).**

Sound Characteristics

Humans and wildlife perceive sound as an auditory sensation created by pressure variations that move through a medium such as water or air. Sound is measured in terms of frequency (pitch) and amplitude (loudness) (Templeton and Sacre 1997, Harris 1998).

Frequency, measured in Hertz (Hz), describes the cycles per second of a sound wave, and is perceived by the ear as pitch. Humans with normal hearing can hear sounds between 20 Hz and 20,000 Hz, and are most sensitive to frequencies between 1,000 Hz and 6,000 Hz. High frequency sounds are more readily absorbed by the atmosphere or scattered by obstructions than low frequency sounds. Low frequency sounds diffract more effectively around obstructions. Therefore, low frequency sounds travel farther.

Besides the pitch of a sound, we also perceive the amplitude (or loudness) of a sound, which is measured in decibels (dB). The decibel scale is logarithmic, meaning that every 10 dB increase in sound pressure level (SPL) is equivalent to moving sound source more than three times closer to the listener (Lynch et. al. 2011). This also means that small variations in SPL can have significant effects on the acoustical environment. For instance, a 6 dB increase in a noise source will double the distance at which it can be heard, increasing the affected area by a factor of four (Figure 4.3.1-2). SPL is commonly summarized in terms of dBA (A-weighted SPL). This metric significantly discounts sounds below 1,000 Hz and above 6,000 Hz to approximate the variation in human hearing sensitivity.

In addition to loudness (amplitude) and pitch (frequency), the duration of sounds, as well as number of times a particular sound is heard (i.e., rate of occurrence), influences whether sounds contribute or detract from a visitor's park experience or a wildlife species' ability to communicate effectively.

### *4.3.2. Data and Methods*

A formal soundscape assessment has not been conducted by NSNSD at Bent's Old Fort NHS. So for the purposes of this assessment, we conducted on-site listening sessions

**Table 4.3.2-1. Summary of on-site listening sessions at Bent's Old Fort NHS.**

| Location | Date | Time | Session Duration | Wind Speed and Direction[1] | Weather |
|---|---|---|---|---|---|
| Inside Fort | June 3, 2013 | 10:30-11:30 AM | 60 minutes | 5-7/SW | 89• and Sunny |
| | June 4, 2013 | 9:30-10:30 AM | 60 minutes | 5-7/NW | 98• and Partly Cloudy |
| Picnic Area | June 3, 2013 | 12:20-12:50 PM | 30 minutes | 8.8-6.2/SW | 89• and Sunny |
| Nature Trail-Cottonwoods | June 4, 2013 | 10:45-11:45 AM | 60 minutes | 6.2-5.1/NW | 98• and Sunny |

[1]Wind speed and direction data are from NOAA Satellite and Information Service (2013)-La Junta monitoring station.

at three locations (described below) from June 3-4, 2013 (Figure 4.3.2-1). Table 4.3.2-1 summarizes the time and conditions of the recording sessions conducted at each of the three locations.

During these sessions, an observer was situated at the designated listening location with a handheld Personal Digital Assistant (PDA). The observer listened for the designated period of time and identified all sound sources and their durations. This type of monitoring took full advantage of human binaural hearing capabilities while providing the closest match to a park visitor's experience. Several limitations to this method included indirectly measuring amplitude, a short sample period, and a small sample size. Instead, this technique primarily provided a baseline for future monitoring efforts and a "snapshot" of soundscape condition.

We augmented the on-site listening method by using the NSNSD's sound level model data for the area surrounding the Historic Site to provide an additional indicator. The model provided a quantitative sound level impact that measured the difference between the Historic Site's natural /ambient sound level versus the existing sound level.

The results for each on-site listening session and for NSNSD sound model maps can be found in Appendix D.

On-site Listening Locations

*Inside Fort*: This location was along the wall between the trade room and dining room. Both 1-hour sessions were recorded in the morning, and a large school group was present during one of the sessions.

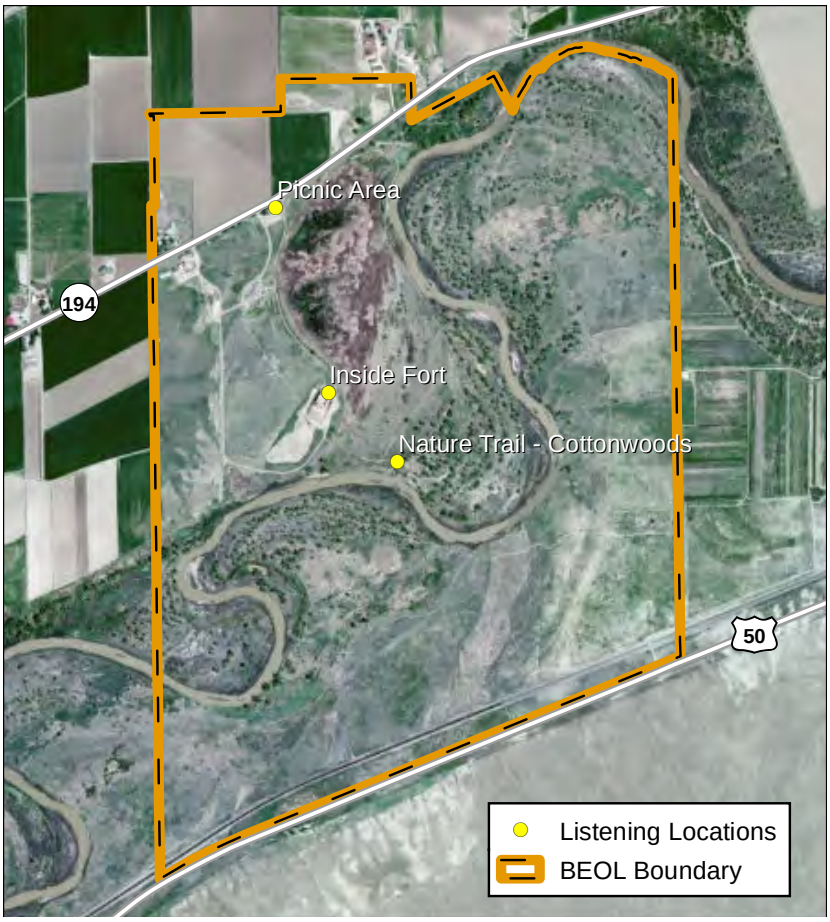



**Figure 4.3.2-1. On-site listening locations.**

*Nature Trail-Cottonwoods*: This location was along the Nature Trail behind the Fort just as you enter the cottonwoods and close to the Arkansas River bend where the wooden fence is located. This session occurred while a school group of ≥ 100 were visiting the Fort. A recording session was also attempted on June 3rd, but due to battery failure, only 13 minutes were recorded and are not included in this assessment.

*Picnic Area:* This location was at the picnic area located near the Fort entrance adjacent

**Table 4.3.2-2. Indicators and measures used to assess the soundscape at Bent's Old Fort NHS.**

| Indicator | Measure | Definition |
|---|---|---|
| Audibility | % Time Audible | The percent of time that a particular sound may be detected by the human ear (Lynch 2011) is the measure for audibility. For determining condition, we focused on the percent of time that noise (only) was heard (as opposed to natural or cultural sounds). |
| Sound Level | Amplitude of Impact Sound Level (regional scale) | "Using long-term sound pressure level measurements from hundreds of sites across the contiguous United States, geospatial models were developed to predict sound levels. These sound models incorporated spatial representations of biological, geophysical, climatic, and anthropogenic factors to assess expected contributions to the existing sound pressure level from both anthropogenic and natural sources, which enable mapping of sound pressure levels at regional and national scales" (cited from Mennitt et al. 2013). This sound level information supplements the qualitative on-site listening results. |
| | Amplitude (at on-site monitoring locations) | Loudness or amplitude of a sound is typically measured in decibels (dB). The decibel scale is logarithmic, meaning that every 10 dB increase in sound pressure level (SPL) is equivalent to moving sound source more than three times closer to the listener (Lynch et. al. 2011). We did not measure amplitude directly; rather we derived inferences from the previously reported amplitude of different sound sources based upon the sounds heard. |

to Highway 194. The school groups that were touring the Fort during the Fort logging session on June 3rd were also picnicking at this site during the recording session.

The primary indicators we used to assess the soundscape condition were audibility and sound level, with one and two measures, respectively (Table 4.3.2-2).

### Indicators/Measures
Sound Level (2 measures)

During the on-site listening sessions, we gathered information about the types of sounds that were audible, how long they were audible, and the number of events for each sound that was heard, using the handheld PDA. We discuss the results as percent time audible for each type of sound heard at each on-site listening location.

### Indicators/Measures
Audibility (% Time Audible)

Sound levels were assessed in two ways (1) using sound models created by Mennitt et al. (2013) to provide quantitative parkwide/regional sound levels, and (2) using on-site monitoring information to qualitatively determine sound levels by referencing common sound levels reported in literature.

Mennitt et al. (2013) created sound level models at regional and national scales. The model used spatial, meteorological, and actual sound level measurements from 100s of sites (primarily located in the west) to model sound levels for natural and existing conditions, as well as to model the impact of the sound levels based on the difference between the modeled natural and existing sound levels. We used the results from this model to provide a quantitative assessment of sound level at Bent's Old Fort NHS.

For the qualitative sound level assessment, we evaluated the relative levels of sounds heard while monitoring on-site to common sound levels reported throughout the literature. While we are aware of the fact that this qualitative approach did not capture the sound levels in a repeatable way, we believe this method still provided important on-site information that may be influenced more directly.

Context for Evaluating Sounds Heard During On-site Listening

Whether or not a given sound contributes to or detracts from the soundscape condition depends largely on whether or not that sound is appropriate for the context. Like many other historic parks, Bent's Old Fort NHS was established because of its historical significance. Its designated purpose includes commemoration, preservation, and maintenance of the Historic Site for visitor education and enjoyment (NPS 2013). As such, sounds that contribute to the education and enjoyment of the Historic Site's visitors,

even though they are not natural sounds, are considered appropriate to the soundscape.

If this were a wilderness setting, natural versus anthropogenic sounds might be a pertinent distinction for how a sound is perceived. However, the context and setting at Bent's Old Fort is quite different in that there are elements of the historic context as well as an educational context. Thus, in addition to the natural sounds that contribute to the sense of place of a prairie setting, the anthropogenic sounds that might have been heard during the 1833-1849 period the Fort was active, also contribute to the soundscape. For example, sounds produced by gatherings of people or by a blacksmith contribute to the understanding and appreciation of the historic context and enjoyment of the Historic Site (Figure 4.3.2-2). Thus, for the purpose of this assessment, we considered sounds that were consistent with the historic context, if present, to contribute to the soundscape condition.

In contrast, some anthropogenic sounds, such as low flying aircraft, vehicles, or excessive human voices may detract from the "sense of place" of the site's historic context and can be perceived negatively as noise, detracting from the soundscape.

For these reasons, we considered sound types within the context of belonging to two classes: (1) natural, cultural, and recreational-appropriate sounds, and (2) noise (any unwanted sound). The first class was considered as having a neutral or positive influence on soundscape condition; whereas excessive noise, especially in locations where noise is unexpected due to designated use was considered to have a negative effect, contributing to a lower soundscape condition. Some common examples of expected sounds at the Historic Site are listed in Table 4.3.2-3.

Additionally, the locations where the sounds were heard, based upon the Historic Site's designated management zones, affected the soundscape condition. Each management zone has designated activities and common sound types. These factors were taken into consideration throughout this assessment.


NPS

**Figure 4.3.2-2. Appropriate sounds at Bent's Old Fort include the cultural sounds of the historic context, such as the blacksmiths seen here, as well as the natural sounds of the Fort's setting.**

### *4.3.3. Reference Conditions*

Studies identifying effects of noise on human health and well being and effects of noise on wildlife serve as guides for the quality of visitor soundscape experience reference conditions shown in Table 4.3.3-1.

We considered the soundscape to be in good condition if sounds heard were consistent with Historic Site designated activities, if no excessive sound/noise levels were present in any area of the Historic Site, regardless of designated use, and if noise-free intervals were common.

We considered a moderate condition soundscape to be one where the designated uses for a higher activity area (e.g. parking lot) began to infiltrate into lower use zones (e.g., historic), noise-free intervals became only moderately common, and noise levels began to be heard throughout the Historic Site.

A significant concern soundscape condition was when noises became incongruent with Historic Site designated activities/purpose and/or were disruptive, regardless of the area within the park. Also, noises generated by military overflights, fast moving traffic, etc., were present.

**Table 4.3.2-3. Types of sounds expected at Bent's Old Fort NHS.**

| Natural, Cultural, and Recreational Sounds | Noises |
|---|---|
| • Birds<br>• Insects<br>• Frogs<br>• Wind<br>• Rustling Leaves<br>• Rain/Thunder<br>• Flowing Water<br>• Living history sounds such as blacksmith anvil,<br>• fire crackling, peacock and farm animal vocalizations<br>• Flag flapping<br>• Interpretive programs<br>• Visitor conversations (normal levels) | • Trains<br>• Planes<br>• Automobiles/Horns<br>• Cash register<br>• Mowing<br>• Generators<br>• Raised voices/yelling |

These reference conditions are roughly divided into two main categories: (1) the effects of noise on the quality of visitor experience, and (2) the effect of location where noise is heard, which are described below.

Effects of Noise on Human Health (serves as a guide to help assess visitor soundscape experience)

There have been numerous studies on the effects of noise on human health and probably the most commonly studied effects are cardiovascular from exposure to noise. The World Health Organization (Berglund et al. 1999) suggests that even prolonged exposure to noise levels below 75dB will not result in noise induced hearing loss. They also conclude that prolonged exposure to air and road traffic noises above 65-70 dB are associated with cardiovascular effects, but this is from exposure times that far exceed what is likely to be encountered during a Historic Site visit. The threshold levels for responses such as raising of blood pressure are much lower. However, these human health responses, at the levels of noise exposure at Bent's Old Fort are not likely to cause any physical damage Thus, for the most part, noise levels exceeding thresholds for damage to human health are not of high concern at Bent's Old Fort. The most likely exception to this is Historic Site staff operating machinery (e.g., mowers, tractors, etc.), although damage to human health is not of high concern, this does not imply that there are no physiological responses to noise.

Effects of Noise on Wildlife (serves as a guide to help assess visitor soundscape experience)

Research has indicated that the effects of noise on wildlife populations can vary widely among species and conditions, although birds have probably been most widely studied. Most effects fall into one of three categories: (1) behavioral and/or physiological effects, (2) damage to hearing from acoustic over-exposure, and (3) interference with communication (Dooling and Popper 2007). Since birds are probably more resistant to hearing loss or damage from noise than are humans (Dooling and Popper 2007) the threshold identified for damage to human hearing should be adequate to also account for damage to wildlife hearing. Similarly, the noise levels that interfere with human communication are also similar to the thresholds identified for interference with communication and/or annoyance.

For example, Dooling and Popper (2007) suggest that it is unlikely that a traffic noise level below an overall level of about 50-60 dB(A) would have much of an effect on acoustic communication or the biology of a bird in a quiet suburban area (see also Kaseloo 2006). Because the thresholds for wildlife appear to be similar to the thresholds we identified for visitor experience and because the responses by wildlife are varied and complex, we have assumed for the purposes of this assessment that a degraded condition for visitors would also likely have potential impacts to birds specifically.

Effects of Noise on the Quality of Visitor Experience

An essential component of the designated purpose of Bent's Old Fort NHS relative to the soundscape is to provide for visitor enjoyment and education. A key element of this is maintaining a sense of place for the Fort such that visitors can visualize being back in time, experiencing the sights, smells, and sounds of the 1800s. Historic Site staff engage in living history activities from the time the Fort was active, which provide a context for the life and trades during that period. From the historic setting of the Fort, with natural sounds from the river, leaves rustling, or birds singing to the historic sounds of the day to day activities of life at Bent's Old Fort, all are part of the education and enjoyment of being transported back in time. However, it is difficult to imagine being in the 1800s while a military jet is flying overhead or a car horn is honking. Thus, we consider condition of the soundscape relative to a visitor being able to gain a sense of place in the Fort's setting, which includes natural and cultural sounds, and an enjoyable educational experience at the Fort. Condition is deteriorated when noise interrupts normal conversation, when such noise is frequent enough or loud enough to detract from the sense of place and/or to be annoying to visitors trying to appreciate the historic context of the Historic Site.

Effect of Location (Management Zone) on Reference Condition.

Inherent in our condition assessment is how sounds are perceived by visitors and whether or not they contribute or detract from the their education and enjoyment of the site. Whether or not sounds are perceived negatively depends not only on the type of sound but also where it is heard. For example, a visitor is probably going to be less annoyed by noises from vehicles if they are in the parking lot than if they are along the nature trail by the river.

Consequently, we take into consideration where sounds are heard throughout the Historic Site and the expectations of different sounds based on management zones as defined in its General Management Plan (NPS 1994b) when considering the condition of the soundscape (Figure 4.3.3-1).




**Figure 4.3.3-1. Designated management zones at Bent's Old Fort NHS.**

## *4.3.4. Condition and Trend*

Overall, the most common sounds heard throughout the Historic Site during the on-site listening sessions were wind, rustling leaves, and bird songs/calls. Additionally, several types of cultural-related sounds were heard while monitoring inside the Fort. The majority of vehicle noise heard was generated from outside the Historic Site's boundary. This included traffic traveling along U.S. Highway 50, which runs along the Historic Site's southern boundary, and from State Highway 194, which bisects the northern portion of the Historic Site (Figure 4.3.4-1). Additionally, the Historic Site has two access roads and several dirt roads that are located throughout the Site, although very little traffic noise along these access roads, if any, could be heard while monitoring.

**Table 4.3.3-1. Activities and associated sounds expected within each management zone (NPS 1994b) that influence the reference condition within that zone.**

| Management Zone (Degree of Human Activity) | Typical Activities and Associated Sounds |
|---|---|
| Historic (Cultural & Natural) (Medium-Low Activity) | This zone, which includes 99% of the Historic Site area, is managed for preservation and interpretation of cultural resources and associated setting to provide use and enjoyment for the public. The dominant sounds, consistent with designated use, range from the natural ambient sounds such as wind, leaves rustling, birds singing, thunder claps, etc. to sounds related to cultural and visitor activities. |
| Development (High Activity) | This zone includes visitor service facilities, including visitor center, picnic area, and parking lots, administrative and operational facilities and the railroad right-of-way. The dominant sounds may be natural sounds when human-created sounds are absent, however, typical noises consistent with designated activities include normal conversation voices, voices from group gatherings, motorized vehicles driving by, short-duration idling, or starting/stopping of vehicles, periodic use of motorized tools and heavy equipment. |

**Table 4.3.3-2. Reference conditions used to assess soundscape condition at Bent's Old Fort NHS.**

| Indicator | Measure | Good | Moderate | Significant Concern |
|---|---|---|---|---|
| Audibility | % Time Audible | Dominant sounds are consistent with park's designated purpose. Natural ambient sounds such as wind, leaves rustling, birds singing, thunder claps, etc. and sounds related to cultural and visitor activities are expected. Some sources of noise (e.g., automobiles) are acceptable in the development zone provided they are consistent with the expectations for that zone and are audible for a small percentage of the time. | The dominant sounds are generally consistent with park's designated purpose, but noise occurs more frequently and noise from the development zone is beginning to infiltrate into the historic zone. A historic sense of place is still maintained, but is periodically interrupted by audible noises. | A high percentage of the audible sounds heard are from noise such that the historic and natural sense of place, therefore, the education and enjoyment of visitors is compromised. |
| Sound Level | Amplitude (loudness) | Natural and historic-context appropriate sounds are consistent with the expected sound levels of the historic Fort. Visitors typically maintain quiet to normal conversation levels (e.g., 40-50 dB), and interpreters talking to larger groups rarely exceed 55-60 dB. There is a sightly higher tolerance for noise levels in the developed areas, but should rarely exceed 60 dB. The natural sound level for the Historic Site modeled for Mennitt et al. (2013) was 26.9-28.7 dBA, which can serve as a sound level reference. | Natural, cultural, and recreational sound levels are generally consistent with the Historic Site's designated purpose, noise > 55 dB is beginning to be heard in many areas so as to cause occasional interference with normal conversation and annoyance among some visitors. Noise greater than approximately 65 dB is still quite rare. | The historic and natural sense of place is compromised due to frequent loud noise(s). Communication among interpreters and visitors is frequently interrupted by loud noise impacting visitor enjoyment and educational experience. Noise levels that might interfere with wildlife behavior and auditory signals, disrupt conversation or evoke annoyance (e.g., exceeding 55-60 dB) may occur. |

*Audibility Within the Fort*

The majority of sounds heard within the Fort were either natural or appropriate anthropogenic sounds related to living history and visitor activities (Figure 4.3.4-2). Wind and bird vocalizations were the primary natural sounds heard during both 1-hour monitoring sessions, and the Fort had the highest noise-free interval recorded. The most common cultural-related sounds included visitor conversations (which is consistent with the Fort being a "babel of a place" (NPS 2013), Historic Site staff providing interpretive talks, and visitor/Historic Site staff foot- steps on the crushed stone throughout the Fort. The different types of Fort-related living history sounds, included the crackling of woodfire, anvil pounding and billows in the blacksmith

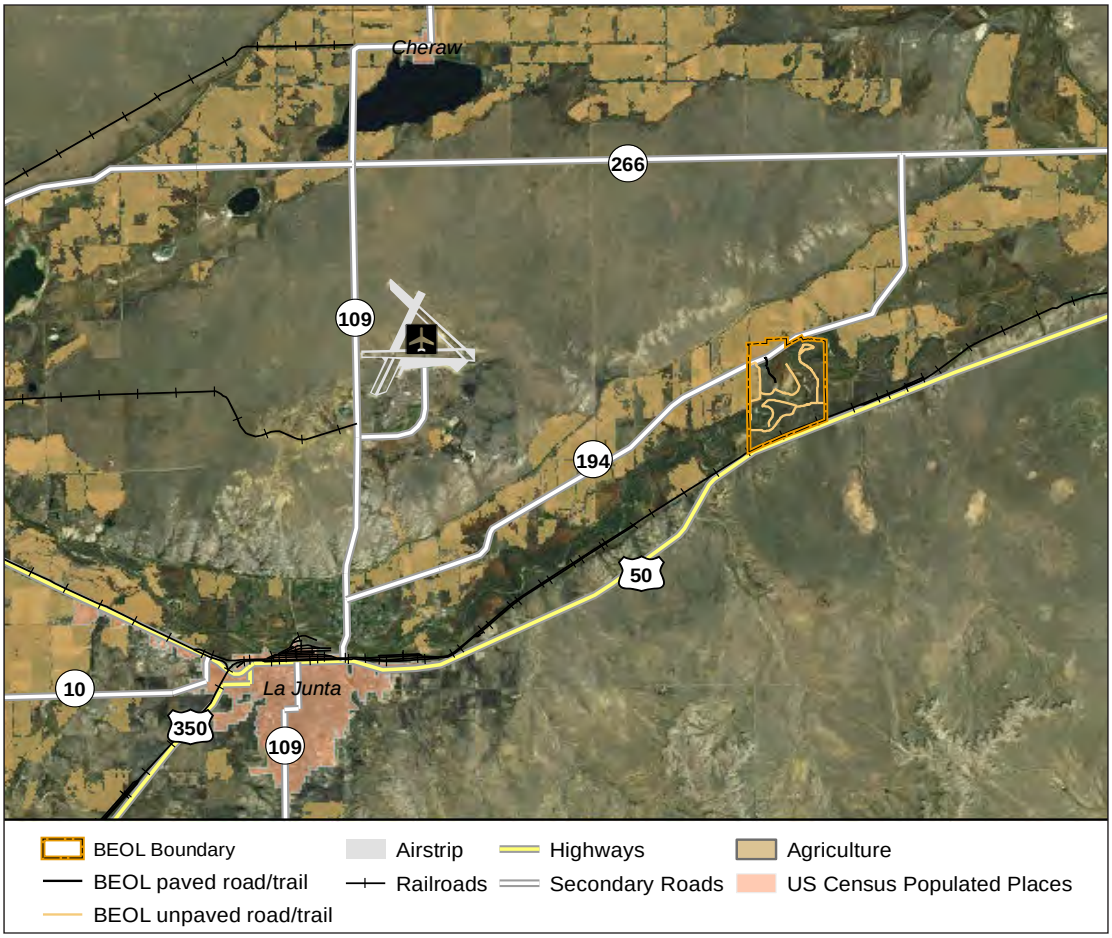



**Figure 4.3.4-1. Surrounding developments and land uses that contribute to the noises heard throughout the Historic Site.**

shop, and the flag clanking against the metal flagpole.

Additional historic context-related sounds heard included farm animal and peacock vocalizations, but all were audible <3% of time, therefore, not shown in Figure 4.3.4-2.

Historic Site staff conversation was audible for the highest percentage of time, but only when visitors were absent. Since staff conversations took place in the absence of visitors, we do not consider this as a noise contributing to the degradation of the Historic Site's soundscape. Additional noises heard from within the Fort included cash register operations and ringing of the phone.

The other noises heard were generated outside the Historic Site's boundary and were from vehicles traveling along Highways 50 and 194, jets, and trains traveling the Burlington Northern Santa Fe Railway, which runs parallel to the Historic Site's southern boundary.

The overall percent time audible of anthropogenic noise heard within the Fort was 53% and 91%, warranting significant concern for this measure.

*Sound Level Within the Fort (on-site listening results)*

The pounding of the blacksmith's anvil and peacock vocalizations were heard and both are appropriate to the Fort's soundscape.

The Fort's soundscape was also periodically punctuated by the loud noises of phones ringing, cash register operations, and in the distance, vehicles traveling along the highways, trains passing, and jets flying overhead.

Materials are transported along this stretch of railway from Chicago, IL, Kansas City, KS, cities along the east coast of the United States, and hubs in southern California (BNSF Railway 2012), thus receiving a fair amount of train activity. According to a Historic Site employee, if the wind is blowing in a southerly or southwesterly direction, a passing train

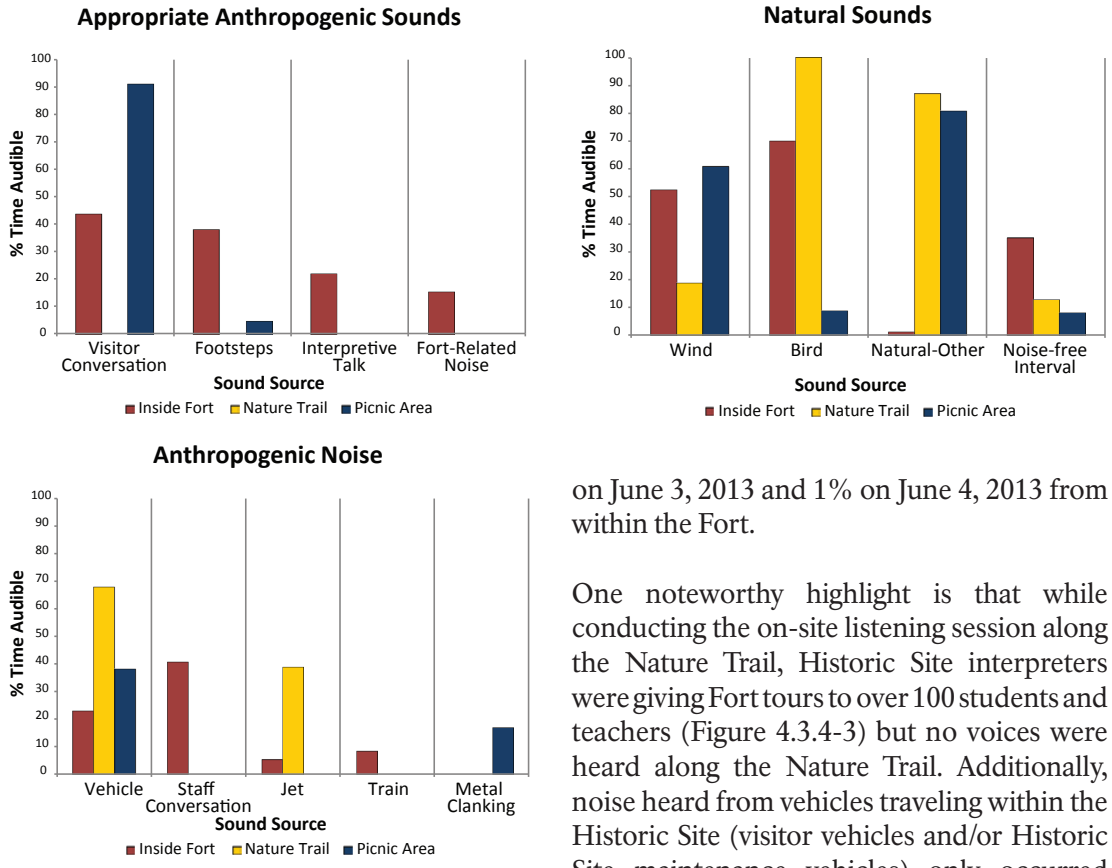



**Figure 4.3.4-2. Sound sources heard and percent time audible at on-site monitoring locations.**

sounds like it is actually in the Fort itself because the level is so loud (Adam Heberlie, pers. comm. June 4, 2013). Although, this experience did not occur during our brief on-site listening sessions.

Of all three monitoring sites, the Fort had the highest percent noise-free interval and is considered good to moderate condition relative to this measure. We included the moderate rating based on the excessively high train noise when conditions are conducive.

*Audibility Along the Nature Trail-Cottonwoods*
The majority of sounds heard along the Nature Trail were nature-based, including wind, leaves rustling, and birds vocalizations. However, noises generated from vehicles primarily traveling along Highway 50, and to a lesser extent along Highway 194, were heard more frequently along the Nature Trail than from inside the Fort (with the exception of semi-trucks).

Noise generated by jets could also be heard more frequently along the Nature Trail, 39% of the time as compared to 11% of the time on June 3, 2013 and 1% on June 4, 2013 from within the Fort.

One noteworthy highlight is that while conducting the on-site listening session along the Nature Trail, Historic Site interpreters were giving Fort tours to over 100 students and teachers (Figure 4.3.4-3) but no voices were heard along the Nature Trail. Additionally, noise heard from vehicles traveling within the Historic Site (visitor vehicles and/or Historic Site maintenance vehicles) only occurred once.

Noises heard at the cottonwoods site occurred 87% of the time, and we considered the soundscape at this location to be of significant concern relative to this measure.

*Sound Level Along the Trail (on-site listening results)*
With the exception of semi-trucks, vehicle noise was distant (therefore lower decibels), making it relatively unobtrusive along the trail.

Aircraft overflights were also heard, but they too tended to be distant and relatively unobtrusive. Of the three locations, this one was the quietest in terms of decibel level and considered to be in good condition.

*Audibility at the Picnic Area*
The picnic area is located adjacent to Highway 194 and the main park entrance so traffic noise was heard 38% of the time, which was the highest amount of noise heard at this location. Other types of sounds heard at the picnic area included visitor-related activity (e.g., conversations, noises at the picnic


MARK BRUNSON

**Figure 4.3.4-3. No sounds were heard from these school groups touring Bent's Old Fort while conducting the on-site listening session along the Nature Trail.**

tables, and vehicles in the parking lots) and cottonwood leaves rustling. The relatively windy condition generated a noise of metal clanking against a pole, which was located adjacent to the picnic area.

Out of the three on-site listening locations, the picnic grounds had the highest percent time audible of a recreational-based sound, which was from visitor conversations, but this was expected due to its designation as a visitor use area. The lowest noise free interval, 4.8%, occurred at the picnic grounds, and the overall percent time audibility of noises recorded was 100%, warranting significant concern.

*Sound Level at the Picnic Area (on-site listening results)*

Vehicle noise was by far the loudest noise heard at the picnic area due to the close proximity of the highway. Even though visitors did not appear to be negatively impacted by the noise generated from traffic traveling along Highway 194 and the main park entrance, it was the most impacted soundscape location, relative to this measure, in the Historic Site due to the increased decibel level. As a result of the louder sound levels of vehicles traveling outside the Historic Site's boundary, we consider the soundscape condition at the picnic area to be of moderate-significant concern.

*Sound Level for All Three Monitoring Sites (park-wide/regional model results)*

The model results for the natural ambient and existing sound levels across the entire Historic Site ranged from 26.9-28.7 dBA and 32.7-37.3 dBA, respectively (Mennitt et al. 2013 and E. Lynch, NSNSD, pers. comm.) (Figure 4.3.4-4). Mennitt et al. (2013) suggested that in a natural environment, the average summertime $L_{50}$, which is the sound level exceeded half of the time and is a fair representation of expected conditions, is not expected to exceed 41 dBA.

The difference between these two ranges is 4.1-9.2 dBA and is referred to as the impact level. According to Mennitt et al. (2013), "an impact of 3dBA suggests that anthropogenic noise is noticeable at least 50% of the hour or more." NSNSD also provides soundscape reference conditions for the purposes of *The State of the Park* reports, which groups parks into urban versus non-urban. If we consider the Historic Site as a non-urban park, the threshold for significant concern is an impact level that is greater than three. If we consider

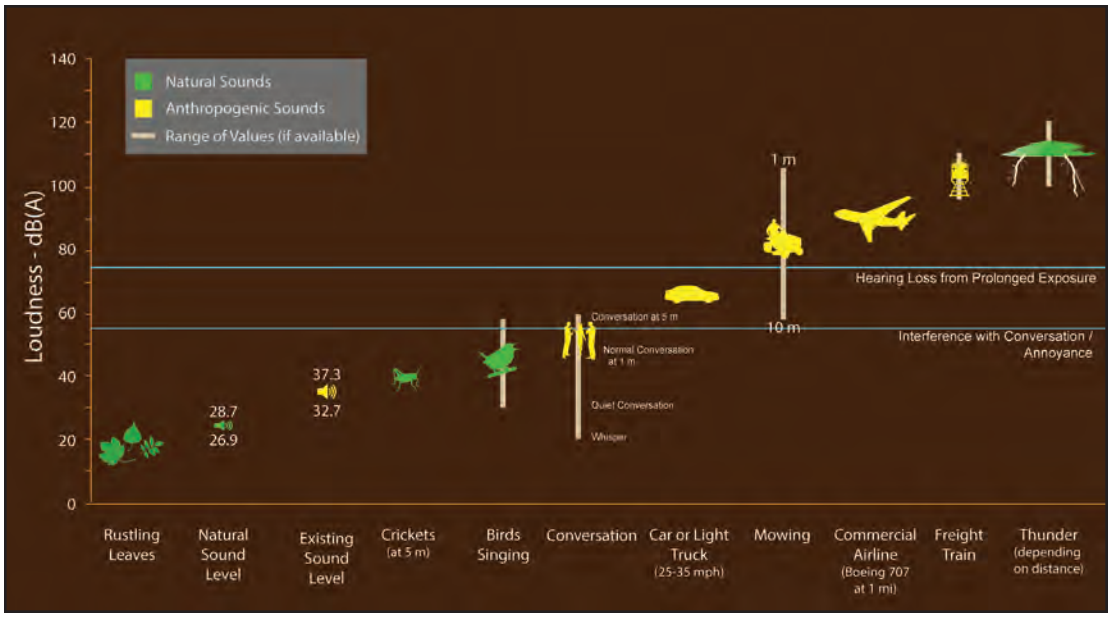
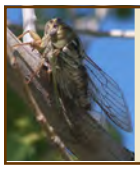



**Figure 4.3.4-4. Approximate sound levels for sounds heard at the Historic Site (at specified distances), and modeled sound levels for Bent's Old Fort NHS (Mennitt et al. 2013).**

**The modeled natural sound level range was 26.9 - 28.7 dBA and the modeled existing sound level range was 32.7 - 37.3 dBA (both (located between rustling leaves and crickets).**

the Historic Site to be an urban park, the threshold for moderate concern is interpreted to be an impact level between 6-12 dBA. We consider Bent's Old Fort NHS fit somewhere between urban and non-urban, which results in a moderate concern for sound levels based on Mennitt et al. (2013) sound model.



**Soundscape**

| Indicators | Measure |
|---|---|
| Audibility | % Time Audible |
| Sound Level | Amplitude (loudness) |

Overall Condition and Trend

For assessing the condition of the Historic Site's soundscape, we used two indicators and three measures, which are summarized in Table 4.3.4-1.

In general, the most common sound heard, with the highest percent time audible at all three locations, was wind and associated wind-induced sound from rustling leaves. Wind is known for its masking /dampening effect on hearing other sounds and is common in the wide open prairie country where Bent's Old Fort NHS is located.

Agricultural land surrounds the Historic Site on three sides of its boundary and while noises from farm machinery including crop dusters, which operate seasonally in the early morning hours (before typical visitation hours), contribute to the types of noises heard throughout the Historic Site during various seasons, they were not recorded during the brief on-site listening sessions conducted June 3-4, 2013.

Additionally, periodic aircraft sounds were heard. The La Junta Municipal Airport is located a little over three miles west of the Historic Site. According to FAA (2013), aircraft operations at the airport average 132 flights per week for a 12-month period ending December 31, 2010. Sixty-seven percent of the flights were for transient general transportation, 28% were for local general aviation, and 5% was military flights.

In large part, noise generated from within the Historic Site, including staff operational activities or visitor vehicle noise were nearly absent, especially while listening within the Fort itself and along the Nature Trail. The majority of noises heard were generated from outside the Historic Site's boundary and included vehicles traveling along both highways, airplanes, and trains.

While the locations where sounds were heard were consistent with designated uses, the percent time audibility of noises always exceeded 50% of the time. As a result of weighing all indicators and measures, we consider the overall soundscape condition to be of moderate concern, with an unknown trend.

**Table 4.3.4-1. Summary of the soundscape indicators/measures and their contribution to the overall soundscape condition assessment.**

| Indicators of Condition | Measures | Condition | Rationale for Condition |
|---|---|---|---|
| Audibility | % Time Audible | Significant Concern | The percent time audibility of all non-natural sounds ranged from 53% of the time to 100%, indicating that noises could always be heard over more than half of the monitoring time. There were a higher number of natural and cultural sounds compared to noises at all three locations, even though vehicles were commonly heard. Additionally, jets were heard from within the Fort and cottonwoods, whereas, the train was only heard while in the Fort. Due to the considerable presence of noise at all three locations, we consider this measure to be of significant concern. |
| Sound Level | Amplitude of sound Level Impact (park-wide/regional model) | Moderate | The modeled impact sound level for the Historic Site ranged between 4.1-9.2 dBA. This range is within a condition rating for moderate concern when evaluating a park classified between a non-urban and urban park using NSNSD thresholds. |
| | Amplitude (of sounds at on-site monitoring locations) | Good-Moderate | The louder noises were heard at the picnic area due to traffic traveling outside the Historic Site's boundary. Vehicle noises were also commonly heard within the Fort and along the Nature Trail, but at lower levels due to the increased distance from the roads. Even though the train noise heard was not very loud while monitoring, according to one employee, if the wind is blowing from the south or southwest, it can be very loud. Consequently, we considered this measure to be between good and moderate condition. |

Level of Confidence and Key Uncertainties

This was a very brief, rapid assessment of the Historic Site's soundscape, establishing a relative baseline for a future quantitative assessment or for similar future rapid assessment comparisons. With such a small dataset and short sample period, our confidence is low. But given the sound level model produced by Mennitt et al. (2013), the confidence level in our evaluation of the soundscape condition throughout the Historic Site is of medium confidence.

### *4.3.5. Sources of Expertise*

The NPS Natural Sounds and Night Skies Division scientists help parks manage sounds in a way that balances the various expectations of park visitors with the protection of park resources. They provide technical assistance to parks in the form of acoustical monitoring, data collection and analysis, and in developing acoustical baselines for planning and reporting purposes.

The NSNSD provided an NRCA soundscape template, which was used to develop Bent's Old Fort NHS' soundscape assessment. They also loaned the PDA for recording sounds at the Historic Site and generated reports from which we based our discussion on. For more information, see http://www.nature.nps.gov/sound/. Finally, they provided the sound model results and maps, which are included in Appendix D.

### *4.3.6. Literature Cited*

Anderssen, S.H., R.B. Nicolaisen, and G.W. Gabrielsen. 1993. Autonomic response to auditory stimulation. Acta Paediatrica 82:913-918

Berglund, B., T. Lindvall, and D.H. Schwela (eds.). 1999. WHO. Guidelines for community noise. World Health Organization, Geneva.

Burlington Northern Santa Fe Railway (BNSF). 2012. BNSF intermodal service schedules. Available at http://www.bnsf.com/customers/prices-and-tools/intermodal-schedules/ (accessed May 7, 2013).

Clough, G. 1982. Environmental effects on animals used in biomedical research. Biological Reviews 57:487-523.

Dooling, R., & Popper, A. 2007. The effects of highway noise on birds. Rockville, MD: Environmental BioAcoustics LLC.

FAA. 2013. La Junta Municipal Airport. Available at http://www.airnav.com/airport/KLHX (accessed May 7, 2013).

Haas G.E. and T.J. Wakefield. 1998. National Parks and the American public: a summary report of the National Parks Conservation Association, conducted by Colorado State University, Fort Collins, CO

Harris, C. M. 1998. Handbook of Acoustical Measurements and Noise Control, 3rd ed. McGraw-Hill, New York.

Kaseloo PA. 2006. Synthesis of noise effects on wildlife populations. IN: Proceedings of the 2005 International Conference on Ecology and Transportation, Eds. Irwin CL, Garrett P, McDermott KP. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp. 33-35.

Lynch, E., 2011. Sand Creek Massacre National Historic Site: Final acoustical monitoring report. Natural Resource Technical Report NPS/NRSS/NRTR—2011//475. National Park Service, Fort Collins, Colorado.

Lynch, E., D. Joyce, and K. Fristrup. 2011. An assessment of noise audibility and sound levels in U.S. National Parks. Landscape Ecology 26:1297-1309.

McDonald, C. D., R.M. Baumgartner, and R. Iachan. 1995. National Park Service aircraft management studies (US Department of Interior Rep. No. 94-2). Denver, CO: National Park Service.

Mennitt, D., K. Fristrup, K. Sherrill, and L. Nelson. 2013. Mapping sound pressure levels on continental scales using a geospatial sound model. Proceedings from Internoise Conference, Innsbruck, Austria, September 15-18, 2013. 11pp.

NOAA Satellite and Information Service. 2013. NNDC climate data online. Available at http://www1.ncdc.noaa.gov/pub/orders/CDO9708536490256.html (accessed July 22, 2013).

National Park Service Organic Act. 1916. (16 USC1). Available at http://www.nature,nps.gov/naturalsounds/laws_policies (accessed May 8, 2013).

National Park Service. 1994a. Report to Congress. Report on effects of aircraft overflights on the National Park System. 21pp.

National Park Service. 1994b. Environmental impact statement and general management plan development concept plan. Bent's Old Fort National Historic Site, Otero County, Colorado. 54pp.

National Park Service. 2006. National Park Service management policies 2006. Management policies 2006. U.S. Department of the Interior, National Park Service, Washington, DC, USA. Available at http://www.nps.gov/policy/MP2006.pdf (accessed May 8, 2013).

National Park Service. 2013. Foundation document Bent's Old Fort National Historic Site. 40pp.

Natural Sounds and Night Skies Division. 2014. NRSS Monthly Webinar - Reducing the Noise Impacts of Park Operations Presentation. Available at http://sharenrss/comm/Pages/WebinarNRSS.aspx (accessed March 20, 2014).

Selye, H. 1956. The stress of life. New York: McGraw-Hill.

Templeton and Sacre. 1997. Acoustics in the built environment: advice for the design team. Architectural Press.

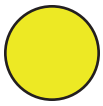
United States Department of Agriculture, Forest Service. 1992. Report to Congress. Potential Impacts of Aircraft Overflights of National Forest System Wildernesses.

## 4.4. Air Quality

**Indicators/Measures**

- Visibility
- Level of Ozone
- Atmospheric Wet Deposition in Total N and Total S

**Condition – Trend – Confidence**



Moderate - Varied - Medium

### *4.4.1. Background and Importance*

Under the direction of the NPS' Organic Act, Air Quality Management Policy 4.7.1 (NPS 2006), and the Clean Air Act (CAA) of 1970 (U.S. Federal Register 1970), the NPS has a responsibility to protect air quality and any air quality related values (e.g., scenic, biological, cultural, and recreational resources) that may be impaired from air pollutants.

One of the main purposes of the CAA is "to preserve, protect, and enhance the air quality in national parks" and other areas of special national or regional natural, recreational, scenic or historic value. The CAA includes special programs to prevent significant air quality deterioration in clean air areas and to protect visibility in major national parks and wilderness areas (NPS-ARD 2012a).

Different categories of air quality areas have been established through the authority of the CAA: Class I, II, and III. Like most National Park Service areas, Bent's Old Fort National Historic Site is designated as a Class II airshed (Figure 4.4.1-1).

These classes are allowed different levels of permissible air pollution, with Class I receiving the greatest protection and strictest regulation. The CAA gives federal land managers responsibilities and opportunities to participate in decisions being made by regulatory agencies that might affect air quality in the federally protected areas they administer (NPS-ARD 2012b).

It's important to note that even though the CAA gives Class I areas the greatest



NPS

**Figure 4.4.1-1. Bent's Old Fort National Historic Site is a Class II airshed.**


NPS

**Figure 4.4.1-2. A cloudy fall day at Bent's Old Fort National Historic Site.**

protection against air quality deterioration, NPS management policies do not distinguish between the level of protection afforded to any unit of the National Park System (NPS 2006).

Air Quality Standards

Air quality is deteriorated by many forms of pollutants that either occur as primary pollutants, emitted directly from sources such as power plants, vehicles, wildfires, and wind-blown dust, or as secondary pollutants, which result from atmospheric chemical reactions. The CAA requires the Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) (40 CFR part 50) to regulate these air pollutants that are considered harmful to human health and the environment (EPA 2012a). The two types of NAAQS are primary and secondary, with the primary standards establishing limits to protect human health, and the secondary standards establishing limits to protect public welfare from air pollution effects, including decreased visibility, damage to animals, crops, vegetation, and buildings (EPA 2012a).

The NPS' Air Resources Division (NPS-ARD) air quality monitoring program uses EPA's NAAQS, natural visibility goals, and ecological thresholds as benchmarks to assess current conditions of visibility, ozone, and atmospheric deposition throughout park service areas.

Visibility affects how well (acuity) and how far (visual range) one can see (NPS-ARD 2002), but air pollution can degrade visibility. Both particulate matter (e.g. soot and dust) and certain gases and particles in the atmosphere, such as sulfate and nitrate particles, can create haze and reduce visibility.

Visibility can be subjective and value-based (e.g. a visitor's reaction viewing a scenic vista while observing a variety of forms, textures, colors, and brightness) (Figure 4.4.1-2) or it can be measured objectively by determining the size and composition of particles in the atmosphere that interfere with a person's ability to see landscape features (Malm 1999). The viewshed section (4.1) of this assessment addresses the subjective aspects of visibility, whereas, this section addresses measurements of particles and gases in the atmosphere affecting visibility.

Ozone is a gaseous constituent of the atmosphere produced by reactions of nitrogen oxides ($NO_x$) from vehicles, powerplants, industry, and fire and volatile organic compounds from industry, solvents,

and vegetation in the presence of sunlight (Porter and Biel 2011). It is one of the most widespread air pollutants (NPS-ARD 2003), and the major constituent in smog. Ozone can be harmful to human health, and it is also phytotoxic, causing foliar damage to plants (NPS-ARD 2003). The foliar damage requires the interplay of several factors, including the interaction of the plant to the ozone, the level of ozone exposure, and the exposure environment. The highest ozone risk exists when the species of plants are highly sensitive to ozone, the exposure levels of ozone significantly exceed the thresholds for foliar injury, and the environmental conditions, particularly adequate soil moisture, foster gas exchange and the uptake of ozone by plants (Kohut 2007).

Ozone penetrates leaves through stomata (openings) and oxidizes plant tissue, which alters the physiological and biochemical processes (NPS-ARD 2012c). Once the ozone is inside the plant's cellular system, the chemical reactions can cause cell injury or even death (NPS-ARD 2012c), but more often reduces the plant's resistance to insects and diseases, reduces growth, and reduces reproductive capability (NPS-ARD 2012d).

Air pollutants can be deposited to ecosystems through rain and snow (wet deposition) or dust and gases (dry deposition). Nitrogen and sulfur air pollutants are commonly deposited as nitrate, ammonium, and sulfate ions and can have a variety of effects on ecosystem health, including acidification, fertilization or eutrophication, and accumulation of toxins (NPS-ARD 2010a). Atmospheric deposition can also change soil pH, which in turn, affects microorganisms, understory plants, and trees (NPS-ARD 2010a). Certain ecosystems are more vulnerable to nitrogen or sulfur deposition than others, including high-elevation ecosystems in the western United States, upland areas in the eastern part of the country, areas on granitic bedrock, coastal and estuarine waters, arid ecosystems, and some grasslands (NPS-ARD 2010b). Increases in nitrogen have been found to promote invasions of fast-growing annual grasses (e.g., cheatgrass) and exotic species (e.g., Russian thistle) at the expense of native species (Brooks 2003, Allen et al. 2009, Schwinning et al. 2005). Increased grasses can increase fire risk (Rao et al. 2010), with profound implications for biodiversity in non-fire adapted ecosystems. Nitrogen may also increase water use in plants like big sagebrush (Inouye 2006).

According to the EPA, in the United States, roughly two thirds of all $SO_2$ and one quarter of all $NO_x$ come from electric power generation that relies on burning fossil fuels. Sulfur dioxide and nitrogen oxides are released from power plants and other sources, and ammonia is released by agricultural activities, feedlots, fires, and catalytic converters. In the atmosphere these transform to sulfate, nitrate, and ammonium and can be transported long distances across state and national borders, impacting resources, including at Bent's Old Fort National Historic Site (EPA 2012b).

### *4.4.2. Data and Methods*

The approach we used for assessing the condition of air quality within the Historic Site's airshed was developed by the NPS-ARD for use in Natural Resource Condition Assessments (NPS-ARD 2010b, 2010c). Interpolated values generated by NPS-ARD, averaged over five years were used to assess condition. NPS-ARD used all available data from NPS, EPA, state, tribal, and local monitors to generate the interpolated values across the contiguous U.S., with a specific value assigned to the center of each park. These values provided estimates for visibility, ozone, and atmospheric wet deposition in the absence of onsite monitoring. Even though the data are derived from all available monitors, the data from the closest monitor will "outweigh" the rest.

#### Indicators/Measures

Visibility

Visibility is monitored by the Interagency Monitoring of Protected Visual Environments (IMPROVE) Program (NPS-ARD 2010a). The NPS-ARD assesses visibility based on the deviation of the current Group 50 visibility conditions from estimated Group 50 natural visibility conditions; (i.e., those estimated for a given area in the absence of

human-caused visibility impairment, EPA-454/B003-005). Group 50 is defined as the mean of the visibility observations falling within the range of the 40th through the 60th percentiles, as expressed in terms of a Haze Index in deciviews (dv). A factor of the haze index is light extinction, which is used as an indicator to assess the quality of scenic vista and is proportional to the amount of light lost due to scattering or absorption by particles in the air as light travels a distance of one million meters (NPS-ARD 2003). The haze index for visibility condition is calculated as follows:

Visibility Condition/Haze Index (dv) = current Group 50 visibility – estimated Group 50 visibility (under natural conditions)

The deciview scale scores pristine conditions as a zero and increases as visibility decreases (NPS-ARD 2010b).

**Indicators/Measures**
Level of Ozone

Ozone is monitored as part of the NPS Gaseous Pollutant Monitoring Program, in partnership with the EPA's CASTNet Program (Porter and Biel 2011). The assessment for ozone levels at the Historic Site was made by referencing NPS ARD's five-year interpolated values.

**Indicators/Measures**
Atmospheric Wet Deposition in Total N and Total S

Atmospheric deposition can be monitored in both wet and dry forms, but for the purposes of this assessment, we will use wet deposition monitoring data only because most areas of the country do not have dry deposition data available, including the Historic Site.

Atmospheric wet deposition is monitored across the United States as part of the National Atmospheric Deposition Program/ National Trends Network (NADP/NTN; NPS-ARD 2003). The values for wet deposition condition are expressed as the average amount of nitrogen (N) or sulfur (S) in kilograms deposited over a one-hectare area in one year (kg/ha/yr) (NPS-ARD 2003).

### *4.4.3. Reference Conditions*

The reference conditions against which current air quality indicators are assessed are identified by NPS ARD (2010b) for NRCAs and listed in Table 4.4.3-1.

Visibility

A visibility condition estimate of less than 2 dv above estimated natural conditions indicates a "good" condition, estimates ranging from 2-8 dv above natural conditions indicate "moderate" condition, and estimates greater than 8 dv above natural conditions indicate "significant concern." Although the dv ranges of these categories were selected somewhat subjectively, the NPS-ARD chose them to reflect the variation in visibility conditions across the monitoring network as closely as possible.

Ozone

The ozone standard set by the EPA at a level to protect human health, 75 parts per billion (ppb) averaged over an eight-hour period, is used as a benchmark for rating current ozone condition. The three-year average of the fourth-highest daily maximum eight-hour average ozone concentrations measured at each monitor in an area must not exceed 75 ppb in order to be in compliance with the EPA standard.

The NPS-ARD rates ozone condition as "good" if the ozone concentration is less than or equal to 60 ppb, "moderate" if the ozone

**Table 4.4.3-1. Reference conditions for air quality indicators.**

| Air Quality Indicator | Significant Concern | Moderate | Good |
|---|---|---|---|
| Visibility | >8 dv | 2-8 dv | < 2 dv |
| Ozone | ≥ 76 ppb | 61-75 ppb | ≤ 60 ppb |
| Wet deposition (total N and total S) | >3 kg/ha/yr | 1-3 kg/ha/yr | < 1 kg/ha/yr |

Source: NPS-ARD 2010b

concentration is between 61 and 75 ppb, and of "significant concern" if the concentration is greater than or equal to 76 ppb.

Wet Deposition

The NPS-ARD considers parks with less than 1 kg/ha/yr of atmospheric wet deposition of nitrogen or sulfur compounds to be in "good" condition, those with 1-3 kg/ha/yr to be in "moderate" condition, and parks with wet deposition greater than 3 kg/ha/yr to be of "significant concern."

### *4.4.4. Condition and Trend*

Condition for all air quality indicators are listed in Table 4.4.4-1.

Visibility

All visibility data were derived from NPS ARD Air Atlas interpolated five-year average values (2006-2010) (NPS-ARD 2012e). The 5-year interpolated values average for the Historic Site's visibility condition fell within the moderate condition rating, which indicates visibility is degraded from the good reference condition of <2 dv above the natural condition. No visibility trend was reported specifically for Bent's Old Fort NHS, but in considering the overall trend of visibility throughout national parks, NPS-ARD (2013) analyzed visibility data for 157 parks during the period of 2000-20099. Visibility on the clearest days improved at most sites; visibility on the haziest days was relatively unchanged at many sites, but several of the sites closest to the Historic Site in Colorado and Kansas showed improvement on the haziest days

Ozone

Ozone data for the Historic Site were derived from the five-year interpolated values average (2006-2010) (NPS-ARD 2012f), which resulted in a moderate ozone condition ranking for Bent's Old Fort NHS.

A list of ozone sensitive species by park are available at NPSpecies - https://irma.nps.gov/NPSpecies/Report (Porter 2003), with two ozone-sensitive plant species found within the Historic Site (NPS-ARD 2006), however, neither species is an ozone bioindicator (Table 4.4.4-2).

An ozone risk assessment was conducted by Kohut (2007) for Southern Plains parks, including the Historic Site. The overall risk was judged to be low at the Historic Site because although ozone levels were somewhat elevated, environmental conditions likely limited ozone uptake at times. The more current condition reported by NPS-ARD (2012f) is moderate. This difference is most likely due to the fact that Kohut (2007) considered environmental conditions that affect plant response to ozone, whereas, NPS-ARD's approach considers more recent ozone conditions but not environmental conditions (e.g., soil moisture levels). We based the current ozone condition at the Historic Site on the most recent data (2006-2010).

Wet Deposition

The data for atmospheric wet deposition condition were derived from NPS-ARD's 2006-2010 interpolated values (NPS-ARD 2012g). The average value for total nitrogen resulted in moderate condition rating and the condition rating was good for total sulfur.

Data from the nearby Las Animas fish hatchery NADP monitor was used to assess deposition trends at the Historic Site (a

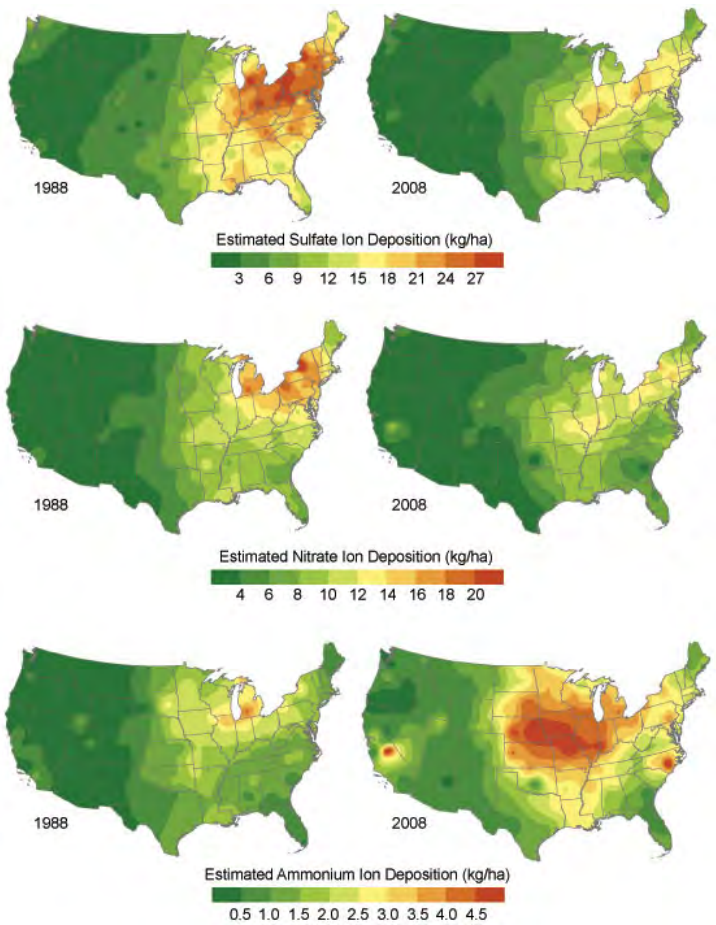
**Table 4.4.4-1. Condition results for air quality indicators at Bent's Old Fort NHS.**

| Data Span | Ozone | Visibility | Total N (kg/ha) | Total S (kg/ha) |
|---|---|---|---|---|
| 2006-2010 | Moderate (74.0) | Moderate (4.4) | Moderate (1.9) | Good (0.7) |

Source: D. NPS-ARD (2012 e,f,g) Air Quality Estimate Tables

**Table 4.4.4-2. Ozone sensitive plants found at Bent's Old Fort NHS (NPS-ARD 2006).**

| Scientific Name | Common Name | Bioindicator |
|---|---|---|
| *Apocynum cannabinum* | Indian hemp | No |
| *Fraxinus pennsylvanica* | Green Ash | No |




HTTP://WWW.NATURE.NPS.GOV/AIR/MONITORING/WETMON.CFM.

**Figure 4.4.4-1. Change in wet deposition levels From 1988-2008 throughout the United States.**

monitor is considered representative for deposition if it is within 16 km (10 miles) of a park). Levels of nitrate in precipitation decreased significantly from 2000-2009, while there were no significant trends for ammonium and sulfate. As a result, there is considered to be no significant trend in total wet nitrogen or sulfur deposition.

Sullivan et al. (2011a), studied the risk from acidification for acid pollutant exposure and ecosystem sensitivity for Southern Plains parks, including the Historic Site. Pollutant exposure included the type of deposition (i.e., wet, dry, cloud, fog), the oxidized and reduced forms of the chemical, if applicable, and the total quantity deposited. The ecosystem sensitivity considered the type of terrestrial and aquatic ecosystems present at the Historic Site and their inherent sensitivity to the atmospherically deposited chemicals. These risk rankings for Bent's Old Fort NHS were considered low for acid pollutant exposure and very low for ecosystem sensitivity to acidification. In general though, arid ecosystems have been found to be very sensitive to nitrogen deposition, which can promote invasions of annual grasses, with subsequent displacement of native forbs and shrubs and increased fire risk (E. Porter, NPS-ARD, pers. comm.).

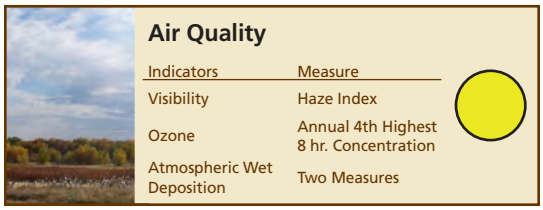
Sullivan et al. (2011b), also developed risk rankings for nutrient N pollutant exposure and ecosystem sensitivity to nutrient N enrichment, and were ranked as low and high, respectively.

In general, nitrate, sulfate, and ammonium deposition levels have changed over the past 20 years throughout the United States (Figure 4.4.4-1). Regulatory programs that mandated a reduction in emissions have proven effective for decreasing both sulfate and nitrate ion deposition primarily through reductions from electric utilities, vehicles, and industrial boilers, although a rise in ammonium ion deposition has occurred in large part due to the agricultural and livestock industries (NPS-ARD 2012h). A new study conducted by Lehmann and Gay (2011), indicated a decrease in sulfate concentrations from 1985-2009 in the area surrounding the Historic Site, and a potential decrease in nitrate concentrations. The observed decrease was statistically significant for sulfate concentrations.

It seems reasonable to expect a continued improvement in sulfate deposition levels because of Clean Air Act requirements, however, at this time, ammonium levels are not regulated by the EPA and may continue to rise as a result (NPS-ARD 2010a).

**Table 4.4.4-3. Summary of the air quality indicators/measures and their contributions to the overall air quality Natural Resource Condition Assessment.**

| Indicator | Measure(s) | Condition | Condition Rationale |
|---|---|---|---|
| Visibility | Haze Index | Moderate | For 2006–2010, estimated average visibility in the Historic Site was 4.4 deciviews above natural conditions, therefore, the condition status warrants moderate concern based on NPS Air Resource Division benchmarks. No trend information is available because there are not sufficient on-site or nearby visibility monitor stations. |
| Level of Ozone | Annual 4th-Highest 8-hour Concentration | Moderate | The estimated ozone level for 2006–2010 at the Historic Site was 74.0 parts per billion, therefore, the condition status warrants moderate concern based on NPS Air Resource Division benchmarks. Ozone-sensitive plants in the Historic Site include *Apocynum cannabinum* (Indianhemp) and *Fraxinus pennsylvanica* (Green ash). No trend information is available because there are not sufficient on-site or nearby ozone monitor stations. |
| Atmospheric Wet Deposition in Total N and total S | Total N in kg/ha/yr | Moderate | For 2006–2010, estimated wet nitrogen deposition was 1.9 kilograms per hectare per year, therefore, the condition status warrants moderate concern based on NPS Air Resource Division benchmarks. Levels of nitrate in precipitation decreased significantly from 2000-2009, while there were no significant trends for ammonium. |
| | Total S in kg/ha/yr | Good | For 2006–2010, estimated wet sulfur deposition was 0.7 kilograms per hectare per year, therefore, the resource is in good condition based on NPS Air Resource Division benchmarks. From 2000-2009, there was no significant trend for sulfate. |




## Overall Condition and Trend

For assessing the condition of air quality, we used three air quality indicators. Our indicators/measures for this resource were intended to capture different aspects of air quality, and a summary of how they contributed to the overall condition is summarized in Table 4.4.4-3.

We consider the overall condition of air quality at Bent's Old Fort National Historic Site to be of a moderate concern with a medium confidence level due to the interpolated values.

The trend for atmospheric wet deposition is measured differently than for atmospheric wet deposition condition but levels of nitrate in precipitation decreased significantly from 2000-2009, while there were no significant trends for ammonium and sulfate. As a result, there is considered to be no significant trend in total wet nitrogen or sulfur deposition (NPS-ARD 2013).

Trends cannot be derived for ozone or visibility since air quality monitoring sites are not located near enough to be representative of the conditions at the Historic Site and onsite monitoring does not occur. A monitor is considered representative if it is located within 10 miles for ozone and within 100 km for visibility

## Level of Confidence/Key Uncertainties

The key uncertainty of the air quality section is knowing the effect(s) of air pollution, especially nitrogen deposition, on ecosystems at Bent's Old Fort NHS.

### 4.4.5. Sources of Expertise

The National Park Service's Air Resources Division oversees the national air resource management program for the NPS. Together with parks and NPS regional offices, they monitor air quality in park units; provide air quality analysis and expertise related to all air quality topics.

### 4.4.6. Literature Cited


Allen, E. B., L. E. Rao, R. J. Steers, A. Bytnerowicz, and M. E. Fenn. 2009. Impacts of atmospheric nitrogen deposition on vegetation and soils in Joshua Tree National Park. Pages 78–100 in R. H. Webb, L. F. Fenstermaker, J.S. Heaton, D. L. Hughson, E. V. McDonald, and D. M. Miller, editors. The Mojave Desert: ecosystem processes and sustainability. University of Nevada Press, Las Vegas, Nevada, USA.

Brooks, M.L. 2003. Effects of increased soil nitrogen on the dominance of alien annual plants in the Mojave Desert. Journal of Applied Ecology. 40:344–353.

Environmental Protection Agency. 2012a. National ambient air quality standards (NAAQS). Available at http://www.epa.gov/air/criteria.html (accessed May 6, 2013).

Environmental Protection Agency. 2012b. Acid rain. Available at http://www.epa.gov/acidrain/what/index.html (accessed May 16, 2013.

Inouye, R.S. 2006. Effects of shrub removal and nitrogen addition on soil moisture in sagebrush steppe. Journal of Arid Environments. 65: 604–618.

Kohut, R.J., 2007. Ozone risk assessment for Vital Signs Monitoring Networks, Appalachian National Scenic Trail, and Natchez Trace National Scenic Trail. NPS/NRPC/ARD/NRTR—2007/001. National Park Service, Fort Collins, Colorado.

Lehmann, C.M.B. and D.A. Gay. 2011. Monitoring long-term trends of acidic wet deposition in U.S. precipitation: results from the National Atmospheric Deposition Program. Power Plant Chemistry (13)7: 378-385.

Malm, William C. 1999. Introduction to visibility. Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, CO 80523.

National Park Service. 2006. Management Policies 2006-The guide to managing the National Park System. Washington D.C. 180pp.

National Park Service Air Resources Division. 2002. Air quality in the national parks, second edition. Lakewood, Colorado. 70pp.

National Park Service Air Resources Division. 2003. Air atlas summary tables for I&M parks. Available at http://www.nature.nps.gov/air/Permits/ARIS/networks/docs/SummariesAirAtlasRevised11072003.pdf (accessed May 6, 2013).

National Park Service Air Resources Division. 2006. Ozone sensitive plant species, by park, November 2006. Available at http://www.nature.nps.gov/air/Permits/ARIS/docs/Ozone_Sensitive_ByPark_3600.pdf (accessed May 6, 2013).

National Park Service Air Resources Division. 2010a. Air quality in national parks: 2009 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2010/266. National Park Service, Denver, Colorado.

National Park Service Air Resources Division. 2010b. Rating air quality conditions. Available at http://www.nature.nps.gov/air/planning/docs/20100112_Rating-AQ-Conditions.pdf (accessed June 1, 2013).

National Park Service Air Resources Division. 2010c. Guidance for evaluating air quality in natural resource condition assessments. Available at http://www.nature.nps.gov/air/planning/docs/20100112_Guidance-For-Evaluating-AQ-In-NRCA.pdf (accessed June 1, 2013).

National Park Service Air Resources Division. 2012a. Clean Air Act and regulations. Available at http://www.nature.nps.gov/air/Regs/cleanAir.cfm (accessed June 1, 2013).

National Park Service Air Resources Division. 2012b. Redesignation of clean air areas. Available at http://www.nature.nps.gov/air/Regs/redesig.cfm (accessed June 1, 2013).

National Park Service Air Resources Division. 2012c. Ozone effects on vegetation. Available at http://www.nature.nps.gov/air/AQBasics/ozoneEffects.cfm (accessed May 6, 2013).

National Park Service Air Resources Division. 2012d. Ozone effects on tree growth. Available at http://www.nature.nps.gov/air/AQBasics/TreeGrowth/index.cfm (accessed May 6, 2013).

National Park Service Air Resources Division. 2012e. Air atlas 5 year average visibility estimates. NPS Air Quality Estimates. National Park Service. Denver, CO. Available at http://www.nature.nps.gov/air/Maps/AirAtlas/IM_materials.cfm (accessed May 6, 2013).

National Park Service Air Resources Division. 2012f. Air atlas 5 year average ozone estimates. NPS Air Quality Estimates. National Park Service. Denver, CO. Available at http://www.nature.nps.gov/air/Maps/AirAtlas/IM_materials.cfm (accessed May 6, 2013).

National Park Service Air Resources Division. 2012g. Air atlas 5 year average wet deposition estimates. NPS Air Quality Estimates. National Park Service. Denver, CO. Available at http://www.nature.nps.gov/air/Maps/AirAtlas/IM_materials.cfm (accessed May 6, 2013).

National Park Service Air Resources Division. 2012h. Wet deposition monitoring. Available at http://www.nature.nps.gov/air/Monitoring/wetmon.cfm (accessed May 6, 2013).

National Park Service, Air Resources Division. 2013. Air quality in national parks: trends (2000–2009) and conditions (2005–2009). Natural Resource Report NPS/NRSS/ARD/NRR—2013/683. National Park Service, Denver, Colorado.

Porter, E. 2003. Ozone sensitive plant species on National Park Service and U.S. Fish and Wildlife Service lands: results of a June 24-25, 2003 workshop, Baltimore, Maryland. Natural Resource Report NPS/NRARD/NRR-2003/01.

Porter, E., and A. Wondrak Biel. 2011. Air quality monitoring protocol and standard operating procedures for the Sonoran Desert, Southern Plains, and Chihuahuan Desert networks. Version 2.00. Natural Resource Report NPS/SODN/NRTR—2011/390. National Park Service, Fort Collins, Colorado.

Rao, L. E., E. B. Allen, and T. Meixner. 2010. Risk-based determination of critical nitrogen deposition loads for fire spread in southern California deserts. Ecological Applications 20:1320–1335.

Schwinning, S.; Starr, B.I.; Wojcik, N.J.; Miller, M.E.; Ehleringer, J.E.; Sanford, R.L. 2005. Effects of nitrogen deposition on an arid grassland in the Colorado plateau cold desert. Rangeland Ecology and Management. 58: 565–574.

Sullivan, T. J., G. T. McPherson, T. C. McDonnell, S. D. Mackey, and D. Moore. 2011a. Evaluation of the sensitivity of inventory and monitoring national parks to acidification effects from atmospheric sulfur and nitrogen deposition: Southern Plains Network (SOPN). Natural Resource Report NPS/NRPC/ARD/NRR-2011/380. National Park Service, Denver, Colorado.

Sullivan, T. J., T. C. McDonnell, G. T. McPherson, S. D. Mackey, and D. Moore. 2011b. Evaluation of the sensitivity of inventory and monitoring national parks to nutrient enrichment effects from atmospheric nitrogen deposition:

Southern Colorado Plateau Network (SCPN). Natural Resource Report NPS/NRPC/ARD/NRR—2011/331. National Park Service, Denver, Colorado.

United States Federal Register. 1970. Clean Air Act. Public Law 95-124. Pages 5673-5965.

## 4.5. Geology

**Indicators/Measures**

- Geologic Resource Integrity

**Condition – Trend – Confidence**



Good - Insufficient Data - High

***This section is extracted from the Geologic Resources Evaluation Report (KellerLynn 2005) for Bent's Old Fort National Historic Site. For more information, go to http://www.nature.nps.gov/geology/inventory***

### *4.5.1. Background and Importance*

Geologic resources serve as the foundation of ecosystems and yield important information needed for science-based decision making in National Park System units. Geology is a major determinant of topography, water and soil chemistry, fertility of soils, stability of hill slopes, and flow styles of surface water and groundwater. These factors, in turn, influence biology, including the distribution of habitats and the locations of threatened and endangered species. Geology also influences human settlement patterns and how people use natural resources—for farming, ranching, industry, construction, hunting, fishing, and recreation.

Bent's Old Fort National Historic Site (NHS) is located in the Great Plains of southeast Colorado. The Great Plains is a land of contrasts and variety including water-carved rock canyons, dramatic rock uplifts, fluvial sediments containing fossils, and rolling hills of eolian deposits. Bent's Old Fort NHS is located in the Colorado Piedmont section of the Great Plains province. The area around the Fort is generally flat with some gently rolling surfaces and the Arkansas River running through it (Figure 4.5.1-1).

The Colorado Piedmont is situated at the foot of the Rockies, largely between the South Platte and the Arkansas Rivers (Figure 4.5.1-2). After leaving the mountains, the South Platte to the north, and the Arkansas to the south, have excavated the Tertiary (65.5- to 1.81-million years old) sedimentary rock layers removing great volumes of sediment. These Tertiary rock units were originally deposited by shifting stream channels, floodplains, swamps, and occasional volcanic ash (KellerLynn 2005).



NINA CHAMBERS

**Figure 4.5.1-1. Bent's Old Fort National Historic Site has mostly flat to gently rolling surfaces surrounded at a distance by hogback ridges.**

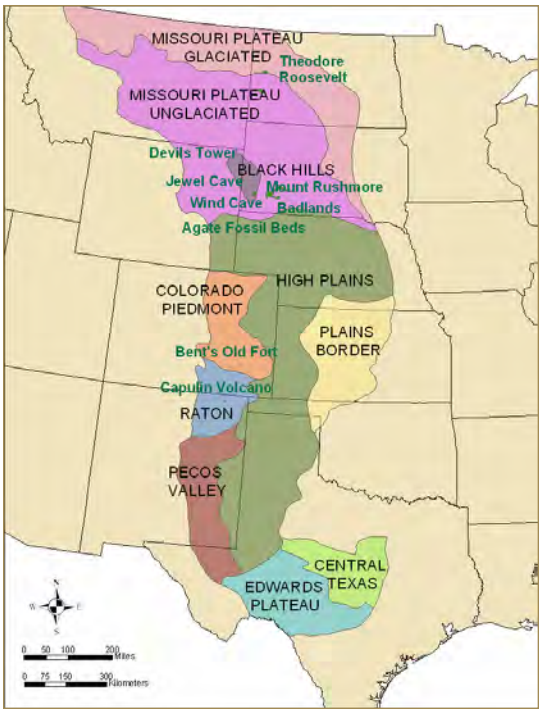



**Figure 4.5.1-2. The Great Plains Physiographic Province and location of Bent's Old Fort NHS in the Colorado Piedmont section (KellerLynn 2005).**

Along the western margin of the Colorado Piedmont, the layers of older sedimentary rock have been sharply upturned by the rise of the mountains. The edges of these upturned layers have been eroded differentially, so that the hard sandstone and limestone layers form conspicuous and continuous hogback ridges (KellerLynn 2005).

Much of the terrain in the valleys of the South Platte and Arkansas Rivers has been smoothed by windblown sand and silt. Northwesterly winds, which frequently blow with near-hurricane velocities, have whipped fine material from the floodplains of the streams and spread it eastward and southeastward over much of the Colorado Piedmont (KellerLynn 2005).

Blowout dunes are the most common dune type in the vicinity of Bent's Old Fort NHS. In the Colorado Piedmont the erosional effects of streams are the most conspicuous features of the landscape. These fluvial features are enhanced by the steep tilting of layered rocks along the western margin of the Colorado Piedmont and modified by wind action, which has softened the landscape with a widespread cover of windblown sand and silt (KellerLynn 2005).

### *4.5.2. Data and Methods*

This limited assessment summarizes the findings from a geologic resource evaluation conducted by the National Park Service Geologic Resources Division (KellerLynn 2005). The evaluation included scoping meetings with park staff and geologic experts to identify geologic issues, features, and processes. A digital geologic map was also produced. For more information about the Geologic Resources Division, visit http://www.nature.nps.gov/geology/.

### *4.5.3. Reference Conditions*

The reference conditions by which geology condition was assessed are listed in Table 4.5.3-1.

Good condition is assigned to parks where no concerns or issues about geologic resources have been identified. Geologic resources and processes are in a generally natural state and function.

Moderate condition is assigned to parks if there are some areas of moderate concern either inside the park, or outside the park that may impact it. Examples of this could be moderate disturbance due to soil erosion or mining exploration in the region.

Significant concern is assigned to parks that have identified areas of concern in assessments conducted by the NPS Geologic Resources Division or have significant impacts occurring inside or outside the park that have the potential to impact park resources.

Level of confidence is assessed depending on the level of information we have on which to base the condition assessment. A Geologic Resources Inventory Report produced by the NPS Geologic Resources Division, or similar report produced by the U.S. Geological Survey or state geologic survey specifically focused on a park's geology, results in a high confidence level for the assessment. A Geologic Resources Scoping Report (or the equivalent) provides a moderate level of confidence. If a Scoping Summary is all that is available and little is known or available about

**Table 4.5.3-1. Qualitative description for determining condition of geologic resources.**

| Class | Description |
|---|---|
| Good Condition | No concerns or issues about geologic resources have been identified. Geologic resources and processes are in a generally natural state and function. |
| Moderate Concern | Some areas of moderate concern either inside the park, or outside the park that may impact it. Examples of this could be moderate disturbance due to soil erosion or mining exploration in the region. |
| Significant Concern | Areas of concern have been identified in assessments conducted by the NPS Geologic Resources Division or significant activities are occurring outside the park that have the potential to impact park resources. |

the geologic resources, then a low confidence level is assigned.

### *4.5.4. Condition and Trend*

Specific indicators and measures related to soil erosion are presented in section 4.9 on grasslands. Discussions on surface water (4.6) and groundwater (4.7) are presented in separate sections in this report. Based on the geologic assessment completed, no specific areas of geologic concern have been identified. The Historic Site is considered to be in good condition (B. Heise, NPS Geologist and Program Administrator, pers. comm. August 22, 2013).

The following discussion on geologic issues and geologic processes are excerpts summarized from the geologic inventory (KellerLynn 2005).

Geologic Issues

Geologic issues are those that may warrant attention from resource managers at Bent's Old Fort NHS as they are relevant for maintenance of facilities, mitigation of hazardous conditions, and protection of resources.

*Eolian Deposits, Climate Change, and Wind Erosion*

Eolian (windblown) deposits blanket large parts of the west-central Great Plains. In eastern Colorado, situated at the higher and drier western margin of the Great Plains, eolian sediment covers about 60% of the area east of the Rocky Mountains. Of this eolian cover, about 30% is sand and 70% is loess (windblown dust) (KellerLynn 2005).

In recent studies, long loess sequences have been shown to contain detailed records of Quaternary glacial-interglacial cycles. Such loess sequences are thought to be a terrestrial equivalent to the foraminiferal oxygen isotope record in deep-sea sediments. Loess is also a direct record of atmospheric circulation and identification of loess paleowinds in the geologic record can test atmospheric general circulation models. In addition, the widespread eolian deposits of eastern Colorado and adjacent parts of the Great Plains are important sources of information for reconstructing the history of aridification in the interior of North America during the Quaternary period (KellerLynn 2005).

Eolian sands are attractive deposits for paleoclimate reconstruction on the Great Plains, too, for a number of reasons. First, eolian sand is highly sensitive to climatic change because stabilizing vegetation on such deposits in semiarid regions cannot tolerate significant reductions in precipitation. Second, research indicates that the eolian deposits of the Great Plains record a history of repeated windblown sand during the Holocene. Third, dune morphology and stratification, and isotopic and geochemical fingerprinting of sand source areas, allow reconstruction of paleowind patterns, which in turn provide the basis for atmospheric circulation models and air mass distributions (KellerLynn 2005).

A better understanding of how climate has varied in drought-prone regions like eastern Colorado is potentially useful for predicting and assessing potential effects of future climate change. The location of Bent's Old Fort NHS places it at center stage for climate change studies. In addition, land-use practices in the region play an anthropogenic role in dust storms and wind erosion. Shifts

to a slightly drier climate could have serious socioeconomic consequences in this as well as other semiarid and arid regions. Population centers in these regions are dependent on water from river systems or on groundwater pumped from aquifers. Demands on these water resources are great and increasing. Also, drought in these regions sets the stage for massive wind erosion of agricultural land and generation of dust storms that could adversely impact areas far downwind of source areas (KellerLynn 2005).

*Flooding*

Bent's Old Fort was built of adobe on the edge of a low terrace projecting southeastward into the floodplain of the Arkansas River (Figure 4.5.4-1). Images showing the river course and floodplain put Bent's Old Fort at the northern edge of—but not actually in—the floodplain. In 1921, however, the "Great Pueblo Flood" crested above the level of the Fort grounds causing most of the remaining original adobe walls to collapse (National Park Service 1975). The site also was threatened by flooding in 1965; however, floodwaters did not reach the ruins or cause any property damage (National Park Service 1975, KellerLynn 2005).

Storms over the upper Arkansas River basin are generally either low-intensity, long-duration rainfall events over a large area or short-duration rainfall events with high intensity over a small area (mostly due to thunderstorms in July and August). Floods on the Arkansas River are of two general types. One type, "spring floods," results from melting snow and is often augmented by storm runoff. The other, "summer floods," results entirely from storm runoff. Spring floods are characterized by comparatively moderate rates of flow of long duration with large volumes of runoff. Summer floods are characterized by high peak rates of discharge with relatively smaller volumes of runoff (KellerLynn 2005).

Historical records reference many floods in the Arkansas River valley above John Martin Reservoir, located about 20 miles (32 km) east of Bent's Old Fort NHS. The earliest known in the area occurred in 1826. The next notable flood was in 1844. Other reported floods occurred in 1859, 1864, 1869, and 1894. These floods were generally confined between Pueblo and the present John Martin Dam, an area which includes Bent's Old Fort NHS. Major floods were experienced at various localities in the subbasin in 1921, 1935, 1942, 1955, and 1965. The flood of 1921 was the greatest flood of record on the Arkansas River at La Junta (for more information, see KellerLynn 2005).

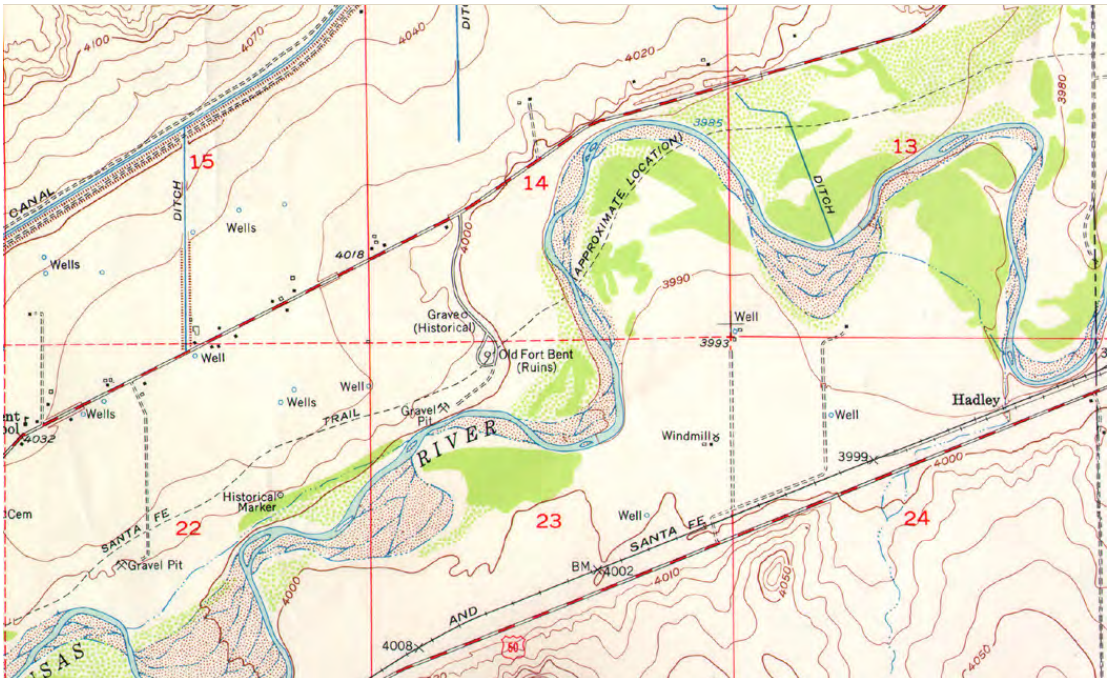



**Figure 4.5.4-1. Topographic map (1953) of Bent's Old Fort NHS location on the northern edge of the Arkansas River floodplain. Source: USGS Hadley, Colorado, quadrangle 1953, in KellerLynn 2005.**

*Mineral Resources*

The principal mineral resources in Otero and Crowley Counties are sand and gravel, which are quarried extensively for road construction. These deposits are found chiefly on top of mesas and ridges along the Arkansas River. Clay and silt, which range in thickness from 3 feet (0.9 m) on the east side of the Fort to 7 feet (2.1 m) on the west side, are possible sources for the manufacture of adobe blocks, which is of historic interest and potentially useful for future repairs to the Fort (KellerLynn 2005).

Locally some building stone has been quarried from the Dakota Sandstone, the Greenhorn Limestone, and the Fort Hays Limestone Member of the Niobrara Formation. With respect to the Historic Site, the hearth in the kitchen, which is original, is made of uncut pieces of limestone, probably Greenhorn Limestone (KellerLynn 2005).

Oil and mineral exploration does not currently take place within the local region of Bent's Old Fort NHS; however, the potential for future exploration and development remains. For instance, most of the limestone and dolomite reservoir beds of the central Kansas oil fields persist westward into eastern Colorado, particularly into Prowers and Bent Counties. Therefore, oil and gas reservoirs may exist in that area. Oil and gas production occurs 25-30 miles (40-48 km) east and northeast of the Historic Site. Three wells have been drilled within 3 miles (5 km) of the Historic Site, but were plugged and abandoned because they were not economically viable (KellerLynn 2005).

*Paleontological Resources*

According to Scott (1963), the Louviers Alluvium in the Kassler quadrangle (Colorado) contains a large assemblage of fossil mollusks and vertebrates, including mammoths, camel, and great bison. Louviers Alluvium is an early Wisconsin-age terrace deposit. Weist and others (1965) (as cited in KellerLynn 2005) mapped two Wisconsin-age terrace deposits (Qtw1 and Qtw2) in the vicinity of the Historic Site and Tweto (1979) mapped a gravel and alluvium deposit that he described as consisting of Broadway and Louviers alluvium (Qg) near Bent's Old Fort NHS. The lower Wisconsin-age terrace deposit (Qtw2) is the potentially fossiliferous unit in the Historic Site. For example, during mapping, investigators found a horse (*Equus* sp.) tooth in a gravel pit. Although no research has been performed or inventory made, the paleontological resources found in this deposit in the Kassler quadrangle also could be in the vicinity of Bent's Old Fort NHS (K. McKinney, U.S. Geological Survey, written communication, April 2004 in KellerLynn 2005).

In 1991, at least 28 *Durania cornupastoris*, an extinct group of bivalved (pelecypods) mollusks, were discovered and collected from the uppermost part of the Bridge Creek Member of the Greenhorn Limestone in a road cut along U.S. 50 about 5 miles (8 km) northeast of La Junta, outside the boundaries of Bent's Old Fort NHS (Cobban et al. 1985, Koch and Santucci 2003). The discovery of the cluster of mollusks is an unusual find of a species that was originally described in France. Aside from fairly abundant occurrences in the Niobrara Formation of Kansas, they are rare fossils in the Upper Cretaceous rocks of the Western Interior. The 1991 find near Bent's Old Fort NHS was the first report of this species in the area (KellerLynn 2005).

Jackson Moore, a NPS archaeologist, discovered a fragmentary mammoth tusk at Bent's Old Fort NHS. He collected tusk fragments between 1963 and 1966 (Koch and Santucci 2003). The remains were found in a gravel bed overlying a white limestone unit (Moore 1973). The fragments have been tentatively identified as *Mammothus columbi* (N. Russel, personal communication, 2000 in KellerLynn 2005). According to the Historic Site's museum records, archaeologist Jerry Dawson collected an additional three mammoth tusk fragments in 1992 (Scott et al. 2001).

Geologic Features and Processes

*Arkansas River*

The Arkansas River is a broadly meandering stream in the vicinity of Bent's Old Fort NHS. It flows approximately 6 miles (10 km) to cover a linear distance of 3 miles (6 km).

The river's meanders are developed on a floodplain that, in general, is less than 0.75 mile (1.2 km) wide. The floodplain is entirely developed in unconsolidated materials, underlain by 30 to 40 feet (9 to 12 km) of fill. The river gradient is about 5 feet per mile (1.5 m/1.6 km), and the sediment load carried is moderately heavy, consisting largely of silt and sand in this reach of the river. During the period of stream gauging recorded at La Junta, the flow of the Arkansas River ranged from no flow to 200,000 cubic feet per second (5,664 $m^3/s$). Large diversions of water are made for irrigation, which accounts in part for the wide range in discharge of the stream. Discharge is also affected by rapid snowmelt in the mountains and cloudbursts within the basin, which can cause heavy flooding in the area (KellerLynn 2005).

Changes have occurred in the river's channel morphology over time. The presence of meander scallops on the edges of the terraces bordering the floodplain and more or less filled oxbow lakes confirm meandering in the past. Evaluation of available data, such as surveys from 1869 and 1882 and aerial photographs from November 1936, indicate that little significant lateral migration of the meanders or shifting of the Arkansas River occurred between 1869 and 1936. Furthermore, very little shifting of the river's course occurred in the reach of the river that runs past the Fort or downstream from the Fort between November 1936 and July 1947. Major changes in the stream took place in upstream reaches, however. The rather straight course of 1869 through 1882, more or less maintained through 1936, became very sinuous by 1947.

Another major change also took place during the period between 1936 and 1947; the Arkansas River became a braided stream. Islands were few and of small size in 1936, but they became numerous and of large size by 1947; this tendency has remained. Since 1936 the amount of water diverted from the river for irrigation has increased significantly. Investigators believe that removal of water during the low flows of summer is responsible for the development of the more braided character of the Arkansas River (KellerLynn 2005).

*Eolian Deposits*

The Arkansas River eolian sand area, which covers 220 square miles (570 $km^2$), consists mainly of a belt of dunes, generally 0.2 to 0.4 miles (0.3 to 0.6 km) wide, along the south side of the river from near La Junta, Colorado, eastward to Kansas. The dune sand in this area has a maximum thickness of about 82 feet (25 m), but averages 33 feet (10 m).

Blowout dunes are the most common dune type in the area. Blowout dunes are large accumulations of sand derived from a "blowout"—a saucer- or trough-shaped hollow formed by wind erosion in a preexisting sand deposit. Presently, most dune sand in the vicinity of Bents Old Fort NHS is stable and covered with vegetation.

Whereas blowout dunes are the most common type in areas south of the Arkansas River, parabolic dunes are dominant throughout northeast and central Colorado. Parabolic dunes are sand dunes with long, scoop-shaped forms, convex in the downwind direction so that their horns point upwind. When perfectly developed, parabolic dunes viewed from above approximate the form of a parabola. Except for the dune belt flanking the south side of the Arkansas River, dune fields are few, small, and widely scattered in southeastern Colorado (KellerLynn 2005).

*River Terraces*

Changes in channel gradient, discharge, or sediment load can lead to a river channel incising its floodplain. The original floodplain is thereby abandoned and is left as a relatively flat bench, known as a river terrace, which is separated from the new floodplain below by a steep slope. The Fort at Bent's Old Fort NHS sits on such a terrace.

Terraces can be formed under a wide range of circumstances. Many episodes of channel entrenchment and terrace formation probably arise from changes in base level or fluctuations in climate, although tectonic deformation along river courses can also lead to terrace development. During the Quaternary Period,

**Table 4.5.4-1. Indicator, measure, and rationale of geology condition.**

| Indicator of Condition | Measure | Condition | Rationale for Condition |
|---|---|---|---|
| Geologic Integrity | None | Good | A geologic resource evaluation report was completed in 2005. There are no geologic concerns, and the geologic resources and processes are in a generally natural state and function. |

a major climatic cooling caused glaciation. Episodic base-level changes are recorded by alluvial deposits, such as terraces, in the Front Range and eastern Colorado. These changes are thought to be caused mainly by cyclic changes in climate, but could partly be a result of uplift that continued into Holocene time (KellerLynn 2005). The alluvium in the vicinity of Bent's Old Fort NHS serves as a record of climatic changes throughout the Quaternary Period. Geologists have studied, described, and named these deposits. The ages of these deposits correspond to the glacial episodes that occurred on continental and regional scales.

*Structural Features*

The area surrounding Bent's Old Fort NHS is bounded on the east and southeast by the Las Animas arch and on the south and southwest by the Apishapa uplift. The Las Animas arch, also termed the Sierra Grande arch, is one of the largest structural features in the vicinity of the Historic Site. The arch has been described as probably a buried mountain range of the early Permian age that extends east of the Rocky Mountains in New Mexico and Colorado. Both of these regional anticlines start at the Sierra Grande uplift near the New Mexico state line (KellerLynn 2005).

These major structural features combine to give the general northward or northwestward dip to the consolidated beds throughout most of Otero and Crowley Counties. In the southwestern part of Otero County the effects of the Apishapa uplift are more pronounced, and the beds generally dip northeastward. Dips are generally between 1° and 3° but locally may be as much as 36°. Dips greater than 3° are more common south of the Arkansas River. Locally, abrupt changes in both the amount and direction of dip occur (KellerLynn 2005).




Overall Condition

In parks that do not have a geologic resource focus, that is, they do not have significant canyons or volcanoes or other prominent geologic features, no specific indicators or measures have been identified by which to assess geologic condition. In these cases, we use professional judgment and qualitative assessment of general geologic integrity to assign condition class and level of confidence. Table 4.5.4-1 clearly states how condition was assessed.

The condition of the geologic resources at Bent's Old Fort NHS is good, with a high level of confidence.

## 4.5.5. Sources of Expertise

The National Park Service's Geologic Resources Division conducts geologic inventories and resource evaluations, and produces digital geologic maps in close partnership with the Inventory and Monitoring Program, park staff, and partners. This section is based entirely on a report (KellerLynn 2005) produced by the Geologic Resources Division, and was reviewed by Bruce Heise, Geologist at the National Park Service Geological Resources Division. The paleontological resources section was reviewed by Vincent Santucci, Paleontologist for the National Park Service.

## 4.5.6. Literature Cited

Cobban, W. A. P., W. Skelton, and W. J. Kennedy. 1985. Occurrence of the Rudist *Durania cornupastoris* (Des Moulins, 1826) in the Upper Cretaceous Greenhorn Limestone in Colorado: Geological Survey Bulletin B, D1-D8.

KellerLynn, K. 2005. Bent's Old Fort National Historic Site, Geologic Resource Evaluation Report. Natural Resource Report NPS/NRPC/GRD/NRR—2005/005. National Park Service, Denver, Colorado.

Koch, A. L. and V. L. Santucci. 2003. Paleontological Resource Inventory and Monitoring: Southern Plains Network. National Park Service Report TIC# D-107, 34 pp.

Moore, J. W., Jr. 1973. Bent's Old Fort: an archeological study. Denver, Colorado, State Historical Society of Colorado, Pruett Publishing Company. 144 p.

National Park Service. 1975. Site improvement, Bent's Old Fort [D-19]. Denver, Colorado, National ParkService, Denver Service Center. 62 p.

Scott, G. R. 1963. Quaternary geology and geomorphic history of the Kassler quadrangle, Colorado. U.S. Geological Survey Professional Paper 421- A. p. 1–67.

Scott, R. L., V. L. Santucci, and T. Connors. 2001. An Inventory of Paleontological Resources from the National Parks and Monuments in Colorado. Pages 178-202 *in* V. L. Santucci and L. McClelland, eds, Proceedings of the 6th Fossil Conference: National Park Service Geologic Resources Division, Technical Report NPS/NRGRD/GRDTR-01/01.

Tweto, O. 1979. Geologic map of Colorado. Reston, Virginia, U.S. Geological Survey, scale 1:500,000.

## 4.6. Surface Water Quality

**Indicators/Measures**

- Water Quality Parameters (7 measures)
- Alkalinity (3 measures)
- Metals (15 measures)
- Primary Nutrients (11 measures)
- Biological Conditions (Biological Oxygen Demand)
- Emerging Contaminants (Presence/ Absence)

**Condition – Trend - Confidence**



Significant Concern– Insufficient Data - High

*The majority of the text for this assessment was written by Evan Gwilliam based upon trip summary reports (2012a,b,c and 2013a,b).*

### *4.6.1. Background and Importance*

Streams and rivers are the integrators within a landscape. They depend upon inputs, such as energy and nutrients, from within their watershed, which in turn, support a wide variety of services. These include habitat for plants and animals, hydrologic cycling, nutrient processing, recreational opportunities, as well as water supply for public and private uses. Since streams and rivers are generally sensitive to stressors, both locally and at the watershed-level, they are one of the most useful ecosystems to monitor to determine long-term conditions and trends (NPS I&M 2012) (Figure 4.6.1-1).

NPS Management Policies (2006) state that parks must work with other governmental agencies to obtain Clean Water Act standards, take necessary action to maintain or restore surface water quality to the standards of the Clean Water Act or to meet federal, state, or local laws and regulations, and to create partnerships with other agencies to maximize resources and expertise to maintain or restore park water resources.

Southern Plains Inventory and Monitoring Network (SOPN) has identified two vital signs for monitoring and assessing surface water at Bent's Old Fort National Historic Site: water quality and water quantity. Only water quality will be addressed in this section.



NPS PHOTO

**Figure 4.6.1-1 Water quality sampling in the Arkansas River along Bent's Old Fort National Historic Site.**

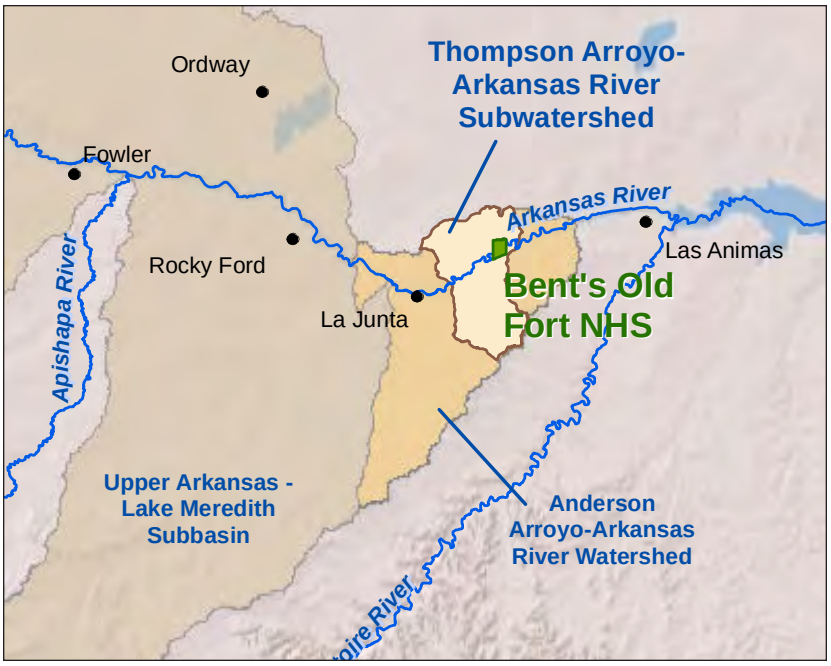



**Figure 4.6.1-2 Bent's Fort is located in the Thompson Arroyo-Arkansas River subwatershed and drains an area of 1,890 square miles.**

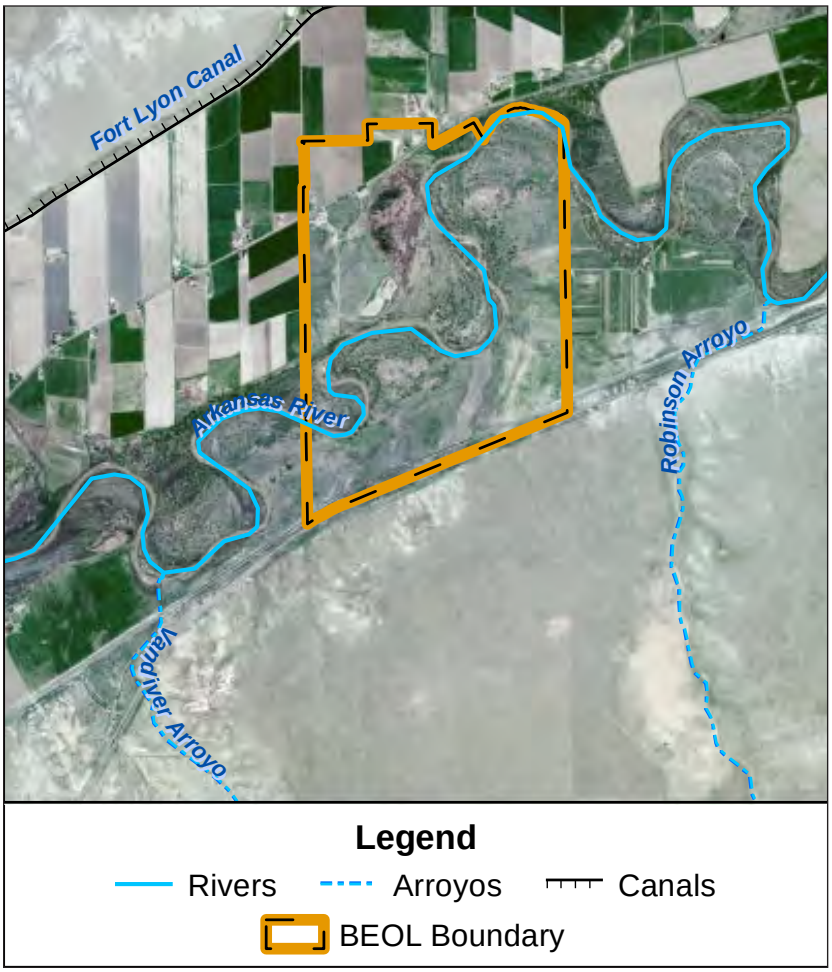



**Figure 4.6.1-3 Major surface water features surrounding and located within Bent's Old Fort NHS**

Water quantity (flow) will be included in the riparian habitat section of this NRCA.

Water has long been a scarce resource in the western and central portions of the Great Plains and very important to Native Americans, early European settlers, and present day inhabitants and ecosystems (Perkins et al. 2005). Bent's Old Fort NHS commemorates the historic role the trading post played in the opening of the West (NPS 2013), which was strategically located along the Arkansas River, which was the international border at that time. The Historic Site contains approximately 2.2 Arkansas River miles within its boundary (Vana-Miller et al. 2010).

The Arkansas River originates in the Rocky Mountains near Leadville, Colorado and is the sixth longest river in the United States (1,469 miles (2,364 km)). It generally flows to the east and southeast and flows through Colorado, Kansas, Oklahoma, and Arkansas. The Arkansas River Basin covers 28,286 $mi^2$ and is the largest basin in Colorado (Tetra Tech 2007a). The Historic Site is located within the Upper Arkansas-Lake Meredith Subbasin and the Thompson Arroyo-Arkansas River Subwatershed (Figure 4.6.1-2) (USGS 2013a). Within the Lake Meredith Subbasin there are approximately 1,413,670 acres of land being utilized for farming or ranching (Tetra Tech 2007a).

The Arkansas River has three distinct sections-one being within the Great Plains where the Historic Site is located. Throughout the Great Plains Region, the Arkansas River widens and flattens markedly compared to its headwaters region. The fertile alluvial soils within the Great Plains region and over 1,000 miles of Arkansas River water diversions, including the Fort Lyon Canal located to the north of the Historic Site (Figure 4.6.1-3), have supported an agricultural economy throughout the area. As a result of the extensive irrigation and water diversions, the groundwater table has risen, become saline, and waterlogged many of the Valley soils (Gates et al. 2006). These soils originated from the underlying sedimentary rocks, which are high in soluble salts (iron, sulfate, selenium). The extensive

irrigation throughout the lower Arkansas River Basin concentrates these soluble salts, which eventually flow into the river, adversely affecting the ecological condition of the Arkansas River (Gates et al. 2006).

Two major reservoirs are located along the Arkansas River: John Martin Reservoir, which was constructed in 1948 and Pueblo Reservoir, constructed in 1975. These reservoirs store water for later season irrigation (Gates et al. 2006). The John Martin Reservoir has dampened the flood flows and created backwater, which have likely contributed to the aggradation of sediments, resulting in a higher river level.

### *4.6.2. Data and Methods*

Water Quality

According to the U.S. Geological Survey Water Science School, water quality is "a measure of the suitability of water for a particular use based on selected physical, chemical, and biological characteristics" (USGS 2012). Surface water quality is important to maintaining a healthy habitat for many aquatic organisms, wildlife, and humans and can provide insights into overall system productivity, can shift species abundance and distributions, and alter nutrient cycles (USDI NPS 2008).

Water Quality Monitoring at the Historic Site

A long-term water quality monitoring program began in October 2012 at Bent's Old Fort NHS following the stream monitoring protocol developed by Gwilliam et al. (2013). Sampling, including several surface water parameters and surface water discharge, has occurred quarterly since October 2012. In addition, one preliminary sampling event occurred in April 2012.

**Indicators/Measures**

Core Water Quality (temperature, specific conductance, pH, dissolved oxygen, turbidity, and *E. coli*)

Typically, parks containing water resources conduct surface water monitoring to determine the trends in core water physiochemistry. Core water quality parameters —temperature, specific conductance (the ability of a solution to conduct an electrical current, i.e., the lower the conductivity, the "purer" the water), turbidity, pH, and dissolved oxygen— reflect the function of the physical and biological environment with which water interacts.

A water quality station (sonde) was installed in the Arkansas River during the October 2012 field sampling to deploy a multiparameter water quality probe for two weeks every quarter. The sonde measures temperature, pH, dissolved oxygen, and specific conductivity every 15 to 30 minutes for continuous data collection (Gwilliam 2012a). Discrete sampling of core water quality parameters also occurred every quarter.

These water quality measures are easily monitored and constitute a means of characterizing potential stressors to the health of aquatic systems. Monitoring for the parameters dovetails with that of the NPS service-wide Water Quality Monitoring Program, which requires each network to collect all of these parameters (except for turbidity) with any water quality monitoring effort (Gwilliam et al. 2013). Ideally, multiple water sampling throughout the water year obtains a better understanding of the range of conditions compared to episodic sampling, which captures information pertaining to that specific date and time only (Schweiger et al. 2012).

*Escherichia coli* (*E. coli*) is one of the main species of bacteria living in the lower intestines of mammals and therefore its presence in water is an indication of fecal contamination. Extreme conditions of this parameter is a good proxy for stream pollution and acts as an early warning for potential pathogen risks for aquatic and terrestrial biota.

The data collected for the core water quality measures are located in Tables 4.6.2-1, -2, -3, and values shown in bold represent continuous sampling from 10/08/2012 – 10/23/2012 versus a single sampling event.

**Table 4.6.2-1. Core water quality results from discrete sampling at Bent's Old Fort NHS**

| Parameter | 4/26/2012 Results | 10/7/2012 Results | 01/29/2013 Results | 5/6/2013 Results |
|---|---|---|---|---|
| Temperature (C) | 18.8 | 14.6 | 3.00 | 10.8 |
| Specific conductivity (micro Siemens/cm) | 2138 (15.08 cfs discharge) | 550 (67.3 cfs discharge) | 1950 | 2250 (12.5 cfs discharge) |
| Turbidity (NTU) | N.C. | 61.8 | 16.8 | 6.06 |
| pH | 8.21 | 8.51 | 8.13 | 8.19 |
| Oxygen concentration (mg/L) | 10.24 | 9.98 | No data | 10.7 |
| E. coli (MPN*) | N.C. | 117 | 101 | 76.8 |

* Most probable number/100ml **N.C. = not collected

**Table 4.6.2-2. Core water quality results from continuous sampling from 10/08/2012 – 10/23/2012**

| Parameter | Mean | Minimum | Maximum |
|---|---|---|---|
| Temperature (C) | 12.8 | 4.84 | 22.2 |
| Specific conductivity (µS/cm) | 1700 | 988 | 1910 |
| pH | 8.36 | 7.84 | 8.65 |
| Oxygen concentration (mg/L) | **3.44*** | **0.02*** | 9.68 |

*Indicates exceedance

**Table 4.6.2-3. Core water quality results from continuous sampling from 4/24/2013 – 5/07/2013**

| Parameter | Mean | Minimum | Maximum |
|---|---|---|---|
| Temperature (C) | 14.0 | 4.13 | 29.0 |
| Specific conductivity (µS/cm) | 1910 | 1740 | 2094 |
| pH | 8.14 | 7.92 | 8.44 |
| Oxygen concentration (mg/L) | 9.38 | 6.01 | 13.1 |

## Indicators/Measures
### Alkalinity

Alkalinity characterizes the ability of a water body to buffer changes in pH. Naturally occurring ions, such as carbonate ($CO_3^{2-}$), bicarbonate ($HCO_3^-$), and hydroxide ($OH^-$) buffer streams from sudden changes in pH due to the addition of acid. Alkalinity of a stream is influenced by surrounding geology and soils and by effluent. Alkalinity benefits wildlife in two ways. First, it protects fish and other organisms against sudden changes in pH. Second, under the right conditions, carbonate and bicarbonate ions facilitate the precipitation of metals from solution, reducing the exposure of aquatic biota to high dissolved metal concentrations. The water quality sampling results for alkalinity are shown in Table 4.6.2-4.

## Indicators/Measures
### Metals

In high concentrations metals cause major disruption of aquatic ecosystems by lowering reproductive success, interfering with normal growth and development, and, in extreme cases, causing death. The relationship of metal toxicity to aquatic species is complex but well established. Surface waters in parks are exposed to metals through both point and non-point sources, including mine drainage, roadways, aerosolized particles dispersed through industrial processes, and by the release of metals naturally occurring in near-surface rock strata and sediments. Most of these contaminants bioaccumulate in aquatic food webs and may pose long-term threats to all trophic levels of the aquatic environment. The water quality sampling results for metals are shown in Table 4.6.2-5.

## Indicators/Measures
### Primary Nutrients

Nutrient levels in a stream result from a hierarchy of biotic and abiotic processes occurring in the watershed, riparian zone, hyporheic zone, parafluvial zone, and the stream itself. Nitrogen and phosphorus are essential macronutrients for plant and animal life but in excess, they can interact with the biological and physical environment to reduce availability of high-quality aquatic habitat, altering the composition and species diversity of aquatic communities. Measures of total nitrogen and total phosphorus indicate the potential for biological effects resulting from nutrient loading. The results for primary nutrient sampling are shown in Table 4.6.2-6.

## Indicators/Measures
### Biological Condition

Measurements of biological condition, along with visual and olfactory qualitative assessments of water condition, complement the other water quality vital signs and provide insight to the overall biological condition of water. Biological Oxygen Demand (BOD) is the measurement referring to the amount of oxygen potentially consumed if all the biologically degradable organic matter, in a given volume of water, were biodegraded. It is an indicator of the potential for a river to become depleted of oxygen. Chemical oxidation of organic matter also influences BOD. Dissolved oxygen levels below 6 mg/L stress fish and other organisms that depend on oxygen for respiration. Biological condition results are presented in Table 4.6.2-7.

## Indicators/Measures
### Emerging Contaminants

Through a cooperative agreement with the Environmental Protection Agency (EPA), NPS-Inventory and Monitoring (I&M) and Water Resources Division; SOPN has begun monitoring emerging contaminants in Network surface water. Emerging contaminants are chemicals characterized by a perceived, potential, or real threat to human health or the environment. Chemicals that

**Table 4.6.2-4. Alkalinity results from sampling at Bent's Old Fort NHS**

| Analyte | 4/26/2012 Results | 10/7/2012 Results | 1/29/2013 Results | 5/6/2013 Results |
|---|---|---|---|---|
| Inorganics (mg/l) | | | | |
| Alkalinity as $CaCO_3$ | 230 | 190 | 220 | 220 |
| Bicarbonate Alkalinity as $CaCO_3$ | 230 | 190 | 220 | 220 |

**Table 4.6.2-5. Metals results from sampling at Bent's Old Fort NHS**

| Analyte | 4/26/2012 Results | 10/7/2012 Results | 1/29/2013 Results | 5/6/2013 Results |
|---|---|---|---|---|
| Dissolved Metals (mg/l) | | | | |
| Arsenic | | 0.0014 | 0.0013 | |
| Boron | 0.29 | 0.27 | 0.24 | 0.29 |
| Calcium | 220 | 200 | 200 | 220 |
| Copper | | 0.0023 | | |
| Iron | | | 0.029 | |
| Magnesium | 87 | 74 | 78 | 87 |
| Manganese | 0.078 | 0.033 | 0.058 | 0.24* |
| Molybdenum | | 0.011 | | |
| Phosphorus | | | | 0.050 |
| Potassium | 5.6 | 5.3 | 4.8 | 6.5 |
| Silica | 11.0 | 11 | 11 | 9.6 |
| Sodium | 190 | 170 | 150 | 180 |
| Selenium | | | 0.0099* | 0.033* |
| Zinc | | 0.014 | 0.018 | |
| Total Metals (mg/l) | | | | |
| Aluminum | 0.11 | 1.0 | 0.37 | 0.10 |
| Boron | 0.30 | 0.27 | 0.25 | 0.29 |
| Calcium | 250 | 200 | 220 | 240 |
| Chromium VI | | | 0.133* | |
| Copper | | 0.0041 | | |
| Iron | 0.15 | 1.1 | 0.41 | 0.16 |
| Magnesium | 920 | 73 | 78 | 81 |
| Manganese | 0.085 | 0.13 | 0.087 | 0.25* |
| Molybdenum | | 0.010 | | |
| Phosphorus | | | | 0.070 |
| Potassium | 6.2 | 5.5 | 4.9 | 6.7 |
| Selenium | | | 0.011 | 0.031* |
| Silica | 130 | 16 | 13 | 9.6 |
| Sodium | 200 | 160 | 150 | 180 |
| Zinc | | 0.012 | | |
| *Indicates exceedance | | | | |

**Table 4.6.2-6. Primary nutrient results from sampling at Bent's Old Fort NHS**

| Analyte | 4/26/2012 Results | 10/7/2012 Results | 1/29/2013 Results | 5/6/2013 Results |
|---|---|---|---|---|
| Inorganics (mg/l) | | | | |
| Bromide | | 0.27 | 0.28 | n/a |
| Fluoride | 1.2 | 1.1 | 1.1 | 1.2 |
| Chloride | 65 | 63 | 49 | 66 |
| Sulfate | 1000* | 960* | 920* | 940* |
| Nitrate, Dissolved | 1.5 | 1.1 | 1.7 | 1.0 |
| Total Kjeldahl Nitrogen | n/a | 1.1 | | |
| Total Nitrogen | 1.6 | 2.2 | 1.7 | 1.6 |
| Phosphorus | | | 0.115 | |
| Total Hardness as $CaCO_3$ | 1000 | 810 | 830 | 930 |
| Total Suspended Solids | | 65 | 13 | 16 |
| Total Dissolved Solids | 1800 | 1600 | 1690 | 1800 |

*Indicates exceedance

**Table 4.6.2-7. Biological condition results from sampling at Bent's Old Fort NHS**

| Analyte | 4/26/2012 Results | 10/7/2012 Results | 1/29/2013 Results | 5/6/2013 Results |
|---|---|---|---|---|
| Organics (mg/l) | | | | |
| Biological Oxygen Demand | 14 | 20 | 2.9 | Not Detected |

**Table 4.6.2-8. Emerging contaminant results from discrete sampling at Bent's Old Fort NHS 10/07/2012.**

| Parameter | Result (ng/L) | Discussion |
|---|---|---|
| Atrazine | 12.7, 17.2 | 200 times less than EPA benchmark |
| Carbamazepine | 18.6 | The concentration was less than half the Minnesota drinking water standard. |
| Hexazinone | 14.9 | 500 times less than the nonvascular plant acute benchmark |
| Metolachlor ESA | 126 | 4,000 times less than the EPA drinking water health advisory level |
| n-Butylparaben | 494 | EPA does not have a standard |
| Sulfamethoxazole | 52.3 | 100 times less than concentrations found to inhibit growth in cyanobacteria |
| Tramadol | 18.6 | EPA does not have a standard |

have not been sufficiently studied may also be considered emerging contaminants. Water samples are collected concurrently with other water quality parameters in the spring, summer and fall quarters. The EPA analyzes the samples for 169 emerging contaminants, including pesticides, herbicides, industrial chemicals, pharmaceuticals and other toxins. The emerging contaminants results are shown in Table 4.6.2-8.

### *4.6.3. Reference Conditions*

The Colorado Department of Public Health and Environment Water Quality Control Commission establishes water quality standards for each Colorado river basin to maintain and improve the quality of the state surface waters (Colorado Department of Public Health and Environment Water Quality Control Commission 2012). The regulations are based upon the best available knowledge to insure suitability for public water supply, domestic, agricultural, industrial and recreational uses, and for the protection and propagation of terrestrial and aquatic life (Colorado Department of Public Health and Environment Water Quality Control Commission 2012). The water quality standards established for the Arkansas River Basin are intended to be used in conjunction with Regulation No. 31 Basic Standards and Methodologies for Surface Water (Colorado Department of Public Health and Environment Water Quality Control Commission 2012).

The water quality standards for the core water quality measures are listed in Table 4.6.3-1. Alkalinity as $CaCO_3$ and bicarbonate of $CaCO_3$ has a detection limit of 5mg/l using EPA analysis method SM 2320B (Gwilliam 2012a). Colorado State standards for metals are shown in Table 4.6.3-2. The EPA has yet to establish concentration standards for most of the emerging contaminants.

### *4.6.4. Condition and Trend*

Core Water Quality Measures

The water in the Arkansas River is typical for the region- turbid and high in salts concentration (e.g., sulfate, calcium) as reflected in specific conductivity results (Tables 4.6.2-1, -2, and -3). Results from the April 2012 and May 2013 sampling events were similar to those collected from sample sites on the Arkansas River near the Historic Site segment (Gwilliam 2012a, 2013b).

During the October 2012 sampling event, the temperature and pH results demonstrated

**Table 4.6.3-1. Core water quality reference conditions**

| Measure | Good Condition |
|---|---|
| Temperature (C) | <27.6[1] |
| Specific conductivity (micro Siemens/cm) | No Standard |
| Turbidity (NTU) | No Standard |
| pH | 6.5-9 |
| Oxygen concentration (mg/L) | >5 |
| E. coli (MPN*) | 126 (geometric mean) |

[1]Temperature standard is seasonal. March-November the acute standard is 28.5 and chronic is 27.6. December – February the acute standard is 14.8, and the chronic is 13.8.

*Most probable number/100ml

**Table 4.6.3-2. Reference conditions for metals**

| Analyte | Water and Fish Reference |
|---|---|
| Dissolved Metals (mg/l) | |
| Arsenic | 0.00002 |
| Boron | Not Established |
| Calcium | Not Established |
| Copper | 1.3 |
| Iron | 1.95[1] |
| Magnesium | Not Established |
| Manganese | Not Established |
| Molybdenum | 0.21 (water supply) |
| Phosphorus | Not Established |
| Potassium | Not Established |
| Silica | Not Established |
| Sodium | Not Established |
| Selenium | 0.17 |
| Zinc | 7.4 |
| Total Hardness | Not Established |

[1]Specifically for Bent's Old Fort NHS

a strong diurnal pattern. The specific conductivity results were irregular, especially during the period of October 15-17, 2012. This could be natural; however, debris may have accumulated on the conductivity probe, which was later dislodged by flow. The dissolved oxygen demonstrates a diurnal pattern during October 8-11, 2012. However, after October 11, the results become irregular. This is a consequence of sediment accumulation around the dissolved oxygen probe, which is positioned approximately eight inches lower than the other probes and is more susceptible to sedimentation. During the next deployment that occurred in late January 2013, the water quality logger position was decreased in depth to avoid this problem .

During the January and May 2013 sampling events, all core water quality results met Colorado State standards (Gwilliam 2013a,b). In May 2013, all parameters demonstrated a strong diurnal pattern. The depth of the water varied by 0.343 meters over the sampling period. The daily high water temperature occurred between 14:00 and 16:00. The decreased water temperature that occurred on May 1-2 was likely a result of cold air temperatures during those days, which was 55 and 51 degrees Fahrenheit, respectively, as compared to 70s-80s for the remaining time period. Daily high specific conductivity occurred between 05:30 and 08:00, with a peak occurring near midnight on May 3. This peak was most likely due to a slight increase in river flow. Dissolved oxygen peaked between 12:00 and 13:00 every day, a few hours before peak water temperature. As sunlight increased over the morning hours, algae photosynthesis was stimulated resulting in increased dissolved oxygen levels, which decreased the oxygen carrying capacity of the water (Gwilliam 2013b).

Additionally, USGS has monitored specific conductance, which is an indicator of dissolved solids (salinity), along the Arkansas and its major tributaries from 1973 - 2007. Specific conductance increased in the Arkansas River from 500 uS/cm in the upstream end of the Lower Arkansas River to 2400 uS/cm below John Martin Reservoir. EPA's drinking water secondary maximum contaminant level (MCL) for dissolved solids is 500 mg/L (EPA 1986), which is equivalent to a specific conductance of about 700 –800 uS/cm in the Lower Arkansas (USGS 1987). This specific conductance was exceeded from near Fowler to below John Martin Reservoir (Tetra Tech 2007b).

Specific conductance varies seasonally based upon water flow and usually lowest during from May-August due to low specific conductance snowmelt runoff and increases during the fall, winter, spring when a larger

percentage of water is composed of irrigation runoff and municipal discharge (Tetra Tech 2007b).

Alkalinity

A comparison of SOPN water quality results from WY2012 with alkalinity data taken from the Arkansas River in the past (NPS 1998) at station BEOL0029 (3 miles upstream of La Junta) indicate that these readings fall within the range of previously observed seasonal results.

These results indicate that the alkalinity of the Arkansas River has in all likelihood not changed much since the samples were collected during a period from 1978 to 1993.

Metals

In the fall of 2012, total arsenic likely exceeded the combined water supply and fish ingestion standard at 0.00002 mg/l. Total Arsenic was not detected in the sample; however, dissolved arsenic was, at 0.0014 mg/l. Total arsenic should be equal to or greater than the dissolved level. This discrepancy is due to a difference in reporting limits: the dissolved arsenic reporting limit is 0.0010 mg/l, and the total arsenic reporting limit is 0.0025. Total arsenic was likely present at a level greater than 0.0014 mg/l and less than 0.0025 mg/l. Therefore, total arsenic exceeded the 0.00002mg/l standard for water supply and fish ingestion. Please note that the total arsenic standard for water supply only is significantly higher and more lenient, at 0.01 mg/l, than the combined water supply and fish ingestion standard (Gwilliam 2012b).

In January 2013, total Arsenic once again likely exceeded the combined water supply and fish ingestion standard at 0.00002 mg/l. Total Arsenic was not detected in the sample; however, dissolved arsenic was, at 0.0013 mg/l. Total arsenic should be equal to or greater than the dissolved level. During the fall sampling event dissolved arsenic was detected at 0.0014 mg/l.

Dissolved Selenium in all sampling periods exceeded the chronic aquatic life-class 2 standard, 0.0046 mg/l. Additionally, in May 2013, both total and dissolved selenium exceeded the state agricultural standards for selenium. This river segment is already on the 303(d) list for Selenium, and these results indicate that dissolved Selenium is still a concern.

The USGS has monitored selenium along the Arkansas River and its major tributaries from 1976 - 2007. At ten of the twelve sites samples throughout the Lower Arkansas River Basin, average selenium concentrations exceeded the chronic table value standard (TVS) of 4.6 µg/L promulgated in CDPHE-WQCC Regulation No. 31 from near Pueblo to below John Martin Reservoir (Tetra Tech 2007b).

In January 2013, the Chromium VI result was also in exceedance of the agriculture, and water and fish standards, both set at 0.1 mg/l. However, there is a caveat; Chromium VI is not processed in a certified lab, it is processed using a portable photometer. The working range of the photometer is 0-1.0 mg/L; the detection limit is 0.02 mg/L. The tolerance, or accuracy is +/- 0.02 mg/L at a concentration of 0.30 mg/L. The measured value of 0.133 mg/L is a possible exceedance

In May 2013, both total and dissolved manganese exceeded state standards, with a total for the agricultural standard at 0.2mg/l and dissolved for the drinking water supply standard at 0.05mg/l. The sample result of the total manganese was 0.25 mg/l and dissolved manganese was 0.24 mg/l.

Primary Nutrients

During all sampling events, sulfate exceeded the water quality site specific standard for this segment of the Arkansas River. The standard is 902 mg/l, and the results were 960, 920, and 940 mg/l. The state sulfate standard for class 2 Aquatic Life is 250 mg/l, however some segments, including the segment along the Historic Site, have been given higher standards because they were identified as having higher naturally occurring levels. The exceedance indicates that there may have been erosion events or discharges upstream of the Historic Site that are higher in sulfate than the ambient water. Further monitoring will indicate whether this is a continuing

problem. All other analytes met state water quality standards.

Biological Condition

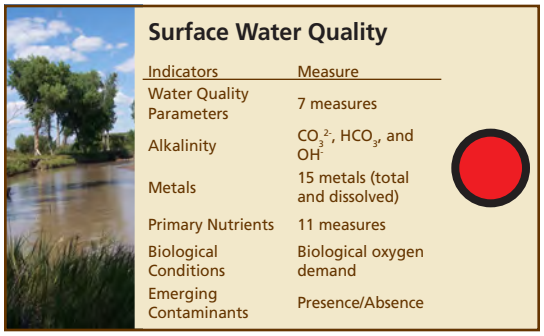
A comparison of SOPN Biological Oxygen Demand (BOD) results from WY2012 with BOD data taken from the Arkansas River in the past (NPS 1998) at station BEOL0029 (3 miles upstream of La Junta) indicate that these readings fall outside the range of previously observed seasonal results.

These results indicate that the BOD values collected by SOPN during WY12 are greater than results from mean results from 1968-1993. BOD values in the 10-20 mg/L range indicate possible discharge of organic material into the stream. There are some factors that may limit the comparability of the two data sets. The BEOL0029 station is located 3 miles above La Junta, and above the outlet of the municipal treatment plants. Also, the BEOL009 station may be closer to cattle yards upstream. Additionally, the flow during the sampling events was different, and this could bias results.

It would be wise to attempt to understand why the BOD collected at the Historic Site is so much higher than previous measurements in the area.

Emerging Contaminants

Seven emerging contaminant analytes were detected during the October 2012 sampling event, however, none of the concentrations exceeded the EPA benchmarks.




Overall Condition

A summary of each indicator and its contribution to the overall water quality condition at the Historic Site is listed in Table 4.6.4-1.

Multiple federal, state, and local agencies throughout the Lower Arkansas Valley have developed a watershed plan to improve water quality (Tetra Tech 2007b).

The watershed plan integrates monitoring conducted by Colorado State University researchers, USGS, and local conservation districts (Tetra Tech 2007b). USGS was asked to compile a comprehensive water quality database and related environmental data for the Lower Arkansas River Basin but has yet to receive funding (Tetra Tech 2007b). When finished the assessment will analyze factors, including all of the core water quality parameters, sulfate, and other major ions, (uranium, selenium, and nutrients) that have affected both current and historic water quality (USGS 2013b).

Previous studies have identified non-point source pollutants as contributing to higher levels of selenium, iron, and uranium, and many of Arkansas River's tributaries listed on Colorado's 303(d) list for selenium and/or iron (Tetra Tech 2007b). Section 303(d) of the Clean Water Act requires states to identify waters not expected to meet the national goal of being "fishable and swimmable" and to develop Total Maximum Daily Loads (TMDLs) for those waters. The 303(d) list identifies priority waters in the Lower Arkansas watershed requiring a TMDL process. The river section through the Historic Site has been listed on the 303(d) list since 1996, primarily for selenium (Table 4.6.4-2) (USEPA 2013). In addition, sedimentation and high salinity are also degrading the river's surface water and alluvium (Tetra Tech 2007a).

Even though the results of the water quality measures at the Historic Site are mixed, the persistently high selenium concentrations have resulted in section 303(d) listing for several years. Because of this and the high specific conductance levels, we consider the Arkansas River water quality condition to be of significant concern, with an unknown trend.

**Table 4.6.4-1. Summary of the surface water quality indicators and their contributions to the overall condition at Bent's Old Fort NHS.**

| Indicator of Condition | Measure | Condition | Rationale for Condition |
|---|---|---|---|
| Water Quality Parameters | pH, dissolved oxygen, temperature, specific conductance, turbidity, and *E. coli* | Significant Concern | The core water quality parameters along this stretch of the Arkansas River is typical, however, the most recent specific conductance level was 2,250 micro Siemens/cm. While no standard exists related to water quality, damage to agricultural crops can occur when specific conductance is between 950-1200 micro Siemens/cm within the Arkansas River (USGS 1998). Because of the very high specific conductance results, we consider this measure to be of significant concern. |
| Alkalinity | $CO_3^{2-}$, $HCO_3$, and $OH^-$ | Good | The alkalinity results were within the range of previously observed seasonal results and is considered to be in good condition. |
| Metals | 15 metals (total and dissolved) | Significant Concern | A ten-year average of interpolated atmospheric wet deposition values were derived to determine that the condition of total nitrogen is of moderate concern and the condition of total sulfur is of good condition at the Monument. |
| Primary Nutrients | 11 measures | Moderate | All analytes met state standards except for sulfate, which exceeded the state standard during all four sampling periods. Asa result we consider the condition of this measure to be of moderate concern. |
| Biological Conditions | Biological oxygen demand | Good | No state standard exists for biological oxygen demand, but when levels are high, dissolved oxygen levels are lower. This was not the case for dissolved oxygen results therefore this measure is good. |
| Emerging Contaminants | Presence/ Absence | Good | Emerging contaminants were sampled for in 2012 and seven were detected, but all were below the established benchmarks. We consider the water quality relative to this measure to be in good condition with an unknown trend. |

**Table 4.6.4-2. Arkansas River 303(d) history report summaries for the area including Bent's Old Fort NHS (EPA 2013).**

| Water Year | Listed Water ID | Waterbody Name | Impairment Cause(s) |
|---|---|---|---|
| 2010 | COARLA01B_3700 | Arkansas River - Colorado Canal To West Of Las Animas | Selenium |
| 2008 | COARLA01B_3700 | Arkansas River - Colorado Canal To West Of Las Animas | Selenium |
| 2006 | COARLA01B_3700 | Arkansas River - Colorado Canal To West Of Las Animas | Selenium |
| 2004 | COARLA01B_3700 | Arkansas River - Colorado Canal To West Of Las Animas | Selenium |
| 1998 | COARLA01 | Arkansas River From Above Fountain Creek To Stateline | Iron; Sulfate; Selenium; Manganese |
| 1996 | COARLA01 | Arkansas River From Above Fountain Creek To Stateline | Iron; Unlisted but Impaired; Sulfate; Manganese |

Level of Confidence/Key Uncertainties/ Threats

The issues that threaten the water quality of the Arkansas River within the Historic Site are occurring on a regional scale and will require many partners and participants to effect a long-term change. Animal feeding operations, irrigation and non-irrigation of agricultural land, grazing, and overall water management have been identified as contributors to non-point pollutants (Tetra Tech 2007b). Gates et al. (2006, 2012) have been monitoring and modeling well and surface water data along the Lower Arkansas River Valley since 1999, including the vicinity surrounding the Historic Site. The feasibility of water management strategies at the Basin scale shows promise that river water quality can be improved through reduction of excess irrigation recharge and canal seepage and increased subsurface drainage, along with several additional benefits to the surrounding agriculture productivity and water conservation (Triana et al. 2010). A key uncertainty is whether enough stakeholders are able and/or willing to implement necessary practices and operations to effect a much needed change. Woods and McDonald (2002) collected surface water quality data twice in 2001 at Day pond and Arch wetland. No additional water quality data have been collected since then to assess current condition of these resources. Vana-Miller et al. (2010) recommended monitoring for a suite of water quality parameters similar to those measured by Woods et al. (2002) in the park's wetlands.

### *4.6.5. Sources of Expertise*

Evan Gwilliam is the Aquatic Ecologist for the Sonoran Desert Inventory and Monitoring Network. Evan received his Master's of Science in Natural Resource Science at University of Rhode Island. The Sonoran Desert and Southern Plains I&M Networks have partnered to develop a long-term stream monitoring protocol to detect status and trends in riparian system 'Vital Signs'.

### *4.6.6. Literature Cited*

Colorado Department of Public Health and Environment Water Quality Control Commission. 2012. Regulation #31. 212 pp.

Gates, T.K., L.A. Garcia, and J.W. Labadie. 2006. Toward optimal water management in Colorado's Lower Arkansas River Valley: monitoring and modeling to enhance agriculture and environment. Colorado Water Resources Research Institute completion report no. 205 and Colorado Agricultural Experiment Station completion report TR06-10. 60 pp.

Gates, T.K., L.A. Garcia, R.A. Hemphill, E.D. Morway, and A. Elhaddad. 2012. Irrigation practices, water consumption, and return flows in Colorado's Lower Arkansas River Valley. Colorado Water Resources Research Institute completion report no. 221 and Colorado Agricultural Experiment Station completion report TR12-10. 116 pp.

Gwilliam, E. 2012a. Trip summary report for Bent's Od Fort National Historic Site. 6pp.

Gwilliam, E. 2012b. Trip summary report for Bent's Od Fort National Historic Site. 7pp.

Gwilliam, E. 2012c. Trip summary report addendum for Bent's Od Fort National Historic Site. 7pp.

Gwilliam, E. 2013a. Trip summary report for Bent's Od Fort National Historic Site. 4pp.

Gwilliam, E. 2013b. Trip summary report for Bent's Od Fort National Historic Site. 6 pp.

Gwilliam, E. et al. 2013. Sonoran Desert and Southern Plains Networks stream monitoring protocol, narrative version 1.0. Manuscript in preparation.

National Park Service. 1998. Baseline Water Quality Data Inventory and Analysis Bent's Old Fort National Historic Site. Technical Report NPS/NRWRD/

NRTR-98-165.National Park Service Water Resources Division Fort Collins, CO 80525. Pp. 399.

National Park Service. 2006. Management policies 2006-The guide to managing the National Park System. Washington D.C. 180pp.

National Park Service. 2013. Foundation document Bent's Old Fort National Historic Site, Colorado. 40 pp.

National Park Service Inventory and Monitoring. 2012. Stream ecological integrity. Available at http://science.nature.nps.gov/im/units/romn/monitor/stream/index.cfm (accessed June 15, 2013).

Perkins, D. W.1, H. Sosinski1, K. Cherwin, and T. F. Zettner. 2005. Southern Plains Network Vital Signs Monitoring Plan: Phase I. National Park Service, Southern Plains Network, Johnson City, TX, USA. **pp. plus appendices.

Schweiger, E.W., L. O'Gan, D. Shorrock and M. Britten. 2012. DRAFT Stream Ecological Integrity at Little Bighorn National Battlefield Monument; Rocky Mountain Inventory & Monitoring Network 2007 – 2010 Stream Monitoring Report. Natural Resource Technical Report NPS/XXXX/NRTR—20XX/XXX. National Park Service, Fort Collins, Colorado.

Tetra Tech. 2007a. Lower Arkansas watershed plan. Prepared for the Southeast Colorado RC&D, Lamar, Colorado. Tetra Tech Job No. 133-5377.001. 23 pp.

Tetra Tech. 2007b. Lower Arkansas watershed plan. Prepared for the Southeast Colorado RC&D, Lamar, Colorado. Tetra Tech Job No. 133-5377.001. 40 pp.

Triana, E., T.K. Gates, and J.W. Labadie. 2010. River GeoDSS for argroenvironmental enhancement of Colorado's Lower Arkansas River Basin. II: evaluation of strategies. Journal of Water Resources Planning Management, 136: 190-200.

U.S.D.I. National Park Service, Southern Plains Inventory and Monitoring Network. 2008. Southern Plains Network Vital Signs Monitoring Plan. Natural Resource Report NPS/SOPN/NRR-2008/028. National Park Service, Fort Collins, Colorado.

United States Environmental Protection Agency. 1986. Secondary maximum contaminant levels (section 143.3 of part 143, National secondary drinking-water regulations): U.S. Code of Federal Regulations, Title 40, Parts 100-149, p. 587 – 590.

United States Environmental Protection Agency. 2013. Watershed assessment, tracking, and environmental results. Available at http://ofmpub.epa.gov/waters10/attains_wb_history.control?p_listed_water_id=COARLA01B_3700&p_cycle=2010 (accessed June 25, 2013).

United States Geological Survey. 1987. Relations of specific conductance to streamflow and selected water-quality characteristics of the Arkansas River Basin, Colorado. USGS Water Investigations Report 87-4041.

United States Geological Survey. 2012. Water quality. Available at http://ga.water.usgs.gov/edu/waterquality.html (accessed June 15, 2013).

United States Geological Survey. 2013a. Water resources of the United States boundary descriptions and names of regions, subregions, accounting units and cataloging units. Available at (http://water.usgs.gov/GIS/huc_name.html#Region11) (accessed June 22, 2013) .

United States Geological Survey. 2013b. Lower Arkansas River comprehensive data Base and data assessment. Available at http://co.water.usgs.gov/projects/CO432-02/index.html (accessed June 25, 2013).

Vana-Miller, D., C. Moore, J. Hughes and K. Noon. 2010. Water resources information and issues overview report: Bent's Old Fort National Historic Site. Natural Resource Report NPS/NRPC/WRD/NRR—2010/258. National Park Service, Fort Collins, Colorado.

Woods, S.W. and L.H. MacDonald, 2002. The cause of basement flooding at Bents Old Fort National Historic Site. Technical Report for contract: Ca-1200-99-009 CSU-23.

## 4.7. Groundwater

**Indicators/Measures**

- Groundwater Elevation (Change in groundwater elevation)

**Condition - Trend - Confidence**



Moderate - Unknown - Medium

*This section is primarily comprised of groundwater text excerpted from Wagner and Martin (2014). Martin researched and wrote groundwater assessment for the purposes of this NRCA.*

### *4.7.1. Background and Importance*

Groundwater resources provide approximately 18% of Colorado's water supply needs statewide, but on the Eastern Plains of the state where perennial surface water is generally ephemeral, groundwater use is typically higher than surface water. However, in Otero County where Bent's Old Fort National Historic Site is located, groundwater withdrawal accounts for less than 5% of total water use (Colorado Geological Survey 2013). Surface water withdrawals from the Arkansas River, through numerous diversions, is the primary water source for local agriculture.

Currently, there are over 1,000 miles of Arkansas River water diversions, including the Fort Lyon Canal, which is located about 6000 feet north of the Fort and is over 50-miles long. As a result of these extensive irrigation and water diversions, a number of environmental consequences have occurred. One is an increase in the water table elevation in some areas due to irrigation seepage into the alluvial aquifer. Following that, some low elevation valley soils have become "waterlogged" due to the water table rise and other soils are undergoing salinization from evaporation of both agricultural waters and shallow groundwater (Gates et al. 2006). At Bents Old Fort NHS, the Fort well room flooded multiple times between 1998-2002. This was the first known occurrence since the reconstruction in 1975 (Figure 4.7.1-1). Also, Historic Site staff has suggested that the largest wetland, Arch Wetland, has changed in size and character over the last few decades, possibly due to higher groundwater levels (Fran Pannebaker, NPS-Bent's Old Fort NHS, pers. comm.).

National Park Service (NPS) Management Policy 4.6.1 states that the NPS will perpetuate surface waters and ground water



NPS

**Figure 4.7.1-1. Flood damage in the Fort's well room at Bent's Old Fort NHS.**

as integral components of park aquatic and terrestrial ecosystems (NPS 2006). It is the policy of the NPS to determine the quality of park surface and groundwater resources and avoid, whenever possible, the pollution or other types of degradation of park waters by human activities occurring within and outside of parks.

## Occurrence and Movement of Groundwater in the Vicinity of Bents Old Fort NHS

Bent's Old Fort NHS is underlain by a continuous, alluvial aquifer contained in the river sediments that completely fill the Arkansas River Valley. Such aquifers are generally long and relatively narrow, following the overall alignment of the local drainages (Figure 4.7.1-2). This alluvial aquifer is bounded below and on its north and south sides by relatively impermeable bedrock, essentially isolating the alluvial aquifer from deeper, more regional groundwater systems.

The width of the valley at the Historic Site is about 9000 feet, and with its very low relief, especially the region around the Arkansas River mostly lies within the greater floodplain (U.S. Army Corps of Engineers 1977). Local land surface elevations within the valley range from about 3990 to 4040 feet and bounding uplands reach heights of about 4150 feet (NGVD29). The valley was carved out of a very thick sequence of relatively impermeable Upper Cretaceous strata, including the Carlile and Graneros shales and the Greenhorn limestone. These low-permeability formations create a basal confining layer for the alluvial aquifer contained in the valley. While numerous small faults have been identified in bedrock outcrops on the valley margins, it is unlikely that there is any substantial hydrologic communication between the alluvial aquifer and deeper bedrock aquifers. Some interflow between these two groundwater systems likely takes place, but overall, the alluvial aquifer is essentially isolated from deeper groundwater systems (Weist 1965).

The configuration of the bedrock surface forms a deep erosional trough with an elevation in the range of about 3980 feet (NGVD29) or less under the Historic Site. This "trough" is filled with alluvial sediments that range in thickness from about 30 to 100 feet deep at the deepest, thinning to near zero feet at the margins. Estimates of the saturated thickness of the aquifer about five miles upstream from the Historic Site are in

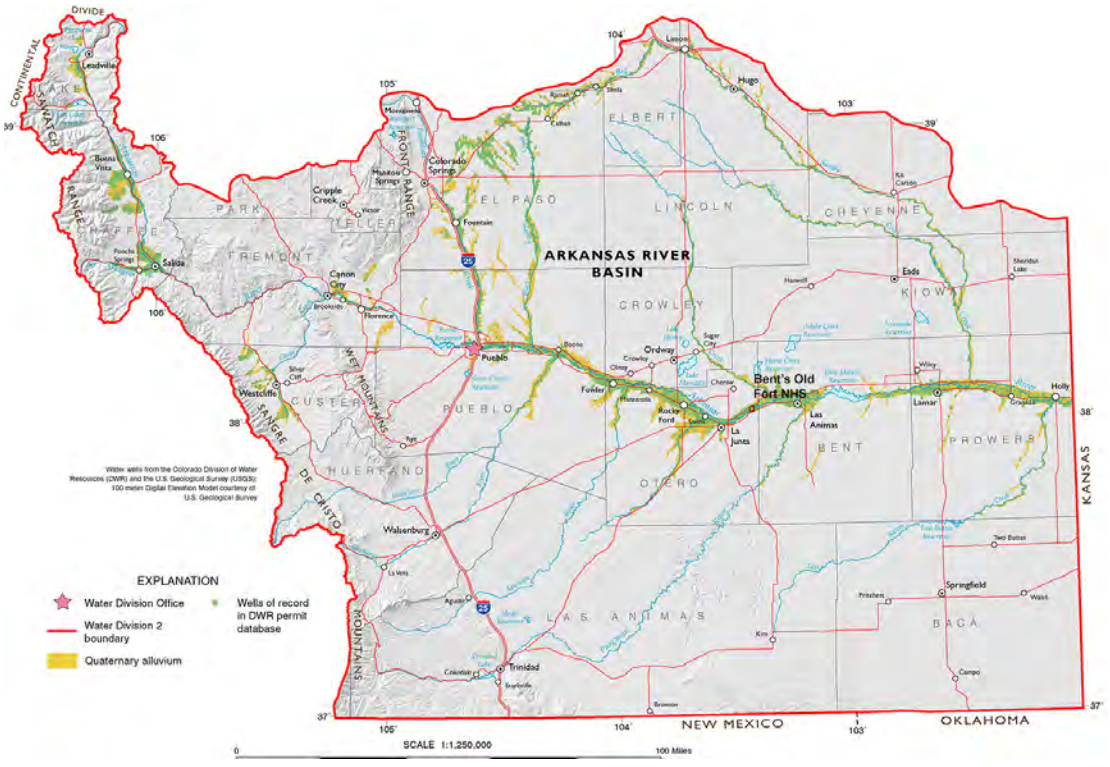



**Figure 4.7.1-2. Overview of the Arkansas River Basin with alluvial aquifers identified in green (http://geosurvey.state.co.us/apps/wateratlas/chapter5_2page1.asp 2003).**

the range of about 30-35 feet in the deepest parts of the valley (Nelson et al. 1989). The alluvium that fills the valley is of Holocene and Pleistocene age sediment and consists of clay, silt, sand, and gravel with some cobbles and boulders (Weist 1965). Extensive, continuous layers of well-sorted, permeable sand and gravel likely exist and probably serve as the primary water bearing zones.

Domestic water comes from Bents Fort Water Company (city water). There is a well in the maintenance building that pumps non-potable groundwater to toilets and three fire hydrants. There are two irrigation wells for prairie restoration, but only one of the wells is currently active (as of December 2014). The Historic Site has water shares with Fort Lyon Canal Company and is a member of the Colorado Water Protective Development Association (A. Heberlie, Biological Science Technician, pers. comm).

In contrast to the underlying confining bedrock, the surface of the alluvial aquifer supports water table conditions and is in direct connection to the atmosphere through the soil zone. Sources of recharge that may enter the aquifer include: direct infiltration, leakage from the Arkansas River and the Fort Lyon Canal, and deep percolation of irrigation water. Discharges from the aquifer include leakage to the Arkansas River; pumpage for municipal, irrigation, and industrial wells; and evapotranspiration.

### *4.7.2. Data and Methods*

A short term groundwater study conducted by Woods and MacDonald (2002) at the Historic Site investigated the source(s) of basement flooding at the Fort by quantifying hydraulic gradients between the river and the aquifer through a single growing season, June to September, 2010. Fifteen shallow observation wells were installed on the floodplain/terrace system (13 of which were installed in March in 2001) to evaluate groundwater near the Fort.

In brief, the study concluded that during the observation period there was always a gradient from the northern portion of the valley towards the river situated to the south. Based on this finding, the authors concluded that basement flooding and hydrologic input to the Arch Wetland was likely a result of seepage from the Fort Lyon Canal and local irrigation in combination of the Arkansas River. Specifically, Woods and MacDonald (2002) indicated that the year the Fort basement flooded (1999) was also a peak flow year for the Arkansas River, more than thirteen times greater than the peak flow observed during their groundwater study in 2001, indicating high flows in the Arkansas River may also have a direct effect on basement flooding

While diversion of surface water provides the majority of water use in the area, there are numerous wells that tap the alluvial aquifer. Within about five miles upstream of the Historic Site there are over 45 wells with associated uses including irrigation, municipal supply, and industrial. In general, groundwater withdrawals increase during times of diminished river flows; when natural surface flows are insufficient to meet demand, groundwater is used for supplemental irrigation water (Watts and Lindner-Lunsford 1992). Over time, groundwater pumping has decreased throughout the region and is believed to be one of the factors contributing to increased groundwater levels (Woods and MacDonald 2002).

**Indicator/Measure**
Groundwater Elevation (Change in groundwater elevation)

Water use at Bent's Old Fort NHS

All of the water that is used at the Historic Site originates as groundwater. Of the six wells contained within the Historic Site's boundary, two are irrigation wells used for prairie restoration, 2 wells are for fire fighting, 2 wells are not in use, and one is a domestic well, and located at the historic Fort (State of Colorado Division of Water Resources 2013). All wells were drilled between 1954-1965.

The four wells present on the Fort grounds range in depth from about 34 to 50 feet (Figure 4.7.2-1). At least two of the wells mentioned (State ID Numbers: 1725725 and 1725802) are subject to regulation by the State

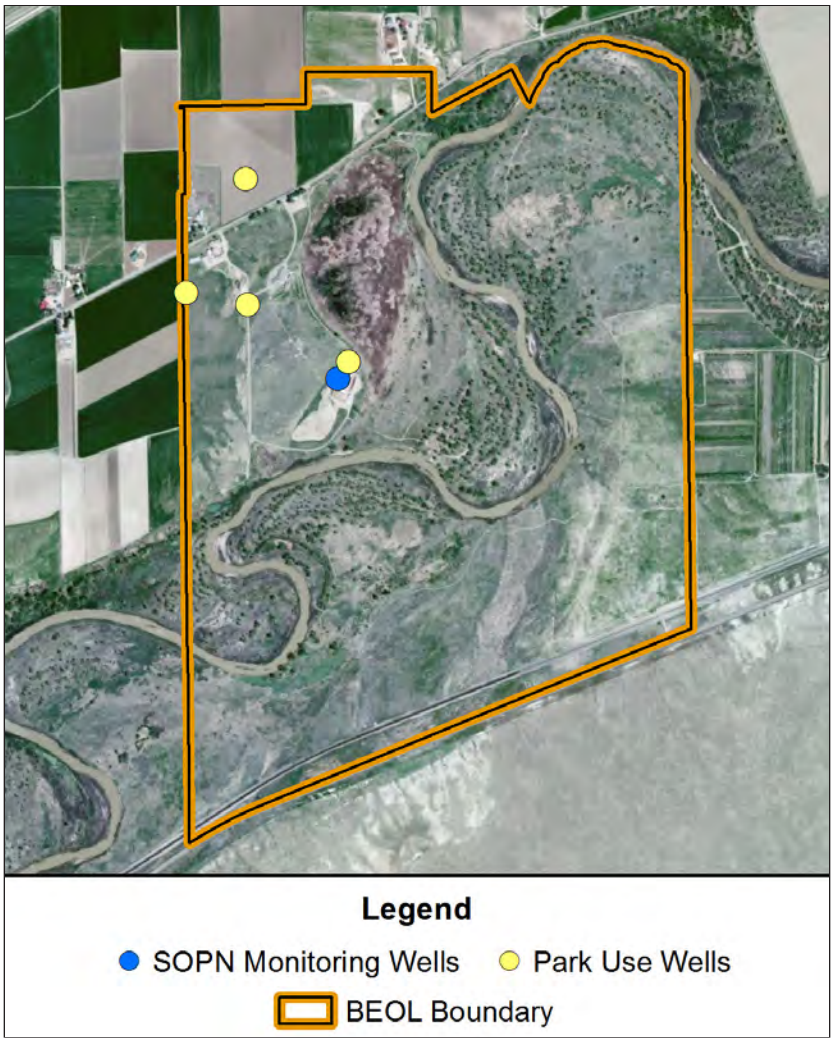



**Figure 4.7.2-1. Groundwater well locations at Bent's Old Fort NHS.**

of Colorado (Hughes 2010). The Historic Site also has 47 shares of water from The Fort Lyon Canal Company (Hughes 2010).

In 2012 the Southern Plains Inventory and Monitoring Network implemented a groundwater monitoring program to analyze the depth and the gradients of the water table in the alluvial aquifer. Four of the groundwater monitoring wells that were installed as part of Woods and MacDonald study in 2002 were evaluated for the Network groundwater study. Unfortunately, three of the four wells had filled in enough to make them non-viable monitoring wells. The only viable well from the quartet is the one just to the west of the Fort (Evan Gwilliam, pers. comm. May 31, 2013). To date, no current groundwater elevation data exist specifically for the Historic Site.

River Stage

The Arkansas River, which runs through the central area of the valley, partially penetrates the alluvial aquifer and is in close association with the immediate groundwater. The river may serve as either a source of recharge to the aquifer when the stage in the river is greater than the altitude of the water table, or a sink for discharge from the aquifer when the gradient is reversed (Watts and Lindner-Lunsford 1992). Consequently, any evaluation of groundwater gradients or flow directions in the alluvial aquifer must include some consideration of flow, particularly stage, in the Arkansas River.

Discharge of the river is measured upstream of the Fort at the USGS gage #07123000, Arkansas River at La Junta and downstream at #07124000, Arkansas River at Las Animas. Both flow records are substantial, with 98 and 73 years at the La Junta and the Las Animas gages, respectively. Flow in the river is affected by diversions of surface and ground water, irrigation return flows, and reservoir storage/release as well as natural variability (Watts and Lindner-Lunsford, 1992)

As suggested, the amount and direction of water flow between the Arkansas River and the alluvial aquifer is a function of both the hydraulic gradient between the water table and the stage of the river, and the conductance of the riverbed-aquifer interface. Net annual flow is from the river to the aquifer at an estimated rate of about 1.2 cfs/mile of river/year, in this area (Watts and Lindner-Lunsford 1993). However, the magnitude and direction of stream-aquifer flux varies seasonally with changes in river stage and water-table elevations and these two parameters may be greatly affected by surface water diversions and groundwater withdrawals.

Fort Lyon Canal

One of the major hydrologic influences in the area is the Fort Lyon Canal, which affects both the river stage and the recharge to the northern edge of the aquifer. Surface water from the Arkansas River is diverted about nine miles upstream from the Fort reducing river stage in downstream reaches. The unlined

**Table 4.7.3-1. Reference condition classes for assessing groundwater condition from an ecological condition, however, there is concern for flooding of historic structures at Bent's Old Fort National Historic Site.**

| Condition Class | Description |
|---|---|
| Good | A good reference condition is one where groundwater level supports resources, such as the riparian-wetland system. We expect variability that reflects annual variation in environmental conditions (e.g., rainfall, evapotranspiration, pumping), but lacks an overall long-term decreasing or increasing water level trend. Natural systems, when well supported by the local water table, are generally resilient enough to maintain viability through natural variations in hydrology, including periods of drought*.<br>*Groundwater levels do not result in flooding of significant historic resources such as the historic Fort. |
| Moderate | A moderate condition is when groundwater levels fluctuate around a water table elevation that only provides marginal support for the resources. In this scenario prolonged drought, excessive withdrawals, or excessive increase in water table levels could result in either loss of the wetland-riparian system, water-logged and/or saline soils*.<br>*Increased groundwater levels result in flooding of significant historic structures. |
| Significant Concern | A significant concern condition is when water levels are so low or high in the alluvial aquifer that there is either no hydrologic support for the wetland riparian system or there are adverse impacts to soils and/or other significant historic resources*.<br>*A significant concern is when frequent flooding of significant historic resources occurs. |

*Indicates consideration of effect of groundwater on significant historic resources.

structure, which runs in a generally west to east direction, continually loses water where it intersects the alluvial aquifer, raising water table elevations locally along its northern edge. Previous estimates of seepage loss from the canal are in the range about one cfs/mile of the canal (Watts and Lindner-Lunsford 1992).

### *4.7.3. Reference Conditions*

The reference conditions by which groundwater condition was assessed are listed in Table 4.7.3-1.

### *4.7.4. Condition and Trend*

Various studies have been conducted regarding the alluvial aquifer and the closely associated Arkansas River (Darton 1906; Snipes et al. 1974; Watts and Lindner-Lunsford 1992; Gates et al. 2012). Overall, the perceived trend is that water table elevations have risen locally since the late 1970s, probably from a combination of factors: increased surface-water infiltration, increased seepage losses from the canal, decreased groundwater pumpage, and increased percolation of irrigation water to the water table (Woods and MacDonald 2002). Additionally, aggradation of the stream bed has increased river stage in the vicinity of the gage at La Junta (#07123000), but according to Wagner and Martin (2014), it is not known if aggradation has occurred within the Historic Site since no signs of excessive sediment deposition were observed during the 2013 riparian habitat assessment. Water levels in wells near the Fort Lyon Canal and in irrigated areas have had larger changes than those near the river, suggesting a link to irrigation practices (Watts and Lindner-Lunsford 1992).

While high water table conditions may have detrimental effects on agricultural soils; the same conditions may help support plant vigor in riparian and wetland systems. A sustained rise in average water table elevations could trigger a shift in riparian-wetland species composition with more facultative and obligate species colonizing the lower and wetter areas, but overall, a relatively shallow water table is a positive attribute of a healthy riparian system.

High water table elevations, however, have created management problems for Historic Site staff by flooding the Fort basement,

leading to the replacement of rotted timbers in 2000. There is concern that permanent damage may be done to the Fort's wood and adobe structure if water table elevations continue to rise and maintain these high levels over time.

Based on interpretation of Woods and MacDonald (2002) findings, Wagner and Martin (2014) suggests that the flooding of the Fort is related to elevated river stages in the Arkansas River but that influences from the Fort Lyon Canal and other irrigation in the area may also likely contribute to the mechanism(s) necessary for flooding to occur (but uncertain as to the degree of contribution). This is consistent with Woods and MacDonald's observations that Fort basement flooding occurred during the 1999 peak river flow of the Arkansas River-one of the highest on record (USGS 2013) but during low to average flow in Arkansas River the groundwater flows are largely influenced by canal seepage and irrigation. Although, this alone may not cause flooding of the Fort.

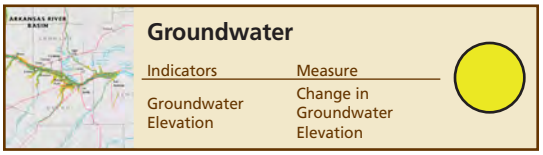
Vana-Miller et al. (2010) also suggested Woods and MacDonald (2002) concluded "*that the flow of water from the river combined with increased leakage from the canal were the likely cause of the high water table levels and subsequent basement flooding in the Fort*." Van-Miller et al. (2010) further stated that a high river stage may reduce the water gradient but that the basement flooding may be coming from the canal instead of the river, resulting in the same unwanted outcome-Fort flooding.

Despite some differing opinions as to whether river stage or seepage and irrigation contribute most to flooding, there is general agreement that both contribute to some degree to the flooding of Fort structures. Martin (2013) suggests further investigation may be needed to ensure efficacy of potential future actions to address the issue of elevated groundwater levels.

Unfortunately, the elements that determine river stage are mostly out of the control of Historic Site staff. The Arkansas River is highly regulated with two major reservoirs; the John Martin Reservoir downstream and Pueblo Reservoir upstream, both of which store and release water for agriculture in Colorado as well as Kansas. Between the Pueblo Dam and the park there are 6 major water diversions, the largest being the Fort Lyon Canal. The Fort Lyon Canal is 113 miles (50 linear miles) and irrigates over 93,000 acres. This regulation dramatically changes natural flood peaks and overall timing of flows with everything available from a dry channel to sporadic, moderate peak flows.

Arch Wetland

The Arch Wetland is groundwater controlled and may have expanded and shifted to a more hydric characteristic possibly from irrigation influences. This is a reasonable assumption given the configuration of the local water table and nearby irrigation, but, according to Wagner and Martin (2014) there is no definitive evidence that this has occurred. Careful monitoring of the groundwater in the vicinity of this wetland could provide insight into the current trend of this water table dependent feature.




Overall Condition/Trend

For assessing the condition of groundwater at the Historic Site, we chose one indicator (groundwater elevation) (Table 4.7.4-1).

Based upon our review of the apparent groundwater condition relative to the ecological reference condition for the riparian system and based upon the reference condition considering the impact to the historic Fort, we assess the condition and trend of the alluvial groundwater resource at the Historic Site to be of moderate concern with an unknown trend continuing into the future.

Key Uncertainties

There are numerous factors that may affect the trend of both the water table elevation in the alluvial aquifer and the stage of the Arkansas River. One of the greatest uncertainties is the natural hydrologic input, which affects both the river flows and groundwater elevations

**Table 4.7.4-1. Indicator, measure, and rationale of groundwater condition.**

| Indicator of Condition | Measure | Condition | Rationale for Condition |
|---|---|---|---|
| Groundwater Elevation | Change in Groundwater Elevation | Moderate | The alluvial aquifer and riparian habitat are interconnected and long-term groundwater levels have supported the riparian system within the Historic Site as evidenced by the system's ability to maintain viability through hydrologic variations. However, increased groundwater levels have caused flooding in the historic Fort, which is one of the site's most significant resources, resulting in a moderate concern condition rating. |

directly, and indirectly and influences the amount of water diverted from the river and pumped from the aquifer. While we know that the groundwater gradient flows from the northwest to the river, we don't fully understand just how significant this flow is to flooding the Fort basement. Even though the canal seepage and irrigation practices increase the water table elevation, this increase may be irrelevant especially during a high water year where flooding would occur regardless of additional inputs to the groundwater system. However, there's also a possibility that when a river stage that wouldn't normally flood the Fort is combined with existing elevated water table levels due to irrigation and seepage, flooding may occur. At this point, a better understanding of the groundwater dynamics is needed to provide better insight for management decisions.

### *4.7.5. Source of Expertise*

The groundwater assessment for the Historic Site was based on information reported by Michael Martin in the riparian habitat assessment conducted at the Site by Wagner and Martin (2014).

Michael Martin is a hydrologist with the NPS Water Resources Division and has his Masters of Science in Watershed Science. Specialty areas include open channel flow, geomorphology, flood analysis, wetlands, and hydrology.

### *4.7.6. Literature Cited*

Colorado Geological Survey. 2013. Groundwater atlas of Colorado. Chapter 1, Introduction. Available at http://geosurvey.state.co.us/WATER/GROUNDWATERATLAS/Pages/GroundwaterAtlasofColorado.aspx (accessed September 17, 2013).

Darton, N.H. 1906. Geology and underground waters of the Arkansas Valley in eastern Colorado. Washington Government Printing Office. United States Geological Survey. Professional Paper Number 52. 168pp.

Gates, T.K., L.A. Garcia, and J.W. Labadie. 2006. Toward optimal water management in Colorado's Lower Arkansas River Valley: monitoring and modeling to enhance agriculture and environment. Colorado Water Resources Research Institute completion report no. 205 and Colorado Agricultural Experiment Station completion report TR06-10. 60 pp.

Gates, T.K., L.A. Garcia, R.A. Hemphill, E.D. Morway, and A. Elhaddad. 2012. Irrigation practices, water consumption, and return flows in Colorado's Lower Arkansas River Valley. Colorado Water Resources Research Institute completion report no. 221 and Colorado Agricultural Experiment Station completion report TR12-10. 116 pp.

Glossary of soil science terms. Soil Science Society of America. Madison, Wisconsin. 138p. Available at https://www.soils.org/publications/soils-glossary (accessed July 27, 2012).

Hughes, J. 2010. Trip report for travel by Jeff Hughes to Bent's Old Fort National Historic Site on June 24, 2010. National Park Service Water Resources Division. 3pp.

National Park Service. 2006. Management Policies 2006-The guide to managing the National Park System. Washington D.C. 180pp.

Nelson, G.A., Hurr, R.T., and Moore, J.E. 1989. Hydrogeologic characteristics of the valley-fill aquifer in the Arkansas River valley, Crowley and Otero Counties, Colorado: U.S. Geological Survey Open-File Report 89-255, 3 sheets.

Rosensheim, J.S. 1988. The Geology of North America, Vol 0-2 Hydrogeology. The Geological Society of North America 1988.

Snipes, R.J. and others. 1974. Floods of June 1965 in Arkansas River Basin, Colorado, Kansas, and New Mexico. Geological Survey-Water Supply Paper 1850-D. 104pp.

Society for Range Management [SRM]. 1999. A glossary of terms used in range management. Society for Range Management. Denver, Colorado. 20p. Soil Science Society of America [SSSA]. 1997.

State of Colorado Division of Water Resources. 2013. Colorado's well permit search. Available at http://www.dwr.state.co.us/WellPermitSearch/View.aspx?receipt=90 (accessed June 10, 2013).

United States Army Corps of Engineers. 1977. Special Flood Hazard information, Arkansas River Anderson and King Arroyo, La Junta and Otero counties. 1977.

United States Geological Society (USGS). 2013. National water information system:web interface. Available at http://nwis.waterdata.usgs.gov/nwis/peak?site_no=07123000&agency_cd=USGS&format=html (accessed September 30, 2013).

Vana-Miller, D., C. Moore, J. Hughes and K. Noon. 2010. Water resources information and issues overview report: Bent's Old Fort National Historic Site. Natural Resource Report NPS/NRPC/WRD/NRR—2010/258. National Park Service, Fort Collins, Colorado.

Wagner, J. and M. Martin. 2014. Trip Report detailing Proper Functioning Condition Assessment for the Arkansas River within Bent's Old Fort National Historic Site. 26pp.

Watts, K. and J. Lindner-Lunsford. 1992. Evaluation of proposed water management alternatives to lower the high water table in the Arkansas River Valley near La Junta, Colorado. Water Resources Investigation Report 91-4046. U.S. Geological Survey, Denver, CO.

Weist, W.G. Jr., 1965, Geology and occurrence of ground water in Otero County and the southern part of Crowley County, Colorado: U.S. Geological Survey Water-Supply Paper 1799, 90 p.

Woods, S.W. and L.H. MacDonald, 2002. The cause of basement flooding at Bents Old Fort National Historic Site. Technical Report for contract: Ca-1200-99-009 CSU-23

## 4.8. Riparian Habitat

**Indicators/Measures**

- Hydrology (5 measures)
- Vegetation (7 measures)
- Erosion/Deposition (5 measures)

**Condition – Trend– Confidence**



Good - Insufficient Data - High

***The majority of this section is excerpted from the Proper Functioning Condition (PFC) Assessment for the Arkansas River Within Bent's Old Fort National Historic Site (Wagner and Martin 2014). For more information, go to http://www.nature.nps.gov/publications/nrpm/nrr.cfm***

### *4.8.1. Background and Importance*

Riparian wetlands are a type of non-tidal wetland formed along river and stream floodplains. These wetlands serve many functions including water purification, flood control, buffering riverbank erosion, habitat for numerous wildlife, fish, shellfish, and plant species, and also provide many recreational opportunities. In the arid west, riparian habitat is often in marked contrast with the surrounding terrestrial vegetation and is strongly influenced by the presence or absence of water (NPS-WRD 2011).

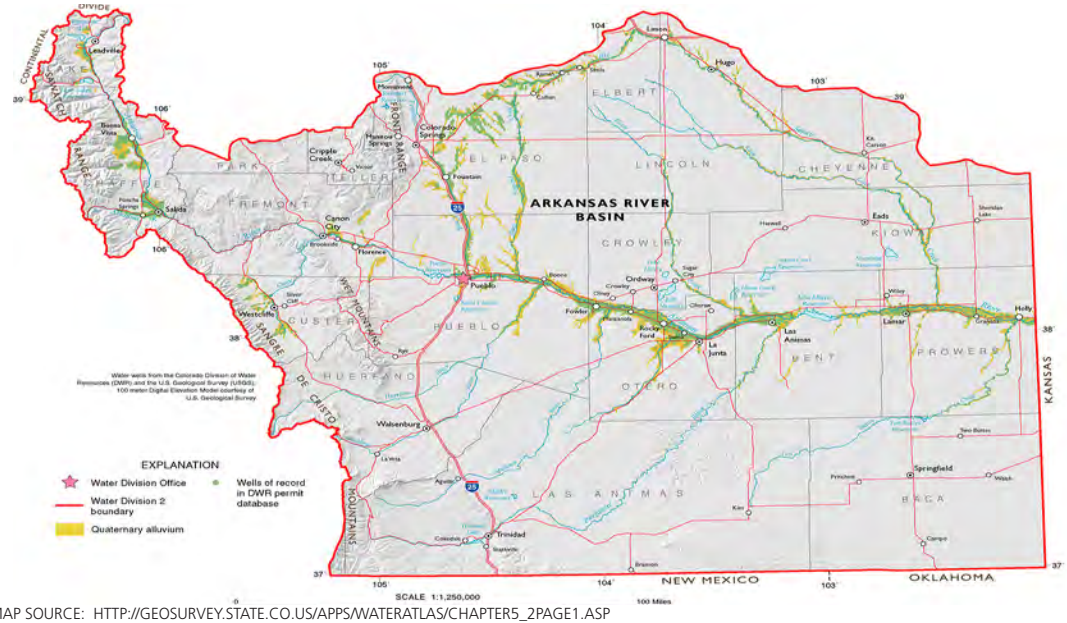
The National Park Service (NPS) has several wetland protection procedures and policies (Director's Order #77-1: Wetland Protection (2002), Procedural Manual #77-1 (2012), and NPS Management Policies (2006)) to ensure a "no net loss" of wetlands throughout the NPS.

Setting

Bent's Old Fort National Historic Site is located on the north bank of the Arkansas River about eight miles downstream from the town of La Junta, Colorado (Figure 4.8.1-1). It was originally built as a trading post on the Mountain Route of the Santa Fe Trail in 1833. Currently, the footprint of the historic Fort is located on a relatively high, fluvial terrace about 550 feet away from the active channel and about 10 - 15 feet above the river.

Arkansas River Characteristics

The Arkansas River is a relatively sinuous, meandering stream somewhat incised into its gently sloping valley, the Arkansas River Valley. The width of the valley at the Historic Site location is between 8,000 and 9,000




MAP SOURCE: HTTP://GEOSURVEY.STATE.CO.US/APPS/WATERATLAS/CHAPTER5_2PAGE1.ASP

**Figure 4.8.1-1. Overview of the Arkansas River Basin with alluvial aquifers identified in green.**

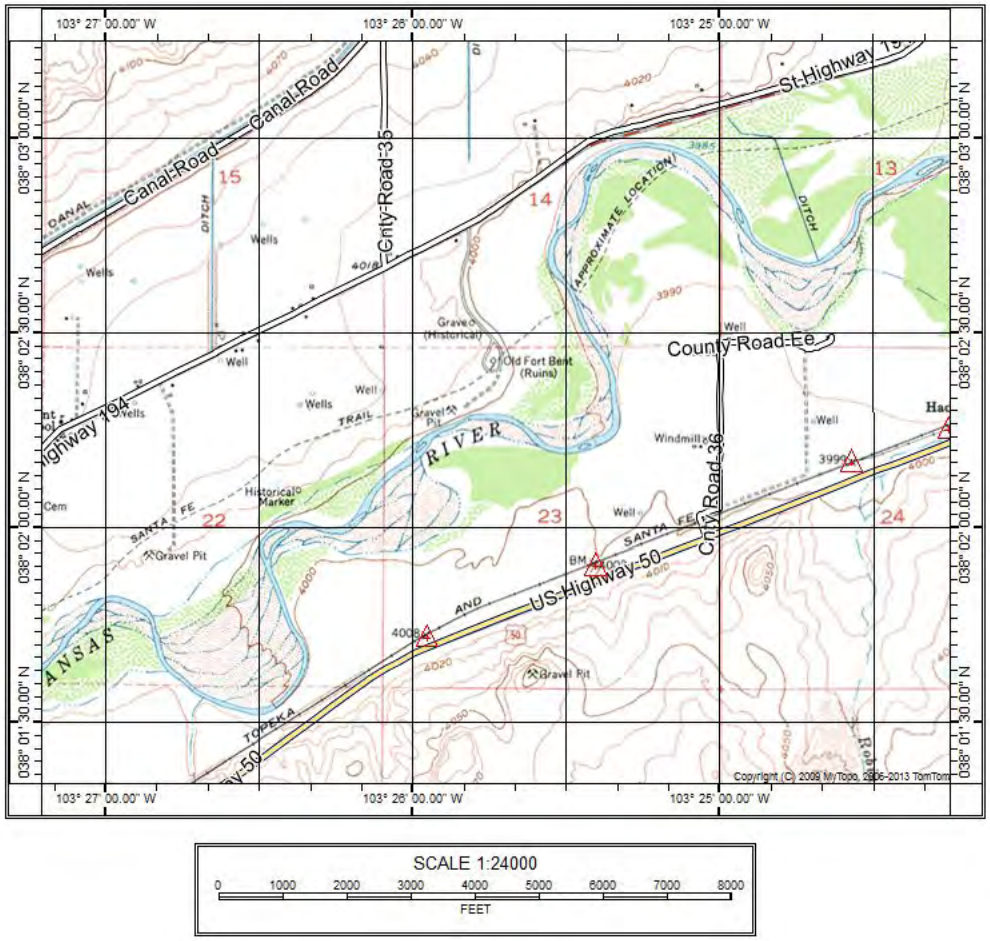



**Figure 4.8.1-2. Topographic overview of the Arkansas River Valley and some of the adjacent uplands (USGS quadrangle, Hadley, Colorado 1953).**

feet, with local land elevations varying from about 3,990 feet near the river to 4,040 feet on the valley margins (Figure 4.8.1-2). The bounding uplands may reach heights of about 4,150 feet (NGVD29). The valley was carved out of a very thick sequence of relatively impermeable Upper Cretaceous strata, and the resulting "trough" was then sequentially filled with fluvial sediments of Pleistocene and Holocene age.

Consequently, the Arkansas River is alluvial, since its bed and banks are made up entirely of fluvial sediment with no bedrock control. The Historic Site owns both sides of the river for a length of about 2.2 river miles, and manages only the right bank for an additional 1,000 feet at the downstream end of the park. The reach within the Historic Site includes four prominent meander bends . Additionally, there is a sizable wetland, the Arch Wetland, which occupies an intermediate level terrace between the active channel and the Fort grounds. This wetland is currently about 55 (54.7) acres and is mostly due north of the Fort.

There appears to be about four distinct terrace levels associated with the Arkansas River along this reach. The lowest terrace is only a couple of feet above the bankfull stage of the channel and is well-colonized in most areas with shrubby riparian vegetation, primarily sandbar willow. The next terrace level is a couple of feet higher than the low terrace and supports riparian vegetation that is generally older than on the lower terrace. Additionally, there is a higher terrace level about five to six feet above bankfull that supports mature cottonwood trees. Farther from the river there is a high terrace that is about 10 to 15 feet above the channel; this is the level where the Fort was constructed.

Flow in the Arkansas River is essentially perennial although substantial water regulation in this area has dramatically altered the natural flow regime. The watershed of the river extends into the Front Range

of the Rocky Mountains so the drainage experiences a snowmelt peak every spring. Additionally, intense rainstorms may produce substantial runoff, potentially creating a second seasonal peak later in the spring or summer. The greatest flood that occurred on this river resulted from an intense rainstorm on a melting snowpack. However, storage and diversion of river water for local agriculture may greatly alter the natural hydrology of the Arkansas River.

Currently, there are over 1,000 miles of Arkansas River water diversions with 6 major water diversions between Pueblo dam and the park. The largest, the unlined Fort Lyon Canal, is located about 6000 feet north of the Fort (Figure 4.8.1-3). The point of diversion from the Arkansas River is about 10 miles upstream of the Historic Site and the canal continues due east for a total of about 50 miles. The cumulative impacts associated with these extensive irrigation and water diversions have resulted in a number of environmental consequences throughout the area. One of these effects is an increase in the water table elevation in some areas due to irrigation seepage into the alluvial aquifer. Following that, some low elevation valley soils have become "waterlogged" due to the water table rise. Additionally, other soils are undergoing salinization from evaporation of both agricultural waters and shallow groundwater (Gates et al. 2006).

In 1948, the John Martin dam was completed about 20 miles downstream of the Fort. Additionally, the Pueblo Dam was completed in 1974, about 75 miles upstream of the Historic Site. Not only has the natural flow regime been disrupted by these dams, but natural sediment transport, channel morphology, riparian vegetation and aquatic habitat characteristics have also been affected to some degree.

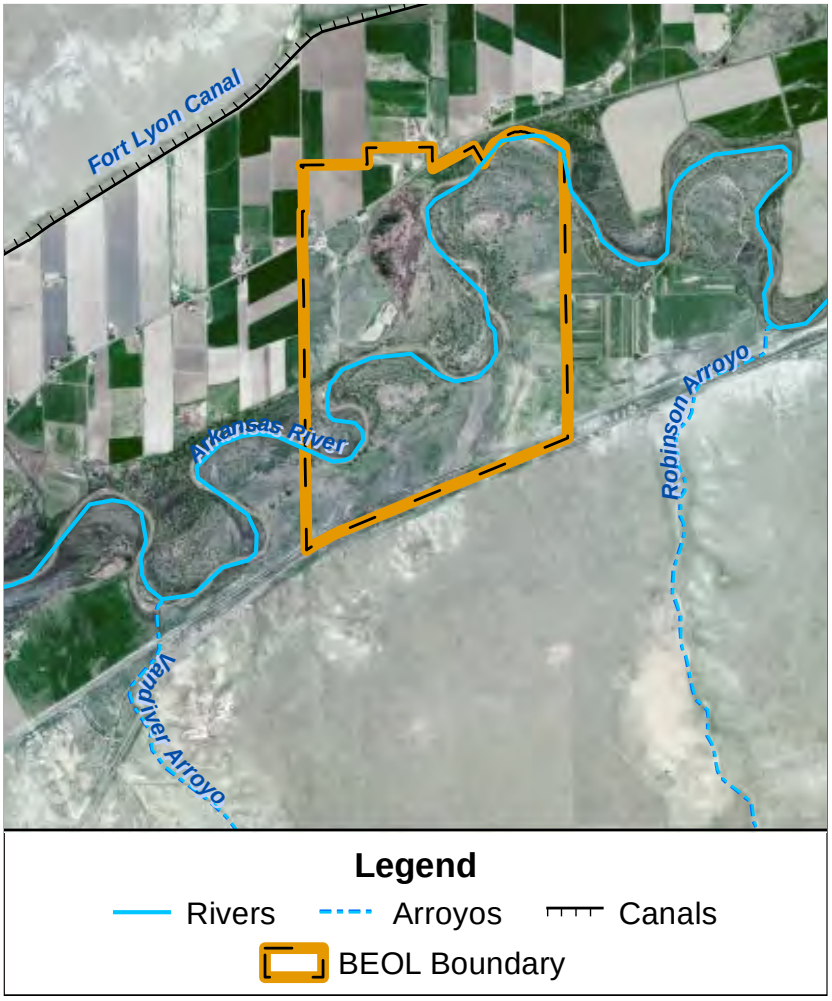



**Figure 4.8.1-3. Major surface water features surrounding and located within Bent's Old Fort NHS**

Recent Geomorphic History of the Arkansas River

Several studies throughout the last few decades have described geomorphic changes of high plains streams throughout this area. For example, there is evidence that the Arkansas River has evolved from a wide, braided stream and floodplain system with sparse riparian vegetation to a relatively narrow, single-thread channel with heavily vegetated floodplains (Dunne and Leopold, 1978; Nadler and Schumm 1981). This change in overall morphology is attributed to a dampening of flood peaks through river regulation and higher water tables due to irrigation seepage, which have created conditions favorable for riparian vegetation establishment. The associated channelization and encroachment of vegetation was probably accompanied by some degree of incision as would be expected with the change from a braided to a single thread, meandering channel form. In some opposition to this idea of a major shift in river morphology, a previous analysis of the river's channel position based on historic surveys, maps, and imagery, concluded that despite the presence of well-developed meanders and erodible bed and banks, which has led to

some channel migration, the position of the Arkansas River has shifted little since 1869 (Swensen, 1970).

### *4.8.2. Data and Methods*

The purpose of our assessment was to determine the overall functional condition or ecological "health" of the river channel and its associated riparian corridor. To complete this assessment, we used "A User Guide to Assessing the Proper Functioning Condition (PFC) and the Supporting Science for Lotic Areas" (Prichard et al. 1998).

An interdisciplinary team of technical experts from NPS' Water Resources Division evaluated 17 hydrology, vegetation and erosion/deposition measures spanning the entire length of the Arkansas River located within the Historic Site. The river was evaluated as a single reach due to an apparent consistency of geomorphic and vegetation characteristics throughout the site.

A riparian area in PFC is in dynamic equilibrium with its stream flow forces and channel processes. The system adjusts to handle larger runoff events with limited change in channel characteristics and associated riparian-wetland plant communities. This limited change, such as some cutbank erosion and point bar expansion in stream meanders, is within the context of natural stream evolution and provides new geomorphic features for riparian-wetland vegetation recruitment. Because of this resiliency, riparian areas in PFC can maintain aquatic habitat, water quality enhancement and other important ecosystem functions, even after moderately large runoff events. In contrast, nonfunctional systems subjected to the same flows might exhibit excessive erosion and sediment loading, loss of aquatic and wetland habitat, and so on.

Both terrestrial and aquatic attributes and processes are important in riparian wetland areas and are used to assess the condition of a given area. The indicators used for this assessment included hydrology, vegetation, and erosion/deposition. The measures within each of these three categories, which included both attributes and processes are listed below.

**Indicator**
Hydrology (5 measures)

Streamflow forces and channel processes are characteristics of a riparian wetland's hydrologic function, and five measures were assessed for this indicator.

#### Measure: Floodplain inundated frequently

A floodplain is topographically flat, a landform of unconsolidated sediments originating from the stream, and subject to periodic flooding, usually a recurrence interval between 1 and 3 years (Prichard et al. 1998). The floodplain's role is to handle a basin's discharge and sediment load by spreading out the water and sediment onto a low area adjacent to the stream. This hydrologic function dissipates energy, which keeps a riparian wetland in functioning condition. Periodic flooding also promotes vegetation growth, which contributes to a properly functioning riparian area as well.

#### Measure: Beaver dams are active and stable

Beaver dams modify the hydrology of the area where constructed, and in some areas are responsible for the creation of floodplains (Gebhardt et al. 1998). However, sometimes when dams are not maintained, they can breach and instantaneously release a massive amount water potentially causing degradation to the riparian system.

#### Measure: Sinuosity, width/depth ratio, and gradient are in balance

Stream channel characteristics play an important role in how well the river system can dissipate energy. A higher stream gradient or a decrease in sinuosity will increase velocity resulting in accelerated erosion. To achieve balance, the size and shape of a stream should be near what would be expected within the setting it occupies.

#### Measure: Riparian wetland area is widening or has achieved potential extent

Sediment capture develops floodplains, which in turn, aids functionality of a riparian wetland area. In addition, as sediment is deposited, vegetation can "take root",

increasing certain types of vegetation such as sedges, willows, and rushes.

### Measure: Upland watershed is not contributing to riparian wetland degradation

Assessing changes in water and/or sediment supply from uplands can help determine functionality of the riparian wetland area affected. Changes in upland conditions can affect the discharge, timing, and duration of streamflow events in lower areas, possibly degrading a riparian wetland's condition.

## Indicator
Vegetation (7 measures)

Most riparian wetlands require some amount of vegetation to achieve functionality (Prichard et al. 1998). Different factors such as type, amount, and proportion of vegetation contribute to a wetland's condition. In order to accommodate periodic flooding, lateral distribution of vegetation is necessary. In addition, plants must be vigorous and able to maintain or recruit into the plant community to serve their various functions. Seven measures were used to assess the condition of this indicator.

### Measure: There is a diverse age-class distribution of riparian wetland vegetation

Age class distribution is often associated with vigor of a system, and multiple age classes of vegetation provide recruitment and replacement. Not all age classes need to be present for a system to maintain or recover from a severe event, and the older age classes can usually persist even with degraded conditions.

### Measure: There is diverse composition of riparian wetland vegetation

Not all plants need to be present within a riparian wetland for the system to maintain itself, but there needs to be enough variety for a wetland to recover and maintain its vegetative component. Limited number of species makes an area more vulnerable to extreme climatic changes or disease, although areas that contain unique water regimes or soils may naturally only support a limited number of plant species.

### Measure: Species present indicate maintenance of riparian wetland soil moisture characteristics

Plants that grow in wetlands are hydrophytes and must be in contact with the water table in order to survive. Different types of plants require different wetness regimes and different plants vary in root depths. The root depths sometimes suggest that a water table may not be close to the surface if the plants growing are ones that usually have deeper root systems. Wetland plants are divided into different categories, indicating their preference for growing in wetlands or uplands and degree of wetness required.

### Measure: Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high streamflow events

Plants that have adapted to riparian wetland conditions, such as cottonwood, aspen, alder, willow, sedge, rush, and some grasses, develop root masses that help stabilize riverbanks, especially during high-flow events. If banks are undercut during storm or high runoff events, many changes can occur to the channel's width/depth ratio, gradient, and sinuosity, which in turn, may decrease the system's ability to dissipate energy. The presence of obligate and facultative wetland plants is usually a good indication that the streambank will remain stabilized.

### Measure: Riparian wetland plants exhibit high vigor

If plants are weakened or stressed, they are less able to withstand stressors making the riparian wetland more susceptible to degradation. On the other hand, plants that exhibit vigor are usually more equipped to maintain or recover from stressors.

### Measure: Adequate riparian wetland vegetation cover is present to protect banks and dissipate energy during high flows

The amount of vegetation present indicates a wetland's ability to dissipate energy, protect riverbanks from collapse, filter sediment, and aid floodplain development, which also dissipates energy during storms or high

runoff. Some bank erosion is a natural part of river channel evolution, but excessive erosion usually indicates some failure in the system.

#### Measure: Plant communities are an adequate source of coarse and/or large woody material

Not all areas support large woody vegetation and many rangeland and meadow riparian wetland areas do not require woody species to maintain channel stability. However, if this type of vegetation is a natural part of the system, it serves as a hydrologic modifier. Usually, during high-flow events, coarse or woody vegetation must be present to withstand the high energy and to recover the system back to a proper functioning condition.

### Indicator
Erosion/Deposition (5 measures)

Erosion and depositional processes are naturally occurring within a stream or river system, however, excessive amounts of either indicate an imbalance in the system. Five measures were used to assess the erosion/deposition processes for this assessment.

#### Measure: Floodplain and channel characteristics are adequate to dissipate energy

Energy dissipation results from the presence of a floodplain, which distributes the water over a larger area, and channel characteristics such as sinuosity, which reduces the velocity of waterflow. In addition, objects such as rocks or large woody debris can also aid in energy dissipation.

#### Measure: Point bars are revegetating

In some channels, point bars form as part of the natural depositional process and subsequent vegetation colonization aids in erosion control when high runoff events occur. The vegetative type has to be ones that are capable of forming root masses that can withstand high flow occurrences.

#### Measure: Lateral stream movement is associated with natural sinuosity

Streams naturally adjust their channel by moving side to side without degrading the overall wetland environment. The movement is affected by many factors such as the type of stream, the type of materials that form the streambanks, and the types and amounts of vegetation growing along the banks. For example, streambanks composed of sandy materials will more easily erode than materials such as clay or silt, which provide more cohesiveness. Excessive movement can negatively impact a river/riparian area by diminishing the system's ability to dissipate energy.

#### Measure: System is vertically stable

This measure is used to determine whether a channel is lowering at a natural versus an accelerated rate. Naturally occurring channel lowering usually occurs over hundreds or more years, whereas, some accelerated lowering can occur over a decade or less. The channel lowering reduces the landscape's overall elevation including the valley bottom through erosion.

#### Measure: Stream is in balance with the water and sediment being supplied by the watershed

Stream channels adjust to water and sediment loads and are classified as either single thread or braided channels. Most braided channels indicate unnaturally high sediment loads, whereas, excessive erosion indicates an imbalance in water flow.

### *4.8.3. Reference Conditions*

A riparian wetland area needs to be in dynamic equilibrium with its streamflow forces and channel processes to be considered in proper functioning condition. This requires the system to maintain itself and/or recover after large runoff events without significant changes to the stream channel characteristics or to the riparian wetland vegetative communities (Martin et al. 2012). However, some change is expected and even necessary to maintain resiliency. In contrast, systems that are functional but susceptible to degradation due to failure in one or more of the attributes associated with either the hydrology, vegetation, or erosion/depositional processes are considered to be in moderate condition. Those systems that are not providing adequate functioning and subsequent protection

**Table 4.8.3-1. The reference conditions used to determine whether the condition of the riparian habitat at Bent's Old Fort NHS is good, moderate, or of significant concern as adapted from Prichard et al. 1998.**

| Good | Moderate | Significant Concern |
|---|---|---|
| A good condition is referred to as a Proper Functioning Condition or PFC. PFC is a state of resiliency that allows a riparian wetland area to hold together during high flow events with a high degree of reliability. The resiliency allows an area to establish vegetative communities that create the structure necessary for fish and waterfowl habitat, to establish floodplains that help dissipate energy, and channel characteristics such as sinuosity and lower gradients, which help prevent streambank erosion. | A moderate concern condition is considered to be "Functional-At Risk" , which means that the riparian wetland area is in fundamental condition, but an existing soil, water, or vegetation indicator(s) is compromised making it susceptible to degradation. However, the majority of the riparian wetland indicators do not need to be compromised to receive a moderate condition rating. | A significant concern condition is considered to be "Nonfunctional". The riparian wetland area is not providing adequate vegetation, landform, or large woody debris to dissipate stream energy associated with high flows, therefore, erosion is not reduced and water quality degradation is occurring. In addition, channel characteristics are such that high flow events either deposit an inordinate amount of sediment or water flow results in excessive erosion. |

are considered nonfunctional. These three states: proper function, functional-at risk, and nonfunctional, comprise the reference conditions against which the Historic Site's riparian habitat was assessed and is based on the condition definitions developed by Prichard et al. (1998) (Table 4.8.3-1). Prichard et al. (1998) also included a fourth condition class-Unknown- when sufficient information was unavailable to make a condition determination, however, this class was not applicable to the Historic Site's assessment therefore was excluded.

### *4.8.4. Condition and Trend*

Results for all indicators and measures are shown in Table 4.8.4-1.

Hydrology

The focus of the hydrology section of the PFC assessment was to determine if the observed channel morphology was stable and in balance with the landscape setting, given prevailing hydrologic and sediment inputs. This was done by determining the frequency of floodplain inundation, evaluating several channel morphology parameters (sinuosity, slope, and width-to-depth ratio), determining the width and trend (widening or narrowing) of the riparian-wetland area, evaluating the influence of upland watershed conditions on hydrologic and sediment characteristics, and other factors.

To evaluate general flow conditions of the Arkansas River, we used the long-term record from the USGS gage at La Junta (#07123000). This gage has been operated continuously since 1924 and has a total record of 98 years. The gage is located about eight miles upstream of the Historic Site, it has a datum of 4039.6 feet (NGVD29) and it drains an area of about 12,210 square miles (USGS 2013).

Flow in the Arkansas River is highly variable, both from year to year and within any given year. Mean annual flow, a rough measure of the relative "wetness" between years, shows wide variability. Mean annual flows calculated by the USGS from published data vary between 47 cubic feet per second (cfs) in dry years to over 800 cfs in wet years. Annual peaks are also quite variable, ranging from lows less than 1000 cfs to large floods that approach and sometimes exceed 20,000 cfs (Figure 4.8.4-1).

The U.S. Army Corps of Engineers (Corps) calculated Arkansas River flood frequencies from the gage at La Junta and published them in a 1977 flood hazard report. The three design floods reported were: the 25-year flood at 48,000 cfs, the 50-year flood at 68,000 cfs and the 100-year flood at 92,000 (U.S. Army Corps of Engineers 1977). All of these are sizable flows, and based on the gage record, are rarely exceeded. In almost 100 years of measurements, the 100-year value has only been exceeded once; the 50-year value, twice, and the 25-year magnitude, three times. About a decade after the Corps' publication, the USGS published two 100-year flood values; one before and one after the closure of Pueblo Dam. The record from 1912 – 1973 (pre-dam) had a 100-year flood magnitude of 96,300 cfs, while the post-dam

**Table 4.8.4-1. Results for the riparian wetland condition assessment at Bent's Old Fort NHS (Wagner and Martin 2014-Appendix).**

| Indicator/Measure | Reach 1 |
|---|---|
| Hydrology | |
| Floodplain | River is regulated; flows are controlled by operations of the Pueblo Reservoir. Point bars, high flow channels and low terraces show clear evidence of recent flow (e.g., recent sediment deposition and flood debris), and park staff stated that this occurs in most years. Channel/floodplain form is as expected for this regulated river (no channel incision). Point bars and low terraces exhibit recruitment and maintenance of native riparian vegetation. |
| Beaver dams | n/a |
| Sinuosity, width/depth ratio, and gradient | Overall channel sinuosity and gradient are in balance with the landscape setting. The sinuosity is about 2.18; the channel gradient is about 0.1 percent; and estimates of width-to-depth ratios are primarily above 12. Point bar/cutbank channel forms appear to be in a dynamically stable condition as expected for this regulated river (no excessive lateral erosion). |
| Riparian wetland area | Riparian zone is at or near potential extent as indicated by gradual lateral migration of the channel across the landscape while maintaining a near-constant channel width (cutbank/point bar form is dynamically stable). |
| Upland watershed | No evidence of excessive sediment or water contributions from upland watershed. Higher terraces/riparian areas are well-vegetated. |
| Vegetation | |
| Age class distribution of riparian wetland vegetation | Cottonwood (Populus deltoides) has three age classes including seedlings and young saplings on point bars and side channel bars, approx. 10-20 year olds common on intermediate elevation terraces and upper point bars, and older trees on higher terraces and old meander scars. Sandbar willow (Salix exigua) recruitment is common on point bars and low terraces all the way to the channel banks. Older sandbar willows are common on most intermediate and some higher terraces, but most show significant signs of drought or other stress on these higher landforms. Herbaceous wetland species are expanding in some streambank areas, but their role in bank stabilization is generally minor compared to sandbar willow. |
| Diverse vegetation composition | Sandbar willow is the dominant woody riparian species on most streambanks, point bars, side channel bars and other low/intermediate terraces. Cottonwoods are present in 3 age classes as described above, but recruitment is sparse compared to sandbar willow. Willow baccharis (Baccharis salicina) is well-represented on some point bar and side channel bars, and peach-leaf willow (Salix amygdaloides) is found very occasionally as individual shrubs to small trees. Although sandbar willows on streambanks, point bars and low terrace features are typically vigorous and expanding, drought stress is clearly evident on intermediate and higher terraces. |
| Soil moisture characteristics | Sandbar willow dominates most low streambanks and bars, but hardstem bulrush (Schoenoplectus acutus), common three-square (Schoenoplectus pungens) and common reed (Phragmites australis) protect some streambanks and are found in patches on some lower point bars and low terraces. Saltgrass (Distichlis spicata) dominates the herbaceous community on many intermediate terraces, with wild licorice (Glycyrrhiza lepidota) common/co-dominant at some locations. Showy milkweed (Asclepias speciosa) is present on many intermediate terraces but not dominant. All of the above are native riparian-wetland species. Cattail (Typha sp.) was found on some low terraces (appeared to be either non-native T. angustifolia or a hybrid of T. angustifolia and T. latifolia). Non-native reed-canary grass (Phalaris arundinacea) was present on some low streambanks and terraces, but cover was limited. |
| Plants have root masses capable of withstanding high streamflow events | Sandbar willow and the rhizomatous, herbaceous native wetland plant cover on channel banks, point bars and low terraces have root masses capable of withstanding high flow events (but refer to "vigorous plants" measure below for further discussion). |
| Vigorous plants | Sandbar willows are vigorous on point bars, side channel bars and most low streambanks, but they show major stress (excessive dead stems and branches) on higher streambank and bar locations and on intermediate terraces. We suspect that this 3rd straight year of well below normal precipitation ("exceptional drought" conditions according to the U.S. Drought Monitor) is a major cause, since plant stress appears to correlate with elevation above bankfull stage. |
| Vegetation cover | Adequate riparian-wetland vegetative cover is present to protect banks and dissipate energy during high flows. |
| Plant communities are coarse and/or large | n/a |

***Table 4.8.4-1. Results for the riparian wetland condition assessment at Bent's Old Fort NHS (Wagner and Martin 2014-Appendix) (continued).***

| Indicator/Measure | Reach 1 |
|---|---|
| Erosion/Deposition | |
| Floodplain and channel characteristics | Shoot cutoffs, overflow channels, channel sinuosity and point bars contribute to energy dissipation. |
| Point bars | Point bars are revegetating with riparian-wetland vegetation. |
| Lateral stream movement | Lateral stream movement is associated with natural sinuosity |
| Vertical stability | The system is vertically stable, and there are no signs of recent incision. |
| Balance of water and sediment | Stream is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition) |

(1974-1984) magnitude was only calculated to be 19,900 cfs (USGS 1985).

The flood of record for the gage at La Junta occurred on June 4, 1921 with a flow of about 200,000 cfs. This flood was over twice the calculated 100-year flood value, and an extremely rare event, even in an unregulated river. The second largest flood took place two years later on August 23, 1923, reaching a peak of 60,000 cfs, and the third largest occurred on May 20, 1955 with a discharge of 50,000 cfs. Both the 1923 and the 1955 peaks were in the range of a 50-year event. From the entire record, about 36 percent of the annual peaks were greater than 10,000 cfs, and 62 percent were between 1000 and 9999 cfs. Only four annual peaks out of 98 were below the relatively modest flow magnitude of 1000 cfs. Of the 98 year record, 28 of the annual peaks were in June; 25 peaks occurred in July; 22 took place in August; and 15 were in May. The other eight annual peaks were in April, September, October and December. All 98 of the annual peaks are reported by the USGS to "have been affected by regulation or diversion."

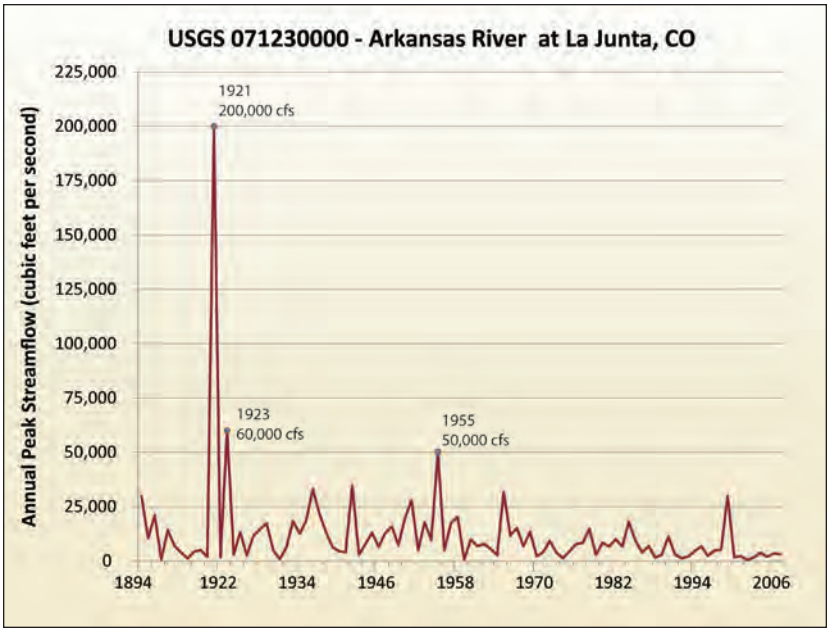



**Figure 4.8.4-1 Annual peak flow record from USGS gage #07123000, Arkansas River at La Junta (USGS 2013).**

The Federal Emergency Management Administration (FEMA) (1985) has published Flood Insurance Rate Maps (FIRM) for this area that depict the 100-year floodplain. The FIRM that covers the Historic Site, Otero County, Colorado, (panel 100 of 325), shows the historic Fort grounds as being marginally within the 100-year floodplain. No depth is reported with the FEMA documentation, but a comparison to the USGS topographic map suggests the depth of this Regulatory Flood is about 10 feet above the river channel in the area of the Historic Site. The Colorado Water Conservation board reported stages of 12 and 14 feet for the 100-, and 500-year floods, respectively (CWCB n.d.). An on-site survey conducted by the NPS using these vertical distances concluded that the Fort structure is slightly more than 12 feet above the channel, and consequently is outside of the 100-year floodplain boundary. However, the location of the structure is close enough to the


NPS STAFF

**Figure 4.8.4-2. The Arkansas River was near bankfull during the 2013 riparian habitat assessment.**

100-year floodplain boundary that a 500-year event would likely surround the footprint of the structure to a depth of less than two feet.

To support a healthy riparian system, high flows must exceed the channel capacity and spill onto the floodplain on a fairly frequent basis. Under natural conditions, the Arkansas River would have flooded every few years, on average. However, even with the highly regulated flow regime that currently exists, flow still appears to access the floodplain regularly. At the time of our 2013 site visit, the river stage was near bankfull (Figure 4.8.4-2), and it was apparent that the lower terraces and other near-channel features like mid- and side-channel bars had experienced fairly recent inundation. This was well evidenced by signs of active overflow channels, bent vegetation on low terraces, and the presence of recently deposited sediment on these features. The higher terrace levels that support the mature cottonwoods are not likely to be flooded with any kind of regular frequency, especially with river regulation. But the low and intermediate terrace levels are close enough to the river level that inundation is possible with relatively small stage increases. So, based on observations made during the site visit and our knowledge of the Arkansas River flow regime, we concluded that the lower terraces and other near-channel features are inundated on a relatively frequent basis.

Several channel parameters, specifically sinuosity, gradient, and width-to-depth ratio are closely related to a stream's ability to dissipate hydraulic energy during flood flows. When these parameters are in balance with the landscape setting, the channel is able to handle larger runoff events with limited change in channel characteristics and associated riparian-wetland plant communities. In a broad valley composed of fluvial sediments like the Arkansas River Valley, these channel parameters have well-defined ranges of stability based on flow mechanics (Prichard et al. 1998).

The sinuosity (channel length/linear distance) along this reach of the Arkansas River is approximately 2.2. This is well above the expected "stable" value of 1.2 for this channel type and landscape setting, and in fact, the well-developed meander pattern would result in good energy dissipation during bankfull flows. The channel gradient (rise/run) along this reach is about 0.1 percent, which is well within the stable range of less than 2.0 percent for this channel type.

To estimate width-to-depth (W:D) ratios, we measured channel widths from areal imagery

and used a below-bankfull channel depth of five feet. With these parameters, calculated W:D ratios ranged from about 13 to 20, all above the stable threshold of 12 for this channel and floodplain form. Even when a somewhat greater channel depth of 7.5 feet was substituted into the calculations, the results were still mostly in the stable range. All of the channel parameters (sinuosity, slope, and width-to-depth ratio) associated with this reach of the Arkansas River at the Historic Site indicated that the river is in balance with the landscape setting.

A healthy riparian system for this landscape setting and hydrologic regime allows for a broad distribution of flood waters that facilitate the establishment and maintenance of riparian vegetation. As the channel slowly migrates across the landscape, point bars forming on the inside bends of meanders provide new locations for cottonwoods, willows and other riparian-wetland species to establish. Flood waters (and irrigation releases) also help replenish the alluvial water table that supports riparian vegetation. During the site visit, we observed a well-established riparian system present to varying degrees throughout the study area. The most active portions of the system were adjacent to the channel and on the low and intermediate terraces. When considered within the confines of the higher terraces, the extent of the riparian vegetation suggests that the riparian-wetland area is at or near its potential extent.

Nowhere in the study reach did we observe isolated deposits of sediment that would suggest excessive upstream erosion and associated deposition along the channel or floodplain. Irrigation return flows reach the river seasonally, from March through October, through a sizable ditch that enters the Historic Site from the north, downstream of the Fort grounds. Additionally, any number of smaller ditches may convey agricultural and/or storm water to this reach of the Arkansas River. Nevertheless, there does not appear to be any systemic degradation of the riparian system as a result of this upland input. Consequently, we concluded that the upland watershed is not contributing to riparian-wetland degradation.

Vegetation

An integral part of the PFC analysis was evaluation of riparian-wetland vegetation along the channel and floodplain. The species composition, percent cover, age structure, energy dissipation capability and other critical vegetation characteristics for the study reach were evaluated.

We observed a diverse age-class distribution of riparian-wetland vegetation throughout most of the riparian area. Cottonwood trees (*Populus deltoides*) were represented by three age classes distributed primarily by elevation. We found seedlings and young saplings on most point bars and side channel bars, though their numbers were relatively sparse. Approximately 10-20 year old cottonwoods were common on intermediate elevation terraces and upper point bars, and older trees occupied higher terraces and old meander scars. Sandbar willow (*Salix exigua*) was the dominant woody riparian species on most stream banks, point bars, side-channel bars and other low/intermediate terraces. This species showed signs of recruitment occurring commonly on point bars and low terraces all the way to the channel banks. Older sandbar willows were common on most intermediate and some higher terraces. So, given the diverse age classes that we observed in these two dominant woody riparian species, we consider this measure to be in good condition.

In addition to the cottonwoods and willows, we observed a diverse composition of other native woody and herbaceous riparian and wetland species throughout the reach. Willow baccharis (*Baccharis salicina*) was well-represented on some point bar and side channel bars, and peach-leaf willow (*Salix amygdaloides*) was found very occasionally as individual shrubs to small trees. While sandbar willow was dominant on most low streambanks and bars, herbaceous wetland species including hardstem bulrush (*Schoenoplectus acutus*), common three-square (*Schoenoplectus pungens*) and common reed (*Phragmites australis*) protected some streambank locations and were found in

patches on some lower point bars and low terraces. On many intermediate terraces saltgrass (*Distichlis spicata*) was dominant, with wild licorice (*Glycyrrhiza lepidota*) fairly common at some locations. Showy milkweed (*Asclepias speciosa*) was also present on many intermediate terraces, but not dominant. We did encounter some non-native species in the riparian area. Cattail (*Typha* spp.) was found on some low terraces (individuals appeared to be either non-native *T. angustifolia* or a hybrid of *T. angustifolia* and the native T. *latifolia*), and reed-canary grass (*Phalaris arundinacea*) was present on some low stream banks and terraces, but cover of these was limited. Consequently, given the dominance and diverse composition of native riparian and wetland species as defined in the PFC manual, we consider this measure to be in good condition.

Maintaining an appropriately high water table and adequate soil moisture through the growing season is vital to support or aid in the recovery of a healthy riparian-wetland system. The plant species observed on the various geomorphic surfaces of this assessment reach (stream banks and low, intermediate and high terraces) suggest that adequate soil moisture and water table elevations have generally been maintained. However, sandbar willows on intermediate terraces showed widespread and significant stress, which we attribute largely to recent drought conditions (see later discussion). We determined that the species present indicate adequate maintenance of riparian-wetland soil moisture characteristics over the longer term.

As discussed previously, sandbar willow was the dominant woody riparian species on most stream banks, point bars and side-channel bars throughout the reach, and plants on these lower geomorphic features were vigorous. This species is clonal, forming dense thickets with root masses capable of withstanding high flows and stabilizing streambanks. Common herbaceous streambank species including hardstem bulrush, common three-square and common reed are all rhizomatous wetland plants that form dense root masses and provide soil stability and protection from streambank erosion during high flow events.

Almost all of the cottonwood trees that we observed appeared to be vigorous, with few signs of stress. Sandbar willows on stream banks, point bars and low terrace features were typically vigorous and appeared to be spreading. However, sandbar willows on the intermediate and higher terraces had widespread and significant signs of stress. It was typical to see 50% or more dead stems on these plants, though many are re-sprouting from their bases or from live branches. However, we are concerned that drought and river regulation may be more significant factors in the decline of willow health on these terraces.

The La Junta, Colorado area is now in an "Exceptional Drought," the most extreme drought condition defined by the U.S. Drought Monitor website (http://droughtmonitor.unl.edu/monitor.html). Precipitation at La Junta was only 7.41 inches (65% of the long-term average) in 2011, 5.53 inches (48% of average) in 2012, and only 0.67 inches (16% of average) for the first five months of 2013 (NOAA 2013).

The exceptional drought conditions, coupled with flow regulation on the Arkansas River, may be contributing to depressed ground water levels and declining willow health at the Historic Site. Amlin and Rood (2002) found that riparian water table declines exceeding 0.75 inches/day can adversely affect growth and survival of willows and cottonwoods. They state that willows (specifically including *S. exigua*) are more sensitive than cottonwoods to rapidly falling water tables, and recommend declines of no more than about 0.4 inches/day for willow establishment. This is consistent with our observation that young to middle-aged cottonwoods on lower terraces showed little to no sign of drought stress despite their equivalent or higher positions on the landscape than sandbar willows.

In 2001, researchers from the University of Montana and Colorado State University installed and monitored staff gages and groundwater wells at the Historic Site to evaluate the cause of basement flooding at the Fort (Woods and MacDonald 2002). They found that ground water fluctuations in the riparian areas were well-correlated with river

stage, whereas wells in the uplands north of the river and in Arch Wetland were controlled primarily by irrigation and leakage from the Fort Lyon Canal and did not correlate well with river stage. These findings suggest that management of river stage could have an effect on riparian water table fluctuations at the Historic Site. The NPS Southern Plains I&M Network recently began monitoring riparian water table elevations at the Historic Site (utilizing some of the wells installed by Woods and MacDonald), but data are not available at this time to analyze rates of water table decline during the growing season.

Although the condition of willows on the intermediate terraces caused us to answer "no" to the measure-riparian-wetland plants exhibit high vigor-, we do not believe this condition is a threat to channel stability in most (up to 20-year return interval) flood events. Loss of these willows on the intermediate to high terraces would reduce some floodplain functions (e.g., willow habitat, energy dissipation in very large flood flows). However, we expect that the vigorous and abundant riparian-wetland vegetation cover on the streambanks, low terraces and point bars and the overall channel-floodplain form would maintain channel stability under most flood conditions.

The last measure for the vegetation indicator asks us to determine if the cover of riparian-wetland vegetation is adequate to dissipate energy and protect against excessive bank erosion during high flows. Our observations of nearly complete cover of streambanks, point bars, side channel bars and lower terraces with vigorous, bank-stabilizing, native riparian-wetland species led us to rate this measure as good.

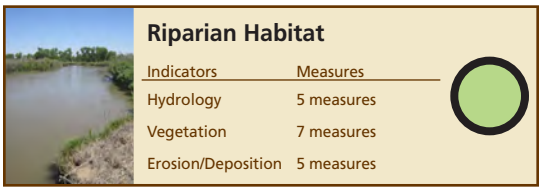
Erosion/Deposition Condition

The primary focus of this indicator was to determine if there is an apparent balance between flow, sediment, and erosion/deposition processes in the river system. A key element of channel stability is energy dissipation during high flows. This usually occurs from interaction with roughness elements associated with the bed and banks such as channel features, substrate, and riparian-wetland vegetation. For the Arkansas River at the Historic Site, channel roughness and channel form likely provide much energy dissipation during frequent to moderately large floods. Characteristics such as floodplains, point bars, and cutoff chutes are present within the river system and all help to diminish flow energy. Also, there are substantial roughness elements like stands of extensive woody vegetation that systemically dissipate energy. For these reasons, we rated this measure as good.

Woody riparian vegetation not only adds stability to the soil through anchoring, but also helps to disperse energy due to hydraulic roughness any time flows exceed bankfull capacity. We observed distinct signs of sandbar willow (and other species) recruitment and establishment on point bars, side-channel bars, low terraces, and other near channel features throughout the reach.

Lateral channel migration occurs throughout the reach as evidenced by numerous cutbank/point bar pairings, meander scars and similar features. The actual rate that this migration is occurring appears to be very slow, and is associated with natural channel migration across the valley bottom. We consider this measure to be in good condition.

Vertical stability is a very important element in evaluating conditions of erosion and deposition in riparian systems. This study reach does not exhibit typical attributes of vertically unstable riparian systems such as a v-shaped channels, steep eroding banks, headcuts, or disconnection of the channel from the floodplain, therefore is considered good.




Overall Condition and Trend

The Arkansas River at the Historic Site has almost complete cover of vigorous, soil-stabilizing riparian-wetland vegetation on its stream banks, side channel bars, and

**Table 4.8.4-2. Summary of the riparian habitat indicators/measures categories and their contributions to the overall riparian habitat resource condition assessment.**

| Indicators | Measures | Condition | General Contribution of this Indicator or Measure to the Overall Resource Condition. |
|---|---|---|---|
| Hydrology | 5 measures | Good | The channel/floodplain form is in balance with the landscape setting. |
| Riparian Vegetation | 7 measures | Good | There are perennial wetland plants in the channel bottom and along the banks to resist erosion and stabilize soils, and a healthy recruitment for riparian tree species |
| Erosion/ Deposition | 5 measures | Good | There is good channel/floodplain formation and no evidence of excessive erosion or deposition. |

lower terraces. The energy dissipation associated with vegetation "roughness" and other channel features suggests a stable morphology and the ability to transmit out-of-bank flows without excessive erosion under most flood conditions. These characteristics help improve floodwater retention and groundwater recharge, and support formation and maintenance of riparian habitat characteristics that support fish and wildlife. We evaluated nearly every measure for the study reach as good. Based on these observations and analyses, we rated the PFC status of the Arkansas River in the vicinity of the Historic Site as being in "proper functioning condition", therefore good.

The declining condition of sandbar willow on the intermediate terraces is of resource management concern due to habitat degradation and reduced energy dissipation during very large to extreme flood events. However, under moderate to fairly large flows, this hopefully temporary condition of willow decline is not expected to destabilize the overall riparian system. We strongly support the NPS Southern Plains I&M Network's efforts to reestablish continuous water table monitoring at critical locations in the Arkansas River riparian zone at the Historic Site. This will support future analysis of rates of water table decline during the growing season and help determine if there are ways to manage river stages for the benefit of riparian vegetation, including under severe drought conditions.

The overall condition assessment is summarized in Table 4.8.4-2.

Level of Confidence/Key Uncertainties

NPS' Water Resources Division scientists conducted the riparian assessment through a technical assistance request to evaluate the functional condition of the Historic Site's riparian habitat area. Based on the expertise of the scientists, we're confident that the findings accurately reflected the condition of the Historic Site's riparian wetland at the time of the assessment.

Threats and Key Uncertainties

According to Prichard et al. (1998), a state of resiliency within a riparian area needs to be maintained to respond to a high-flow event. As stated previously, we are concerned that drought and river regulation may be more significant factors in the decline of willow health on the river terraces. Management of river stage could have an effect on riparian water table fluctuations at the Historic Site.

### *4.8.5. Sources of Expertise*

The National Park Service's Water Resources Division scientists, Michael Martin and Joel Wagner, provided the expertise for this assessment.

Michael Martin is a hydrologist with the NPS Water Resources Division and has his Masters of Science in Watershed Science. Specialty areas include open channel flow, geomorphology, flood analysis, wetlands, and hydrology.

Joel Wagner is the Wetlands Program Team Leader with the NPS Water Resources Division and has his Masters of Science in Environmental Science (Water Resources).

Specialty areas include wetlands science, hydrology, restoration and regulatory issues.

### *4.8.6. Literature Cited*


Amlin N.M. and S.B. Rood. 2002. Comparative tolerances of riparian willows and cottonwoods to water-table decline. Wetlands: 22, 338-346.

Colorado Water Conservation Board [CWCB]. n.d. Flood. Available at http://cwcb.state.co.us/water-management/flood/Pages/main.aspx (accessed February 2014).

Dunne, T. and L.B. Leopold. 1978. Water in Environmental Planning. W.H. Freeman & Co. pp. 687-693.

Federal Emergency Management Agency [FEMA]. 1985. Map service center. Available at https://msc.fema.gov/webapp/wcs/stores/servlet/mapstore/homepage/MapSearch.html?isFloodMap=true&AddressQuery=La%20Junta%2C%20Colorado (accessed February 2014).

Gates, T.K., L.A. Garcia and J.W. Labadie. 2006. Toward Optimal Water Management in Colorado's Lower Arkansas River Valley: Monitoring and Modeling to Enhance Agriculture and Environment. Colorado State University.

Gebhardt, K., C. Bohn, S. Jensen, W.S. Platts. 1998. Use of hydrology in riparian classification. Pages 53-59 in Prichard et al. 1998, Practical approaches to riparian resource management—an educational workshop. Bureau of Land Management. Billings, MT.

United States Geological Survey [USGS]. 1953. Hadley, Colorado Quadrangle Map. Available at http://www.rare-maps.com/details.cfm?type=maps&rid=1565505 (accessed February 2014).

Martin, M., J. Wagner, K. Noon, and T. Folts-Zettner. 2012. Trip report detailing a proper functioning condition assessment of Big Sandy Creek. 27pp.

Nadler, C.T. and S.A. Schumm. 1981. Metamorphosis of South Platte and Arkansas Rivers, Eastern Colorado. Physical Geography: 2, 95-115.

National Climate Data Center [NOAA]. 2013. National Climate Data Center. Available at http://droughtmonitor.unl.edu/monitor.html (accessed 2013).

National Park Service. 2002. NPS Director's Order #77-1: wetland protection. Online (http://www.nps.gov/policy/DOrders/DO77-1-Reissue.html). Accessed July 19, 2013.

National Park Service. 2006. Management policies 2006-The guide to managing the National Park System. Washington D.C. 180pp.

National Park Service. 2012. National Park Service procedural manual #77-1: wetland protection.

National Park Service Water Resources Division. 2011. Wetlands in the national parks. Online. (http://nature.nps.gov/water/wetlands/aboutwetlands.cfm). Accessed July 19, 2013.

Prichard, Don, J. Anderson, C. Correll, J. Fogg, K. Gebhardt, R. Krapf, S. Leonard, B. Mitchell, and J. Staats. 1998. A user guide to assessing proper functioning condition and the supporting science for lotic areas. Technical reference 1737-15. Bureau of Land Management, Denver, Colorado.

Swensen, F.A. 1970. Meandering of the Arkansas River Since 1833 Near Bent's Old Fort. USGS Professional Paper 700-B, pp. B210 – B213.

United States Army Corps of Engineers. 1977. Special Flood Hazard information, Arkansas River Anderson and King Arroyo, La Junta and Otero counties.

United States Geological Survey [USGS]. 1985. Hydrologic Events and Surface

Water Resources. Water Supply Paper 2300.

United States Geological Survey [USGS]. 2013. National Water Information System: web interface. Online. (http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=07123000). Accessed November 5, 2013.

Wagner, J. and M. Martin. 2014. Trip Report: Proper Functioning Condition (PFC) Assessment for the Arkansas River within Bent's Old Fort National Historic Site (FOLS). 26pp.

Woods, S.W. and L.H. MacDonald. 2002. The cause of basement flooding at Bents Old Fort National Historic Site. Technical Report for contract: Ca-1200-99-009 CSU-23

## 4.9. Grasslands

**Indicators/Measures**

- Hydrology Soil/Site Stability and Hydrologic Function (10 Measures)
- Biotic Integrity (5 measures)

**Condition – Trend - Confidence**



Moderate – Improving - High

Grasslands as a whole are one of the dominant vegetation types of Bent's Old Fort NHS and an integral part of the cultural landscape. Even vegetation types that may be formally classified as woodland (e.g., Cottonwood (*Populus spp.*)) communities, can have a pronounced grassland component (Figure 4.9.1-1).

### *4.9.1. Background and Importance*

The central grassland region of North America is one of the largest contiguous grassland environments on earth (Lauenroth et al. 2008), and depending on which classification is used, there are at least three distinct grassland types: tallgrass prairie, mixed grass prairie, and shortgrass steppe (prairie). Bent's Old Fort NHS is located with the region generally classified as shortgrass steppe. The shortgrass steppe is located within the warmest and driest area and is the least productive of all grassland types, uniquely adapted to survive drought conditions (Lauenroth et al. 2008). The species that characterize the archetypal shortgrass steppe are blue grama (*Bouteloua gracilis*) and buffalo grass (*Buchloe dactyloides*).

Grasslands at Bent's Old Fort NHS

While Bent's Old Fort NHS is situated within the broad category of shortgrass steppe there is also considerable variation in grasslands throughout the Historic Site. The soils are generally well drained (Stevens et al. 2007). The Colorado Natural Heritage Program conducted vegetation classification and mapping at Bent's Old Fort NHS as part of the USGS-NPS Vegetation Characterization Program; a cooperative effort by the U.S. Geological Survey (USGS) and the National Park Service (NPS) to classify, describe, and map vegetation communities in more than 280 national park units across the United States. This program uses a hierarchical classification scheme, the National Vegetation



NPS PHOTO

**Figure 4.9.1-1 . Grassland at Bent's Old Fort NHS.**

Classification Standard (http://biology.usgs.gov/npsveg/nvcs.html), as a basis for classifying vegetation. The Colorado Natural Heritage Program identified thirteen map classes used to describe the landscape. Among these were six National Vegetation Classification (NVC) plant associations, one alliance, two non-natural map classes (Disturbed, Development), three local types, and one un-vegetated natural class (Open Water)(Stevens et al. 2007). Of these, eight map classes had a prominent grassland component (Figure 4.9.1-2)(Table 4.9.1-1).

Precipitation at the Historic Site is quite seasonal with much of its rainfall (average of approximately 12 inches/year) occurring in late spring and summer. The area receives

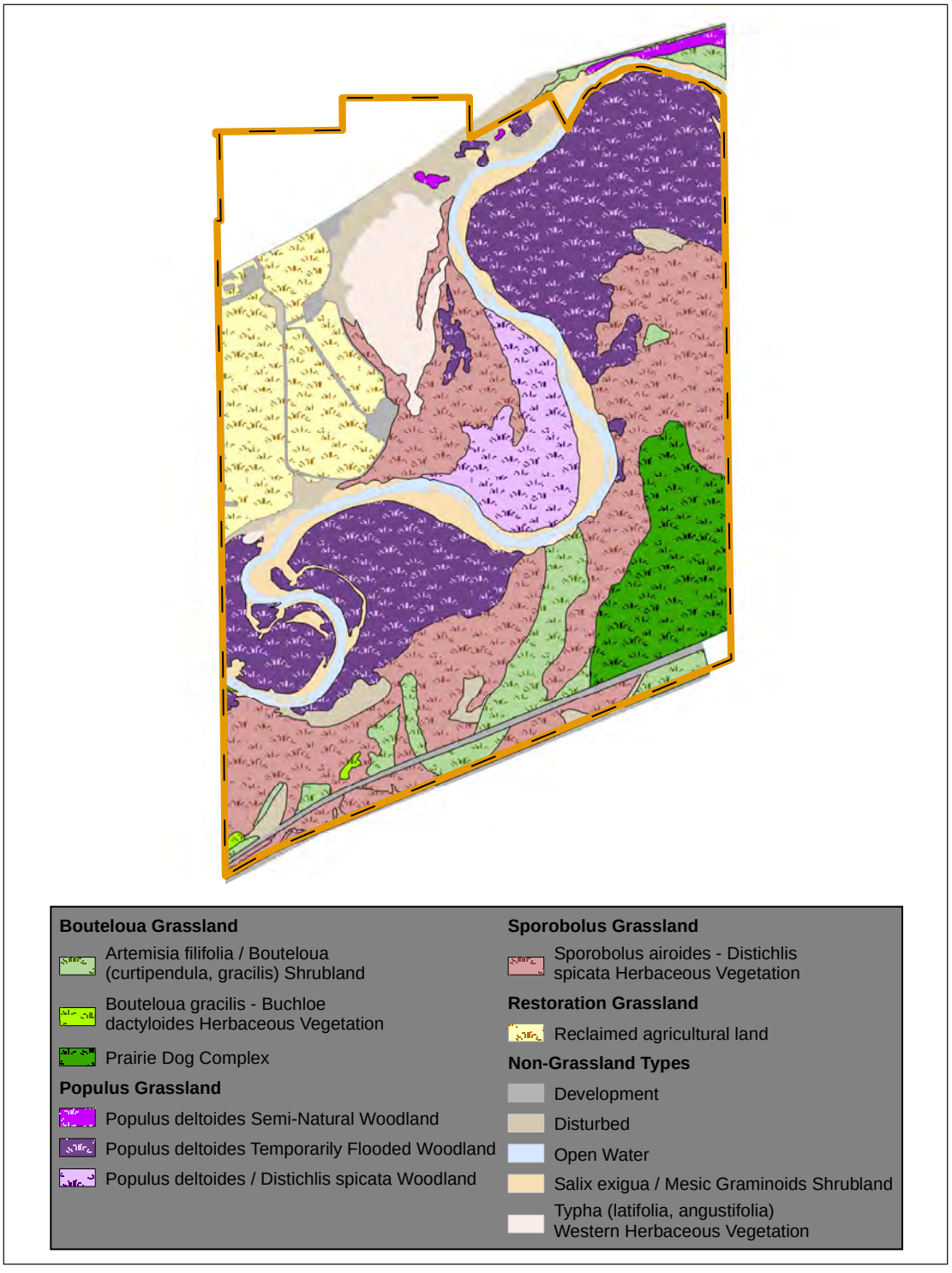



**Figure 4.9.1-2. The 13 map classes identified by Stevens et al. (2007) including the six plant alliances used by the National Vegetation Classification (NVC) system.**

**Table 4.9.1-1. The eight different National Vegetation Classification (NVC) plant associations identified by the Colorado Natural Heritage Program and their corresponding area occupied.**

| NVC Plant Association | Primary Class | Area (hectares / acres) | |
|---|---|---|---|
| Artemisia filifolia / Bouteloua (curtipendula, gracilis) | Shrubland[1] | 43.99 | 17.80 |
| Bouteloua gracilis - Buchloe dactyloides | Grassland | 1.16 | 0.47 |
| Populus deltoides / Distichlis spicata Woodland | Woodland[1] | 39.52 | 15.99 |
| Populus deltoides Semi-Natural Woodland | Woodland[1] | 4.16 | 1.68 |
| Populus deltoides Temporarily Flooded Woodland | Woodland[1] | 193.99 | 78.50 |
| Prairie Dog Complex | Grassland | 54.12 | 21.90 |
| Reclaimed agricultural land | Grassland/Restoration | 77.37 | 31.31 |
| Sporobolus airoides - Distichlis spicata | Grassland | 205.72 | 83.25 |

[1]Includes a prominent grass component

an average annual total snowfall of 20 to 25 inches. Average summer temperatures for July and August are approximately 90-95°F. and average temperatures of the coldest month, January, ranges from approximately 15 to 45°F.

Historic Context

Grasslands at Bent's Old Fort NHS are clearly part of its cultural heritage. The grasslands were home to native cultures and the native flora and fauna, most notably, the vast herds of bison, were essential to the way of life for the plains tribes. The grasslands later became the hunting grounds and travel route during the westward expansion along the Santa Fe Trail (Figure 4.9.1-3). As the west was settled, the vast herds of bison were eventually replaced by cattle (Smeins 1980). The impact of cattle on the landscape was quite different than that of bison. While herds of bison tend to exhibit short spurts of intense grazing, cattle persisted for longer periods, often congregating near water. The grazing patterns by bison allowed grasslands to recover, often for several years; whereas cattle were a more constant impact.

The grasslands of Colorado were also experiencing dryland farming by the 1880's, which later gave way to irrigation. The Fort Lyon Canal Company was established during that time (Sherow 1989), and the state of Colorado was soon ranked first in the nation for area of irrigated agricultural land. Pressures on the landscape were dramatically increased around the Fort during its active period as travelers and traders pastured their animals, and hunted for game.



**Figure 4.9.1-3. One of the values of grasslands, is the importance that they played in the historic context. The ability for visitors to imagine the historic setting can dramatically add to their sense of place in that historic context.**

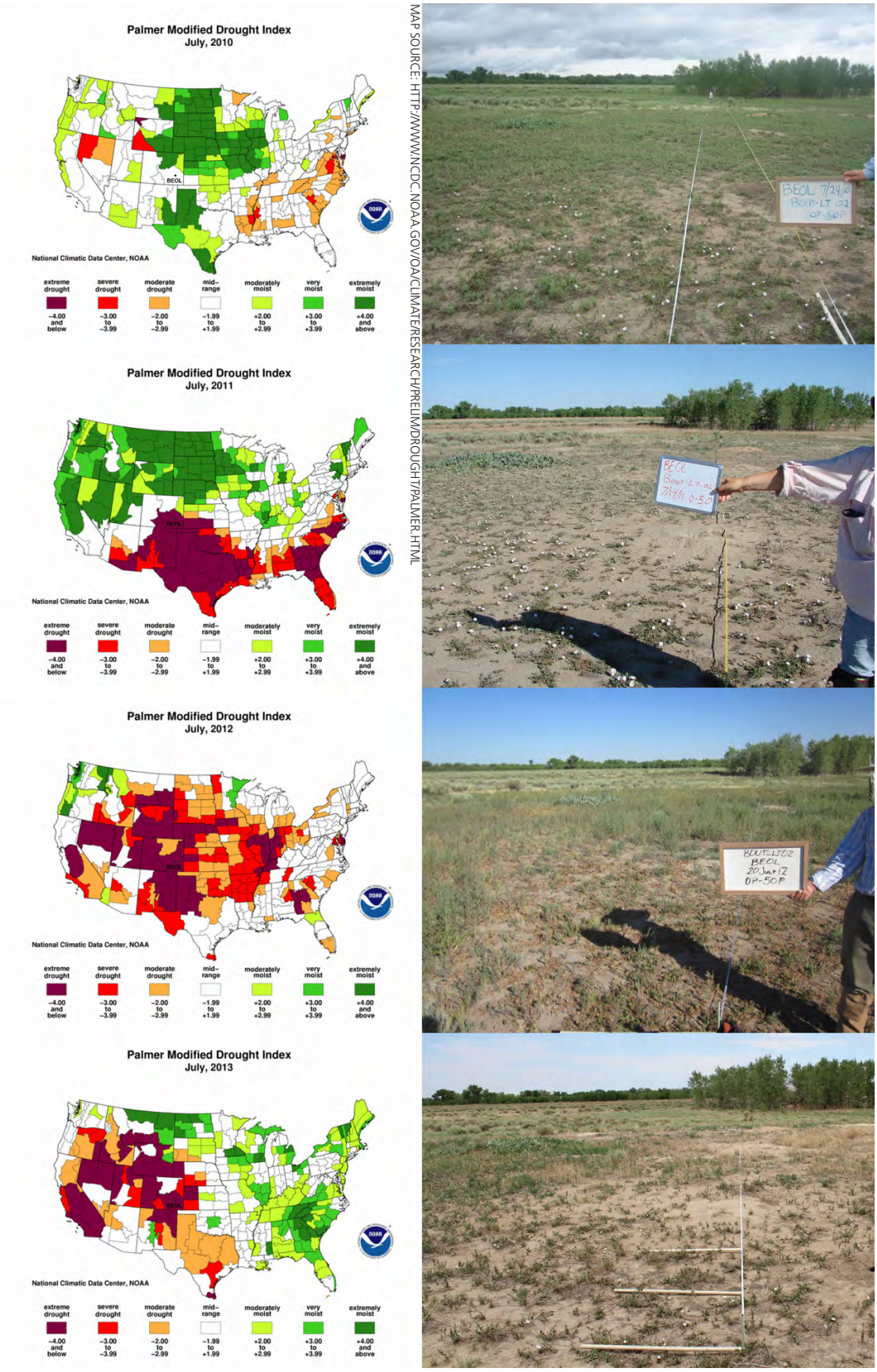



**Figure 4.9.1-4. The Palmer Modified Drought Index for each of the four years for which data from Bent's Old Fort NHS were available. Also shown to the right of each map are photos taken from a monitoring transect (LT02_0-50T) for the corresponding time period.**

Conditions During Assessment

It is important to recognize that a major drought occurred during the time period of this assessment. During the summer of 2010 Bent's Old Fort NHS was experiencing conditions that were considered in the mid-range of variability; whereas during 2011-2013 the Historic Site was considered as being in an extreme drought (Figure 4.9.1-4). We have tried to take these conditions into account in our interpretations, but the reader should be aware that such conditions may have an important impact on our assessment.

### *4.9.2. Data and Methods*

We considered three categories of measures/ indicators for the assessment of grassland condition at the Historic Site based on the approach presented by Pellant et al. (2005): soil/site stability, hydrologic functioning, and biological integrity. These categories are defined by Pellant et al. (2005) as follows:

*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.

*Hydrologic Function* - The capacity of an area to capture, store, and safely release water from rainfall, run-off, 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 normal 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, animals, and microorganisms occurring both above and below ground.

In combination, the measures from each of these categories provide the basis for this assessment. We have summarized the measures for each of these groups below.

The soil/ site stability/hydrologic function measures were assessed primarily through a site visit and rapid assessment in early June 2013 conducted by Pete Biggam, (Biggam 2013) who is a soil scientist with NPS' Geoscience and Restoration Branch.

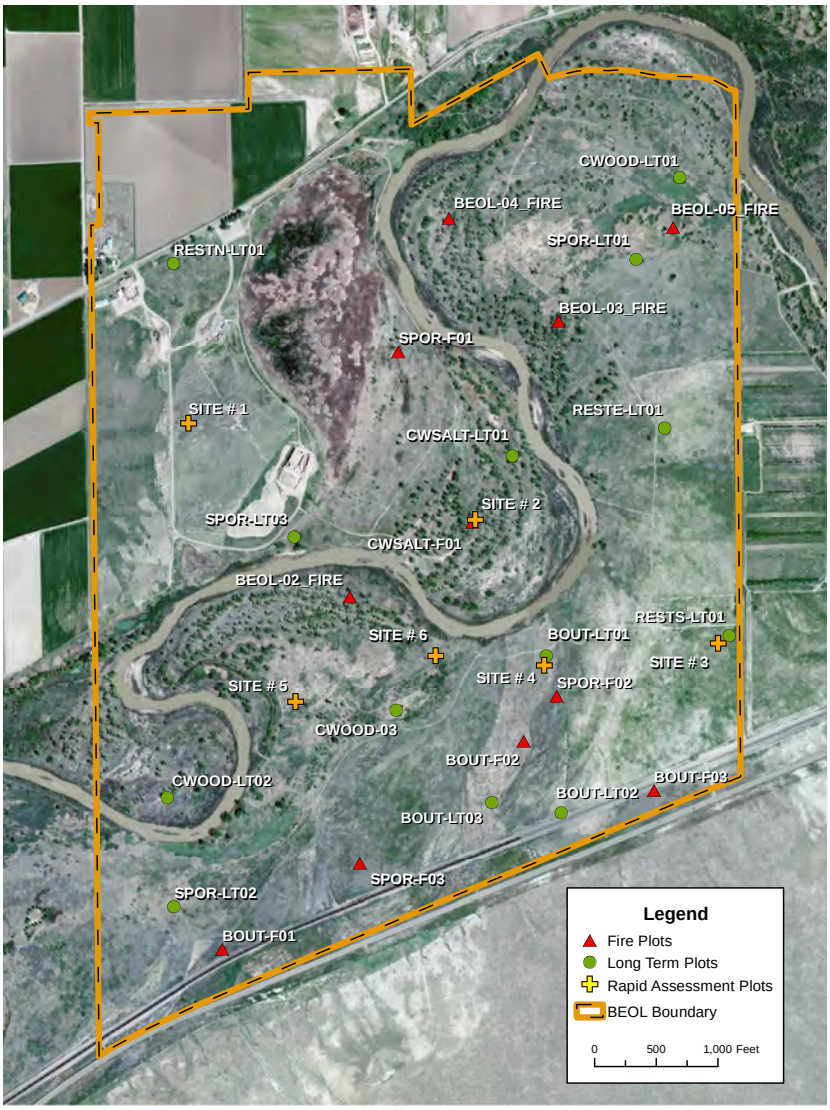



**Figure 4.9.2-1. Location of Soil Rapid Assessment points and grassland monitoring plots at Bent's Old Fort NHS.**

## Indicator

### Soil/Site Stability and Hydrologic Function

The rapid soil assessments consisted of evaluating six selected sites at the Historic Site (Figure 4.9.2-1).

The methodology for these assessments used an approach based on those described in the qualitative assessment protocol "Interpreting Indicators of Rangeland Health (Version 4.0) (http://usda-ars.nmsu.edu/monit_assess/index.html), in which Soil/Site Stability qualitative measures (Table 4.9.2-1) were

used to assess the ability of an area to limit redistribution and loss of soil resources by wind and water.

Qualitative measures can provide land managers and technical assistance specialists with a good communication tool, and when used in association with quantitative monitoring and inventory information, they can be used to provide early warnings of resource problems on upland rangelands.

These measures were used in conjunction with soil survey information and ecological site descriptions for the six selected evaluation areas, each of which were approximately 1/3 acre in size. It is important to note that only the Soil/Site Stability qualitative measures were observed and documented on site, and these were what were used to perform the rapid soil assessments. The rapid soil assessment was used to determine the departure from the expected soil/site stability attributes.

## Indicator
### Biotic Integrity

The assessment for the biotic integrity of grasslands was made via a combination of a field assessment by grassland experts Tim Seastedt (University of Colorado at Boulder) and our SOPN Botanist Tomye Folts-Zettner, and using data collected as part of the Southern Plains Network's ongoing grassland monitoring. In collaboration with additional SOPN and Historic Site staff, the first task was to determine appropriate measures of grassland biotic integrity. Using the qualitative measures of rangeland health presented in (Pellent et al. 2005) as a starting point, the grassland experts, in collaboration with SOPN and Historic Site staff developed a suite of five measures of grassland biotic integrity that was deemed appropriate for this assessment. These measures are summarized in Table 4.9.2-1 and described in greater detail below.

Based on these measures, a rapid field assessment was conducted based on visits to multiple sites at Bent's Old Fort NHS. Each site was qualitatively evaluated by the experts based on the measures developed. We then used data collected during the past four years of monitoring to augment the opinions by our experts and to provide a more quantitative baseline for future assessment. These data were collected by the Southern Plains Inventory and Monitoring Network (SOPN) and the Southern Plains Fire Group, following Folts-Zettner et al (2013a). Grassland monitoring data were collected in 2010-2013 along 14 transects, each with five subplots, as part of this monitoring effort (Folts-Zettner et al 2013b) (Figure 4.9.2-1). At each subplot, the percent cover was estimated for each species within a 1x2m quadrat.

Landscape-scale Diversity

The plant communities and alliances are generally expected to reflect local conditions of soils, moisture, disturbance, etc. As such, we would expect the diversity across the Historic Site to generally reflect the variation in these site characteristics. However, it is not reasonable to expect a one to one correspondence between local communities and their corresponding sites because a multitude of factors can influence the local expression of vegetation communities at a given site. Rather, we are trying to determine that some reasonable level of landscape diversity exists and that it generally corresponds to changes in ecological conditions. To assess this, we compared the vegetation communities observed during the Historic Site vegetation mapping (Stevens et al. 2007) with soil types (NRCS 2012) and ecological sites (NRCS 2007).

Local Species Composition

The intent behind this measure is to see if the species composition is generally consistent with what might be expected for the site, given the local conditions (soils, disturbance, moisture, etc). We considered this from two perspectives. First, was the degree to which the local communities consisted of native vs exotic species. Details about which exotic species are present and their effect on the site are presented in greater detail in Chapter 4.11. Here we just provide an initial indication of the extent of invasion by exotic species by looking at the proportion of native and exotic species. Second, we looked at the species composition of the native species relative to

**Table 4.9.2-1. Indicators and measures used to assess grasslands at Bent's Old Fort NHS.**

| Indicator | Measure | Definition |
|---|---|---|
| Soil/Site Stability and Hydrologic Function | Rills | A small, intermittent water course with steep sides, usually only several centimeters deep (SSSA 1997). Rills generally are linear erosion features. |
| | Water Flow Patterns | Flow patterns are the path that water takes as it moves across the soil surface during overland flow. |
| | Pedestals and/or terracettes | "Plants or rocks that appear elevated as a result of soil loss by wind or water erosion (does not include plant or rock elevation as a result of non-erosional processes such as frost heaving), and "Benches" of soil deposition behind obstacles caused by water erosion." |
| | Bare ground | All land surface not covered by vegetation, rock, or litter (SRM 1999). As used in this document, visible biological crusts and standing dead vegetation are included in cover estimates or measurements and therefore are not bare ground (e.g., mineral soil). |
| | Gullies | A furrow, channel, or miniature valley, usually with steep sides through which water commonly flows during and immediately after rains or snowmelt (SRM 1999). Small channels eroded by concentrated water flow. |
| | Wind-scoured, blowout and/or depositional areas | Areas, generally in interspaces, where the finer soil particles have blown away sometimes leaving residual gravel, rock, or exposed roots on the soil surface |
| | Litter Movement | The uppermost layer of organic debris on the soil surface, essentially the freshly fallen or slightly decomposed vegetal material (SRM 1999). In this document, it includes persistent and non-persistent organic matter that is in contact with the soil surface. |
| | Soil surface resistance to erosion | The top layer underneath vegetation canopy and characteristics of presence/absence/configuration of debris |
| | Soil surface loss or degradation | Intactness of uppermost soil layer |
| | Compaction layer | A near surface layer of dense soil caused by the repeated impact on or disturbance of the soil surface. When soil is compacted, soil grains are rearranged to decrease the void space and bring them into closer contact with one another, thereby increasing the bulk density (SSSA 1997). |
| Biotic Integrity | Landscape-scale Diversity | The extent to which landscape-scale diversity reflects spatial pattern of soils and disturbance. |
| | Local Species Composition, | The extent to which species composition within a site (e.g., ecological site) deviates substantially from the expected native species compliment either from exotics or native species. |
| | General Life Cycles Relative to Disturbance | The proportion of annual, biennial and perennial species relative to the time since disturbance. |
| | Relative proportion of functional groups (e.g., graminoid, forbs, shrubs, etc.) | The relative proportions of functional groups relative to what would be expected based on site characteristics (e.g., lack of forbs, excessive shrub density, etc.) |
| | Relative proportion of C3 and C4 species. | The relative proportions of C3 and C4 plants relative to what would be expected based on site characteristics |

what might be expected for that site. This was based on a combination of NRCS Ecological Site Descriptions and expert opinion. As we have done for other measures, this assessment is based primarily on percentage cover, rather than the number of individual species because most species are quite rare and cover provides a more realistic assessment of species composition.

General Life Cycles Relative to Disturbance

It is generally expected that the number of annual species at a given site would be higher immediately following a disturbance, and would shift toward an increasing number of perennials as time passes since a disturbance. The persistence of annuals after a disturbance could indicate some basis for concern. For example roadside areas that are frequently and unnaturally disturbed might be expected

to have a greater persistence of annual species compared to interior sites.

Relative Proportion of Functional Groups
The composition of functional groups can have a dramatic effect of grassland ecosystems and their associated processes (Tilman et al. 1997, Pellant et al. 2005). Tilman et al. (1997) found that functional composition and functional diversity were principal factors explaining plant productivity, plant percent nitrogen, plant total nitrogen, and light penetration. They further concluded that habitat modifications and management practices that change functional diversity and functional composition would likely have a dramatic effect on ecosystem processes.

Relative Proportion of C3 and C4 Species -
Shortgrass Prairies typically have a high proportion of perennial C4 (warm season) grasses (Lauenroth et al. 2008). The morphological and physiological characteristics of these plants make them highly adaptable to withstand stressors such as drought or grazing by large herbivores such as cattle((Lauenroth et al. 2008). The proportion of C3 and C4 grasses can also dramatically influence how these grassland communities respond to climate change and levels of $CO_2$, although the nature of such response has been much debated (Wand et al. 1999).

### *4.9.3. Reference Conditions*

Soil/Site Stability and Hydrologic Function
Pellant et al. (2005) described general reference conditions they considered to be an optimal functional state (their none to slight category) under natural disturbance regimes (Table 4.9.3-1). They then described general descriptions for departures from that optimal state into four other categories of condition. These categories ranged from their optimal state to an extreme or total state of degradation.

We considered the condition of grasslands as "good" if the current condition fell either within Pellant et al.'s (2005) "none to slight", or "slight to moderate" categories. The "moderate" ranking was assigned if the departure from optimal fell within Pellant et al's (2005) "moderate" class. And finally, we considered the condition of grasslands as significant concern if the departure from optimal fell within Pellant et al's (2005) "moderate to extreme" or "extreme to total" classes.

Biotic Integrity
Determining definitive quantitative reference conditions for grassland communities at Bent's Old Fort NHS is somewhat problematic given the dynamic nature of these resources. Part of our consideration in choosing the measures we have used for biotic integrity is that they are moderately robust to the potentially substantial seasonal and annual variation that plant communities often exhibit. We began with a conceptual framework for assigning condition based on what might be expected for the site conditions at Bent's Old Fort NHS (Table 4.9.3-2). We recognize, however, that seasonal and annual variation in such things as rainfall and disturbance can results in dramatic shifts in specific measurement that are still within an acceptable range of natural variation. In particular, the drought that has occurred at Bent's Old Fort NHS the past three years may have dramatically influenced some measures of biotic integrity.

Our measure of landscape-scale diversity focuses on whether or not the diversity of plant communities reflects to a reasonable extent the diversity in site characteristics. As such, we used the spatial pattern of soil types (NRCS 2012) and ecological sites (NRCS 2007) as a general reference for the extent and pattern of landscape diversity that might be expected.

For the remaining measures, we used a combination of the Natural Resources Conservation Service's ecological site descriptions (NRCS 2007) and expert opinion as a general reference for plant community characteristics that might be expected given the soil types and ecological sites that occur at Bent's Old Fort NHS. It is important to note however, the values in the ecological site descriptions are typically only provided for what are considered the historic climax plant communities (HCPCs), and variations in the

**Table 4.9.3-1. Reference conditions for soil/site stability/hydrologic function measures.**

| Measure | Significant Concern | | Moderate | Good | |
|---|---|---|---|---|---|
| | Extreme to Total | Moderate to Extreme | Moderate | Slight to Moderate | None to Slight |
| Soil/site Stability and Hydrologic Function | | | | | |
| Rills | Rill formation is severe and well defined throughout most of the site. | Rill formation is moderately active and well defined throughout most of the site. | Active rill formation is slight at infrequent intervals; mostly in exposed areas | No recent formation of rills; old rills have blunted or muted features. | Current or past formation of rills as expected for the site. |
| Water Flow Patterns | Water flow patterns extensive and numerous; unstable with active erosion; usually connected | Water flow patterns more numerous and extensive than expected; deposition and cut areas common; occasionally connected. | Number and length of water flow patterns nearly match what is expected for the site; erosion is minor with some instability and deposition. | Number and length of water flow patterns match what is expected for the site; some evidence of minor erosion. Flow patterns are stable and short. | Matches what is expected for the site; minimal evidence of current or past soil deposition and erosion. |
| Pedestals and/or terracettes | Abundant active pedestalling and numerous terracettes. Many rocks and plants are pedestaled; exposed plant roots are common. | Moderate active pedestalling; terracettes common. Some rocks and plants are pedestaled with occasional exposed plant roots. | Slight active pedestalling; Most pedestals are in flow paths and interspaces and/or on exposed slopes. Occasional terracettes present. | Active pedestalling or terracette formation is rare; some evidence of past pedestal formation, especially in flow patterns on exposed slopes. | Current or past evidence of pedestaled plants or rocks as expected for the site. Terracettes uncommon or absent. |
| Bare ground | Much higher than expected for the site. Bare areas are large and generally connected. | Moderate to much higher than expected for the site. Bare areas are large and occasionally connected. | Moderately higher than expected for the site. Bare areas are of moderate size and sporadically connected. | Slightly to moderately higher than expected for the site. Bare areas are small and rarely connected. | Amount and size of bare areas match that expected for the site. |
| Gullies | Common with indications of active erosion and downcutting; vegetation is infrequent on slopes and/or bed. Nickpoints and headcuts are numerous and active. | Moderate in number to common with indications of active erosion; vegetation is intermittent on slopes and/or bed. Headcuts are active; downcutting is not apparent. | Moderate in number with indications of active erosion; vegetation is intermittent on slopes and/or bed. Occasional headcuts may be present. | Uncommon, vegetation is stabilizing the bed and slopes; no signs of active headcuts, nickpoints, or bed erosion. | Match what is expected for the site; drainages are represented as natural stable channels; vegetation common and no signs of erosion. |
| Wind-scoured, blowout, and/or depositional areas | Extensive | Common | Occasionally present | Infrequent and few. | Match what is expected for the site. |
| Litter movement | Extreme concentrated around obstructions. Most size classes of litter have been displaced. | Moderate to extreme; loosely concentrated near obstructions. Moderate to small size classes of litter have been displaced. | Moderate movement of smaller size classes in scattered concentrations around obstructions and in depressions. | Slightly to moderately more than expected for the site with only small size classes of litter being displaced. | Matches that expected for the site with a fairly uniform distribution of litter. |
| Soil surface resistance to erosion | Extremely reduced throughout the site. Biological stabilization agents including organic matter and biological crusts virtually absent. | Significantly reduced in most plant canopy interspaces and moderately reduced beneath plant canopies. Stabilizing agents present only in isolated patches. | Significantly reduced in at least half of the plant canopy interspaces or moderately reduced throughout the site. | Some reduction in soil surface stability in plant interspaces or slight reduction throughout the site. Stabilizing agents reduced below expected | Matches that expected for the site. Surface soil is stabilized by organic matter decomposition products and/or a biological crust. |

***Table 4.9.3-1. Reference conditions for soil/site stability/hydrologic function (continued).***

| Measure | Significant Concern | | Moderate | Good | |
|---|---|---|---|---|---|
| | Extreme to Total | Moderate to Extreme | Moderate | Slight to Moderate | None to Slight |
| Soil surface loss or degradation | Soil surface horizon absent. Soil structure near surface is similar to, or more degraded, than that in subsurface horizons. No distinguishable difference in subsurface organic matter content. | Soil loss or degradation severe throughout site. Minimal differences in soil organic content and structure of surface and subsurface layers. | Moderate soil loss or degradation in plant interspaces with some degradation beneath plant canopies. Soil structure is degraded and soil organic matter is significantly reduced. | Some to no soil loss has occurred and/or soil structure shows signs of degradation, especially in plant interspaces | Soil surface horizon intact. Soil structure and organic matter content match that expected for site. |
| Compaction layer (below soil surface) | Extensive; severely restricts water movement and root penetration. | Widespread; greatly restricts water movement and root penetration. | Moderately widespread, moderately restricts water movement and root penetration. | Rarely present or is thin and weakly restrictive to water movement and root penetration. | Matches that expected for the site; none to minimal, not restrictive to water movement and root penetration. |

**Table 4.9.3-2. Reference conditions used to assess the current condition for measures of grassland biotic integrity.**

| Measure | Significant Concern | Moderate | Good |
|---|---|---|---|
| Landscape- scale diversity | Significant lack of spatial landscape heterogeneity that does not reflect the expected diversity for the soil types and sites | Moderate lack of spatial landscape heterogeneity that does not fully reflect the spatial pattern of soils and disturbance | Landscape-scale diversity reflects spatial pattern of soils and disturbance |
| Local species composition | Species composition deviates substantially from the native species compliment that would typically occur at such sites. Such a deviation could also be either from exotics or native species. | Species composition moderately deviates from the expected native species compliment either from exotics or native species in such a way that does reflect typical types of natural disturbance (e.g., fire or prairie dogs). | Species composition reflects expected native species compliment consistent with the site characteristics (e.g., from ESDs). Species composition need not reflect expected climax communities if their current state reflects typical types of natural disturbance (e.g., fire or prairie dogs). |
| General Life Cycles Relative to Disturbance | Substantially higher proportion of annual species than expected in sites not recently disturbed. | Proportion of perennial species is moderately lower that what might be expected given the site and time since disturbance. | Proportion of perennial species is approximately what would be expected given the site and time since disturbance. |
| Relative proportion of functional groups (e.g., graminoids, forbs, shrubs, etc.) | Proportions of functional groups differ substantially from what might be expected based on- site characteristics (e.g., lack of forbs, excessive shrub density, etc.) | Proportions of functional groups exhibit moderately departure from what might be expected given the site and disturbance history. | Proportions of functional groups (e.g., grasses, forbs, and shrubs) are consistent with what might be expected given the site characteristics. |
| Relative proportion of C3 and C4 species. | Sites dominated by C3 grasses at shortgrass sites traditionally dominated by C4 grasses. | Higher than expected proportion of C3 grasses given the ecological site and disturbance history. | Appropriate mix and natural variability of C4 (warm season) and C3 (cool season) grasses for the site (to maximize resilience) |

**Table 4.9.4-1. The assessment of measures used to assess soil/site stability/hydrologic function at each of six rapid-assessment points at Bent's Old Fort NHS.**

| Indicator | Measure | Site Assessment[1] | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| Soil/Site Stability and Hydrologic Function | Rills | NS | NS | ET | NS | NS | NS |
| | Water Flow Patterns | NS | NS | ME | ME | NS | NS |
| | Pedestals and/or terracettes | NS | NS | NS | M | NS | NS |
| | Bare ground | M | NS | ET | ET | M | NS |
| | Gullies | NS | NS | NS | NS | NS | NS |
| | Wind-scoured, blowout and/or depositional areas | NS | NS | M | SM | SM | NS |
| | Litter Movement | NS | NS | M | SM | SM | NS |
| | Soil surface resistance to erosion | M | NS | ME | M | SM | NS |
| | Soil surface loss or degradation | M | NS | ME | M | SM | NS |
| | Compaction layer | SM | NS | SM | SM | NS | NS |
| **Overall Soil and Site Stability Rating** | | **SM** | **NS** | **ME** | **M** | **SM** | **NS** |

[1] NS = None to Slight, SM = Slight to Moderate, M = Moderate, ME = Moderate to Extreme, ET = Extreme to Total

dynamics of those communities are presented only through qualitative descriptions and/or generalized state and transition models. Consequently we do not strictly adhere to the HCPCs as a reference condition in the sense that departures from that reference necessarily represent a degraded quality; rather as a general guide to be used in conjunction with expert opinion to determine resource condition.

### *4.9.4. Condition and Trend*

Field notes from the grassland assessment are presented in Appendix E.

Soil/Site Stability / Hydrologic Function

The results from Biggam's rapid assessment indicated that the overall current condition of the soil/site stability/hydrologic at Bent's Old Fort NHS was moderate, with departures from expected varying greatly among sites (Table 4.9.4-1). Some sites, such as sample sites #2, within the Cottonwood groves, and #6 in the inland saltgrass that was treated for Tamarisk removal are in relatively good condition from a soils perspective; whereas, others such as sample #3 in the prairie dog town are in relatively poor condition with some measures such as rills and bare ground being extreme, and are a result of previous efforts to reseed the site in which cultivation practices were used to facilitate the use of a seed drill. It should be noted that some measures are undoubtedly influenced by the extreme drought conditions that have occurred over the past three years (Figure 4.9.4-1). However, we are confident that the drought conditions do not account for all of the concerns with respect to soil stability and hydrologic function, and a moderate condition rating is warranted even after taking drought into consideration and previous land management activities.



**Figure 4.9.4-1. Several measures of grassland resource condition can be dramatically influenced by the extreme drought conditions during the time of this assessment.**

Biotic Integrity

*Landscape-scale Diversity*
The spatial patterns of plant community distribution generally coincide with that of the ecological sites and soils (Figure 4.9.4-2). Further, during the rapid assessment, our grassland experts did not express much concern over a lack of diversity among sites, although there was some concern about local diversity within sites (discussed below). Thus, landscape-scale diversity was considered in reasonably good condition with no evidence for any degrading trend.

*Local Species Composition*
Species composition at local sites has clearly been affected by ongoing drought conditions and we have tried to take that into account in our assessment. As previously indicated, we do not have an expectation for species composition to match the species list for historic climax plant communities of the appropriate ecological site descriptions (NRCS 2007), although we did take these descriptions into account along with expert opinion.

The condition of local species diversity was quite variable among sites and ranged from relatively good (taking into account the drought) at some sites (e.g., sites 1 and 2) to sites of moderate condition (e.g. the sand sage communities at site 4). to areas that would be considered of significant concern (e.g., the prairie dog town at site 3)(Appendix E). In some cases, condition is expected to improve following the drought and in other cases management activities such as restoration are working toward improved condition. The condition at local sites probably reflects the historic land use and/or disturbance at those sites more so than the ecological site, although undoubtedly some ecological sites are more resilient to historic land uses than others. As a result of condition of local species diversity ranging from good to significant concern among sites, we considered the overall condition of this measure to be moderate.

*Annual vs Native Species* -- One of the major threats to grasslands and other plant communities is invasive species. Invasive species have been directly linked to the replacement of dominant native species (Tilman 1999), the loss of rare species (King 1985), changes in ecosystem structure, alteration of nutrient cycles and soil chemistry (Ehrenfeld 2003), shifts in community productivity (Vitousek 1990), and changes in water availability (D'Antonio and Mahall 1991).

Based on four years (2010-2013) of grassland sampling 60 of 74 (81%) of the total species we observed were native (Table 4.9.4-2). Of these, the proportion of native species was generally higher for grasses (88%) than forbs

**Table 4.9.4-2. The number and percentage of native and exotic species of each life form found on Bent's Old Fort NHS during the 2010-2012 grassland monitoring sampling.**

| Life Form | Native | Exotic | Total | Percent Native |
|---|---|---|---|---|
| Grass | 15 | 2 | 17 | 88% |
| Forb | 41 | 11 | 52 | 79% |
| Shrub | 2 | 0 | 2 | 100% |
| Tree | 2 | 1 | 3 | 67% |

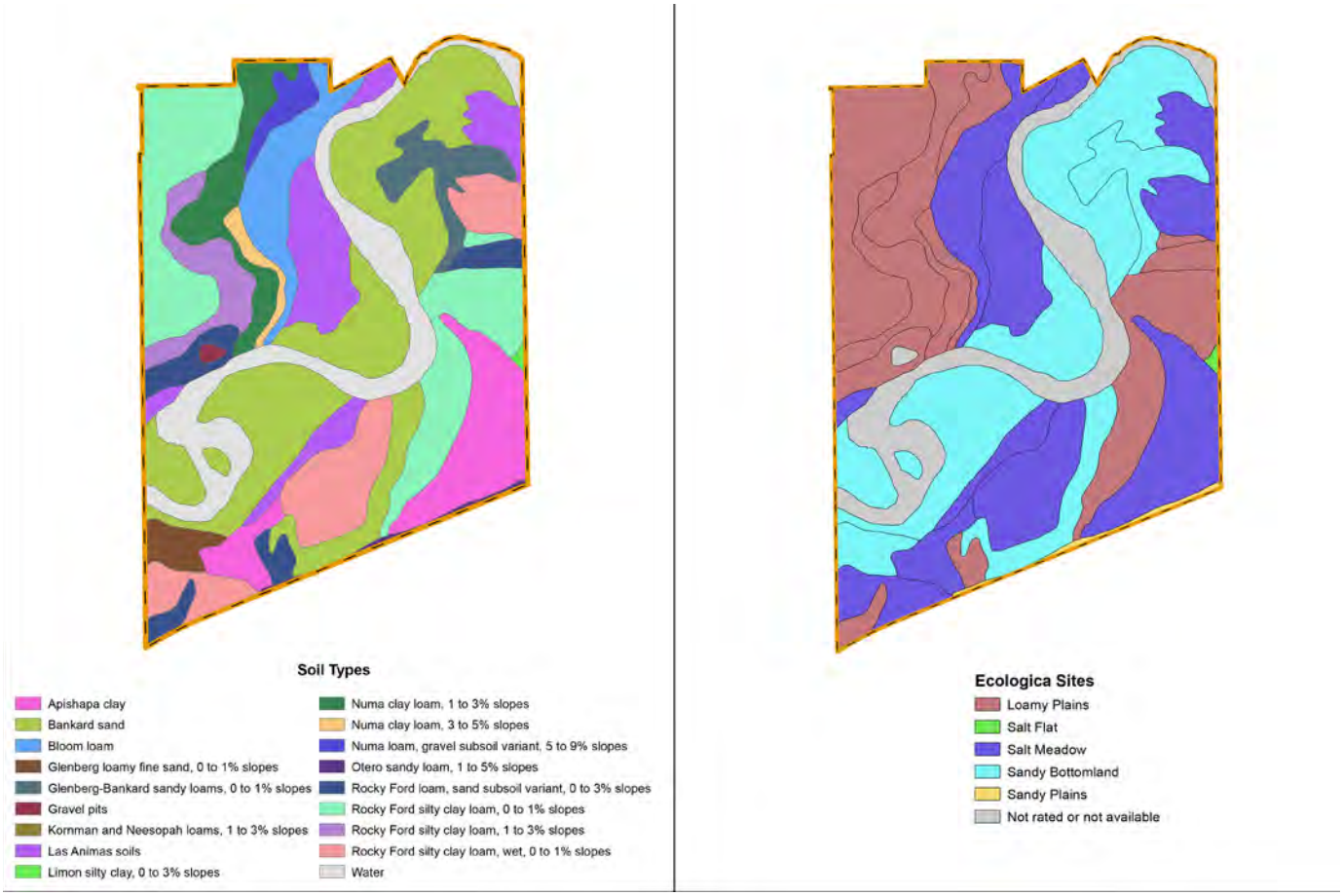
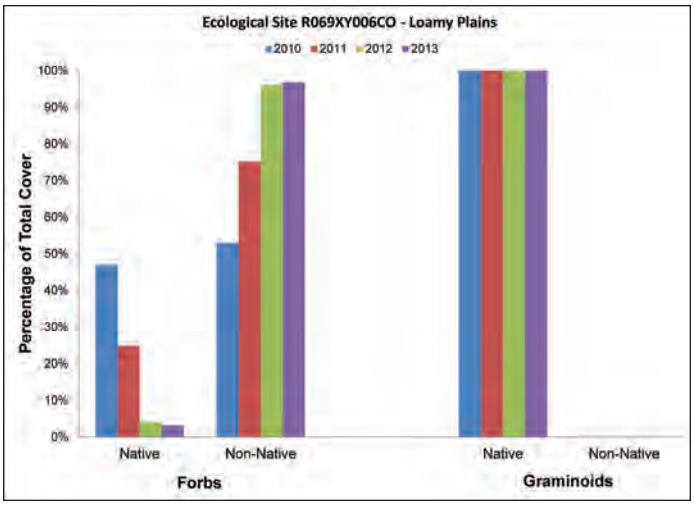
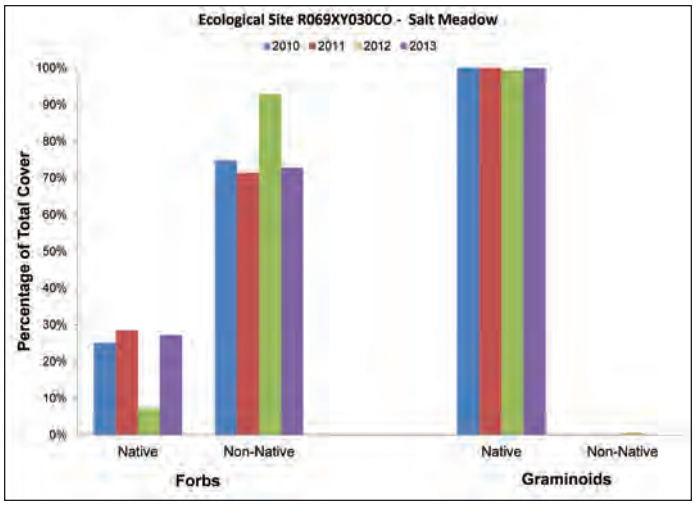



**Figure 4.9.4-2. The distribution of soil types based on NRCS (2012), ecological sites based on NRCS (2007) and plant communities based on Stevens et al. (2007).**



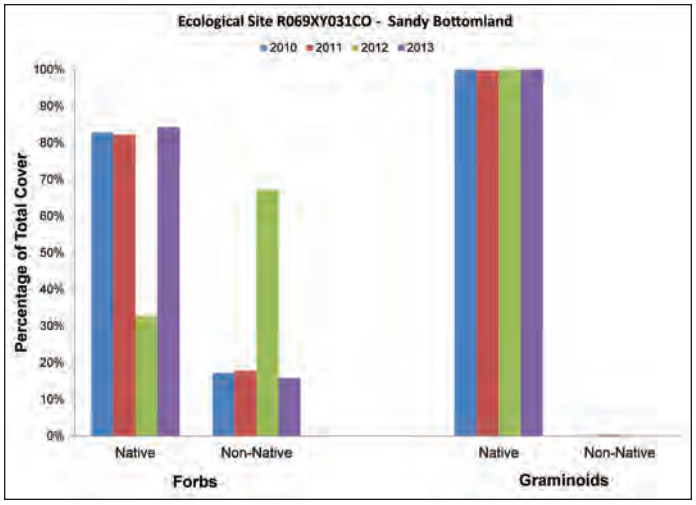




**Figure 4.9.4-3. The percentage of native and exotic grasses and forbs for each ecological site samples in 2010-2013 at Bents' Old Fort NHS.**

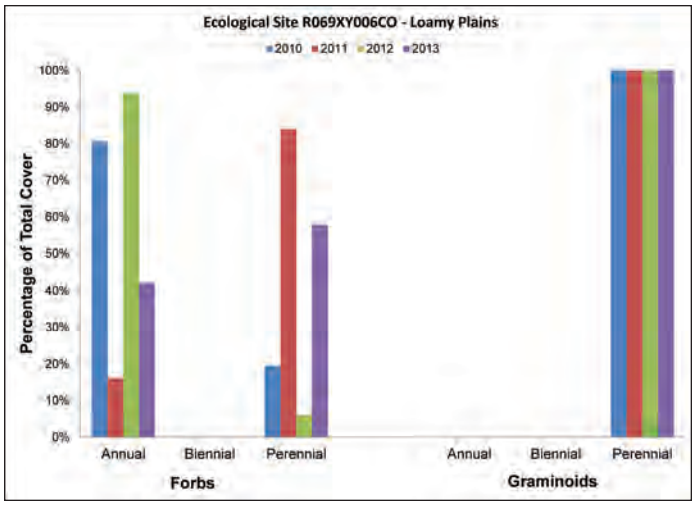
(79%). However, the number of species does not take into account how prevalent those species are on the landscape. Based on the percentage of cover, grasses on our sample plots were almost exclusively native species and forb cover was dominated by non-native species at two of three primary ecological sites (Figure 4.9.4-3).

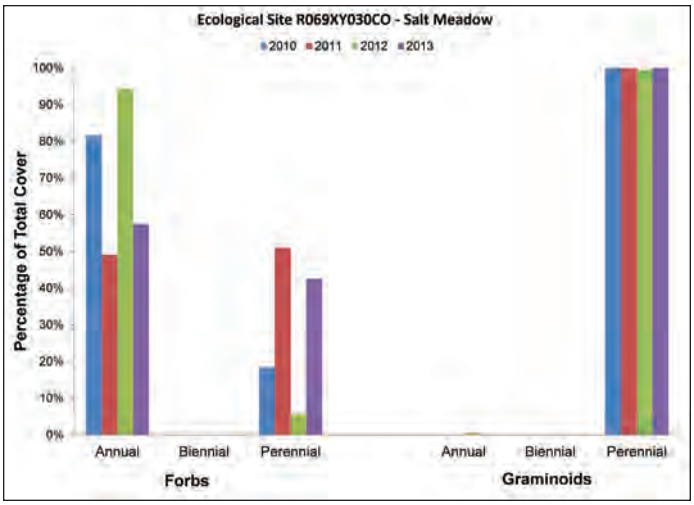
These results are based on grassland monitoring plots, which are located throughout the Historic Site. Two additional sources of information about exotics are the SOPN exotic monitoring transects and a supplementary rapid assessment grid that was sampled in 2011. Both of these sources of information are presented in depth in Chapter 4.10. However, both of these sources of data focused explicitly and exclusively on exotic species in order to gain a better understanding of their distribution and density; thus do not consider how prevalent these exotics are relative to native species. The SOPN exotic monitoring transects focus explicitly on areas considered as high risk for invasion of exotics; thus are not representative of grasslands in general. The supplementary rapid assessment grid covers the entirety of the Historic Site at 150 m intervals; thus does represent the overall Historic Site, but does not take into account native species.

*General Life Cycles Relative to Disturbance*

The proportion of annual, biennial and perennial species provides an indication of the stability of the site, and it is generally expected that the proportion of annual species at a given site would be higher immediately following a disturbance, but would shift toward an increased proportion of perennials as time passes since a disturbance. Data from our grassland monitoring samples indicated that grasses were nearly all perennial (Figure 4.9.4-4). Forbs were considerably more variable among sites and years. Based on what is considered the historic climax plant communities (NRCS 2007), the proportion of perennial species was generally expected to be high for grasses and more variable for forbs (Table 4.9.4-3).

As previously discussed, we did not have any expectation for the proportion of annuals, biennials, and perennials, to coincide exactly with historic climax plant communities, in



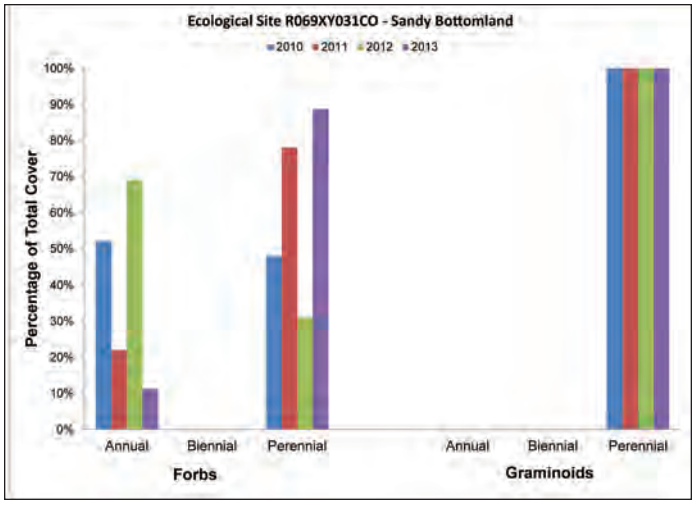




**Figure 4.9.4-4. The percentage of annual, biennial, and perennial grasses and forbs for each ecological site and each years sampled.**

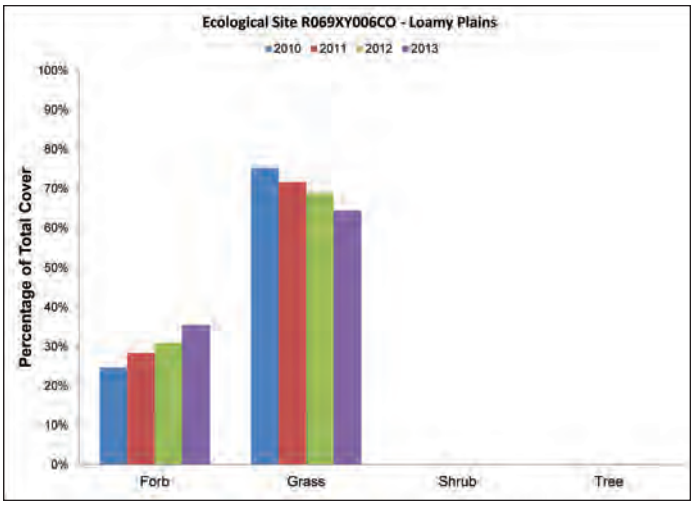
part because of local site variability and not all sites are at a climax stage. At Bent's Old Fort NHS, sites that exhibited relatively low proportion of perennials were sites that have experienced disturbance from prairie dog colonies and more pronounced response to recent drought. Thus, it not surprising that we observe a higher proportion of annual species on these sites. The time frames over which we might expect a shift toward increasing perennial species probably depends on the intensity and duration of the disturbance.

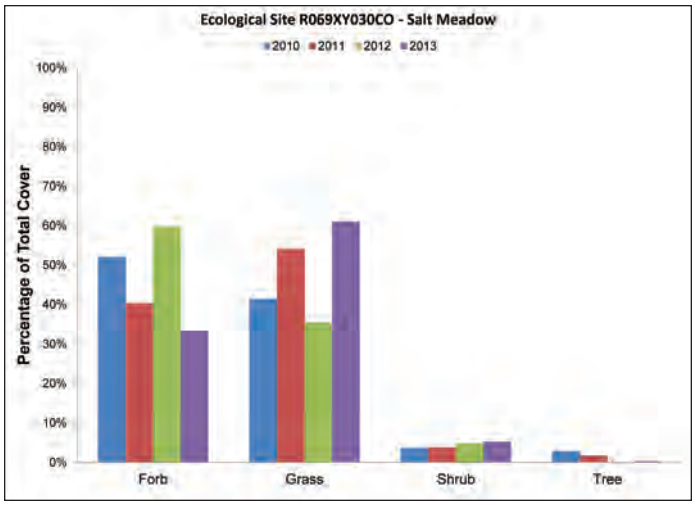
There was little concern about this measure for the grasses, but the condition of this measure for forbs was more varied. Here again, at some sites there was little concern about this measure for forbs. There was however, some concern that site 3 (the prairie dog town) had a high proportion of annual forbs, and at other sites (e.g., 5 and 6) Kochia was probably affecting the proportion of perennial forb cover.

**Table 4.9.4-3. The number and percentage of perennial grass and forb species observed at each ecological site on Bent's Old Fort NHS during the 2010-2013 grassland monitoring sampling.**

| Ecological Site No. | Ecological Site Name | Life Form | Percent Perennials Observed 2010-2013 |
|---|---|---|---|
| R069XY006CO | Loamy Plains | Graminoid | 100% |
| R069XY006CO | Loamy Plains | Forb | 45% |
| | | | |
| R069XY030CO | Salt Meadow | Graminoid | 100% |
| R069XY030CO | Salt Meadow | Forb | 25% |
| | | | |
| R069XY026CO | Sandy Bottomland | Graminoid | 100% |
| R069XY026CO | Sandy Bottomland | Forb | 57% |

[1]Based on values reported for minimum and and maximum production, no range of variation can be estimated.



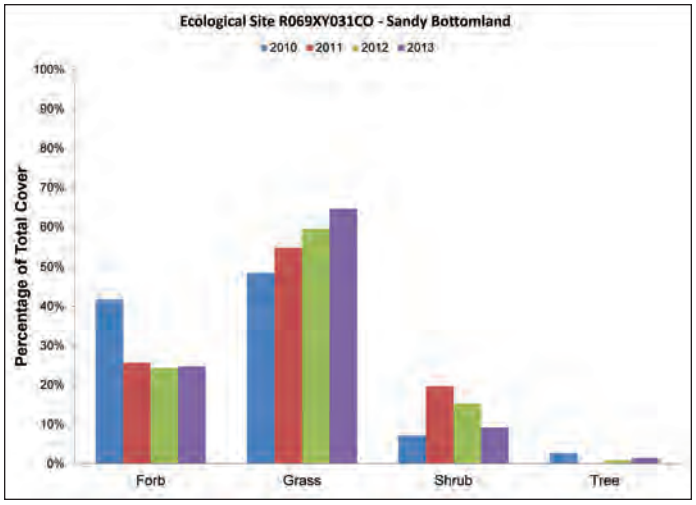



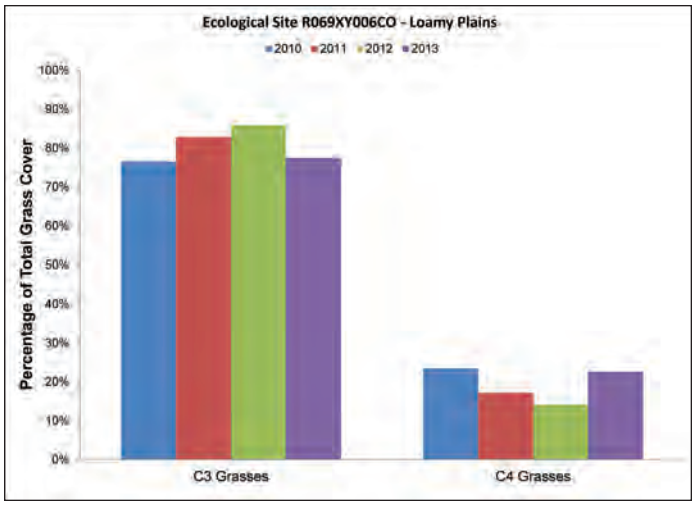

**Figure 4.9.4-5. The percentage of life forms for each ecological site samples in 2010-2013 at Bent's Old Fort NHS.**

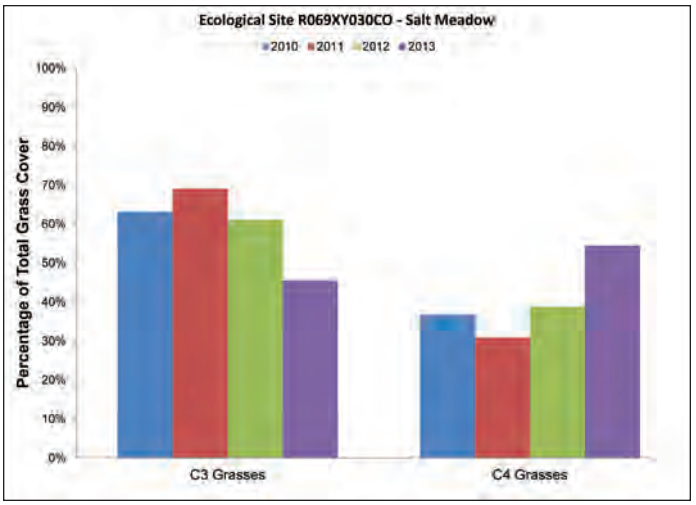
Based on this assessment, we considered Bent's Old Fort NHS to be in good to moderate condition overall with respect to this measure.

*Relative Proportion of Functional Groups* -
Similarly to our other measures, the proportion of functional groups and relative concern regarding this measure was highly variable among both rapid assessment sites and ecological sites (Table 4.9.4-4) and showed some annual variability among years (Figure 4.9.4-5). Some rapid assessment

**Table 4.9.4-4. The number and percentage cover of each life form observed at each ecological site on Bent's Old Fort NHS during the 2010-2013 grassland monitoring sampling.**

| Ecological Site No. | Ecological Site Name | Life Form | Percent Observed 2010-2013 |
|---|---|---|---|
| R069XY006CO | Loamy Plains | Graminoid | 70% |
| R069XY006CO | Loamy Plains | Forb | 30% |
| R069XY006CO | Loamy Plains | Shrub | 0% |
| R069XY006CO | Loamy Plains | Tree | 0% |
| | | | |
| R069XY030CO | Salt Meadow | Graminoid | 47% |
| R069XY030CO | Salt Meadow | Forb | 47% |
| R069XY030CO | Salt Meadow | Shrub | 4% |
| R069XY030CO | Salt Meadow | Tree | 1% |
| | | | |
| R069XY026CO | Sandy Bottomland | Graminoid | 56% |
| R069XY026CO | Sandy Bottomland | Forb | 31% |
| R069XY026CO | Sandy Bottomland | Shrub | 12% |
| R069XY026CO | Sandy Bottomland | Tree | 1% |



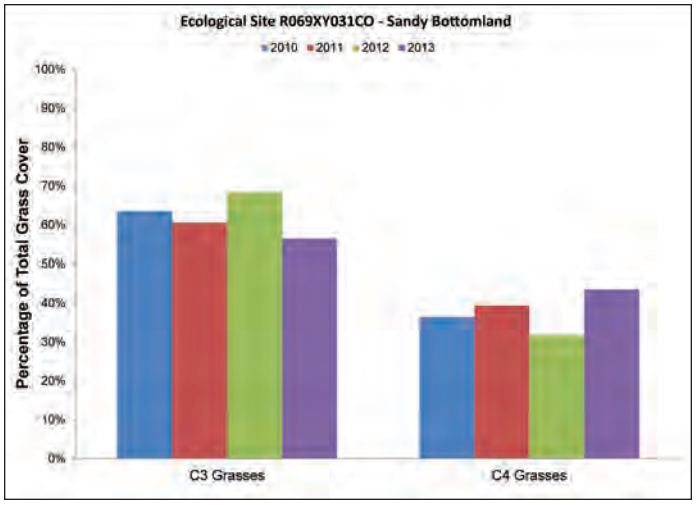




**Figure 4.9.4-6. The percentage of C3 and C4 grasses for each ecological site samples in 2010-2013 at Bent's Old Fort NHS.**

sites (e.g., site 2 in the cottonwoods) were considered in good condition, whereas others such as in the prairie dog town (e.g, site 3) were considered to be of significant concern, almost completely lacking in grasses or shrubs.

As previously mentioned, the Historic Site has been actively engaged in management options that might improve conditions (e.g., exotic plant control and prairie restoration), but in its current state, we consider this measure as being of moderate condition, reflecting the variation from good to significant concern.

*Relative Proportion of C3 and C4 Species* – Results from the SOPN monitoring data indicated a balance of C3 and C4 grasses with C3 grasses being slightly more prevalent (Figure 4.9.4-6). The rapid assessment sites were a bit more varied with some sites having a good mix of C3 and C4 grasses (e.g., site 2) while others (e.g., site 5) were dominated by C3 grasses and still others (e.g., site 4) dominated by C4 grasses.

It is often the case that shortgrass prairie sites are dominated by C4 grasses in this region. Petit (1974) found 75% of the above ground biomass in a site near Amarillo TX, to be 74% C4 grasses, and this is also consistent with what has been observed on the Short Grass Steppe LTER site in Colorado (Lauenroth and Milchunas 1992, Lauenroth et al. 2008). Some of the variation in C3 to C4 ratios may be explained by the different ecosites, and some may be explained by land use history, including restoration activities. Although the experts did not express alarming concern over these patterns, there was enough to warrant us considering this measure as good to moderate overall.

Predicted, generalized climate change impacts for this region are drier, hotter, and more severe storms (and more frequent, severe fires). Should these predictions be correct, it may alter C4 and C3 species composition.

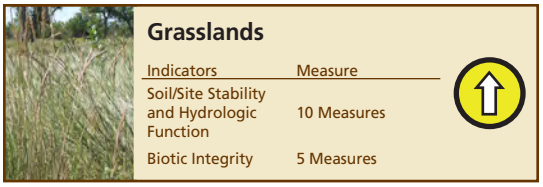
<u>The Role of Fire in Grassland Condition at Bent's Old Fort NHS</u>

Historical records of fire frequencies for prairies of the southern Great Plains before settlement are generally nonexistent or unreliable because there are no trees to

carry fire scars from which to estimate fire frequency (Ford and McPherson. 1996). Although fire is generally reported to play a prominent role in health and functioning of grasslands (e.g., Joern and Keeler 1995), this role likely varies substantially among grassland types. In particular, the role of fire as a primary determinant of grassland structure likely decreases strongly from tallgrass prairie to shortgrass steppe as a result of the gradient in productivity and fuel (Kucera 1981, Oesterheld et al. 1999, Scheintaub et al. 2009). In fact, grassland experts Drs. Alan Knapp and William Lauenroth (pers comm.) suggest that fire probably plays a much lesser role in maintaining a healthy prairie in the shortgrass steppe than other drivers such as herbivory and climate variation.

One of the perceived benefits of fire in grassland systems is the reduction of litter. In tallgrass prairie, litter removal increases soil temperature and light leading to increased productivity (Hulbert, 1988; Knapp and Seastedt, 1986). However, shortgrass steppe has minimal litter accumulation (Burke et al. 1998), and Scheintaub et al. (2009) reported a positive relationship between litter and productivity, suggesting that litter may facilitate, or at least not inhibit productivity as it does in tallgrass prairie. However, Scheintaub et al. (2009) also suggest that further research is needed on the relationship between littler and productivity in short grass steppe.

The absence of fire is also generally thought to have contributed to fuel accumulation, such that when fires do occur it is possible that they fires burn at a greater severity than they did historically, especially where shrubs have encroached. However, whether fire has a positive, neutral or negative benefit on grassland condition will depend on several factors (season, frequency, potential for exotic plant response, etc) that will need to be considered carefully by the Historic Site and fire management program. The uncertainty associated with the use of fire as a vegetation management tool might also warrant that such action be undertaken under an adaptive management framework including monitoring of the response.




Overall Condition

For assessing the condition of grasslands, we used a variety of indicators/measures that were not mutually exclusive but were intended to be different ways of capturing the essence of what we thought represented the condition of the Historic Site's grasslands. Grassland condition can be assessed from many different angles, but we chose two main categories for this resource. A summary of how they contributed to the overall grassland condition is summarized in Table 4.9.4-5. Based on the measures, data, and expert opinion, we consider the overall condition of the grasslands at Bent's Old Fort NHS to be in moderate condition with an improving trend. For nearly all indicators and measures, condition was highly variable among sites, often ranging from good to significant concern. Sites such as the prairie dog down are dominated by exotic forbs while other sites are in relatively good condition. Thus, our moderate condition rating reflects a balance between these variable results.

It should also be noted that the condition of grasslands is the result of a long history of land use and ecological conditions that began long before the establishment of the Historic Site, and that of Bent's Old Fort. Consequently, we do not consider the sites with grassland problems to be a result of NPS management; quite the contrary. Bent's Old Fort NHS natural resource staff have been actively engaged in restoring areas in more degraded condition. Thus, we believe that many areas of the Historic Site would be in substantially worse condition if it were not for the efforts of the Historic Site staff. We are also anticipating conditions to be improving as the region shifts from extreme drought conditions to more normal rainfall patterns and as Historic Site management continues to

**Table 4.9.4-5. Summary of the grassland indicators and measures and their contributions to the overall assessment of grassland condition.**

| Indicator | Measure | Condition | Condition Rationale |
|---|---|---|---|
| Soil/Site Stability and Hydrologic Function | 10 measures | Moderate | Departures from expected conditions for most measures of Soil/Site Stability and Hydrologic Function were highly variable among sites, often ranging from significant concern to good among sites. The moderate condition rating overall reflects this variability among sites. |
| Biotic Integrity | 5 measures | Moderate | Similar to the measures of soils, measures of biotic integrity were highly variable among sites, often ranging from significant concern to good among sites. The moderate condition rating overall reflects this variability among sites. The vast majority of grassland species at Bent's Old Fort NHS are native and the percent cover was dominated native species. However, some sites were completely dominated by non-native forbs. |

address exotic plants and restoration of native prairies.

Level of Confidence/Key Uncertainties

Overall, our confidence in this assessment is high, although as is generally the case, there are uncertainties. Some of the key uncertainties for the grassland assessment include annual variability, the effect of drought conditions, and the potential success of ongoing management actions.

Annual variability in rainfall, temperatures, diseases, etc. can have a dramatic effect on some measures (e.g., plant species composition), which in turn, affects our interpretation of grassland condition. However, this assessment was conducted, at least in part, during drought conditions. The stress from drought conditions has likely influenced some of our measures, but this influence would also likely imply our assessment is a bit conservative. That is, conditions may have appeared even better had they been assessed under more typical rainfall period.

### *4.9.5. Sources of Expertise*

During the course of this assessment, we consulted with the following individuals who provided subject matter expertise as well as an on-site rapid assessment.

Dr. Timothy Seastedt is a Professor at University of Colorado, Boulder, Department of Ecology and Evolutionary Biology. He also has an extensive background of research and publications related to the ecology of grasslands.

Peter Biggam is a soil scientist at the NPS Natural Resources Program Center Geoscience and Restoration Branch, who specializes in, but also has an extensive background in range science and management. Biggam visited Bent's Old Fort NHS as part of a rapid assessment team and the parts of this assessment related to Soil/Site Stability and Hydrologic Function are based on Biggam's assessment.

### *4.9.6. Literature Cited*

Biggam, P. 2013. Trip Report – Rapid Soil Assessments for Bent's Old Fort National Historic Site. NPS, Unpublished Report, in prep.

Burke, I.C., Lauenroth, W.K., Vinton, M.A., Hook, P.B., Kelly, R.H., Epstein, H.E., Aguiar, M.R., Robles, M.D., Aguilera, M.O., Murphy, K.L., Gill, R.A., 1998. Plant–soil interactions in temperate grasslands. Biogeochemistry 42, 121–143.

D'Antonio, C.M. and B. E. Mahall. 1991. Root profiles and competition between the invasive, Exotic perennial, Carpobrotus edulis, and two native shrub species in California coastal scrub. American Journal of Botany 78(7): 885-894. 1991.

Ehrenfeld, J.G. 2003. Effects of exotic plant invasions on soil nutrient cycling processes. Ecosystems (2003) 6: 503-523

Folts-Zettner, T. , R. Gatewood, and H. Sosinski. 2012. Grassland and fire effects monitoring in the Southern Plains Network: Southern Plains Network and Southern Plains Fire Group Collaboration Project Report 2010 and 2011. Natural Resource Technical Report NPS/SOPN/NRTR—2012/537. National Park Service, Fort Collins, Colorado.

Folts-Zettner, T., R. Gatewood, R. Bennetts and K. Cherwin. 2013a. Grassland monitoring protocol and standard operating procedures for the Southern Plains I&M Network and Fire Group. Natural Resource Technical Report NPS/SOPN/NRTR— 2012/00X. National Park Service, Fort Collins, Colorado. (in press)

Folts-Zettner, T. , H. Sosinski, and R. Gatewood. 2013b. Grassland and fire effects monitoring in the Southern Plains Network: Southern Plains Network and Southern Plains Fire Group Collaboration Project Report 2012. Natural Resource Technical Report NPS/SOPN/NRTR—2013/721. National Park Service, Fort Collins, Colorado.

Ford, P.L. and G.R. McPherson. 1996. Ecology of fire in shortgrass prairie of the southern Great Plains. Pp. 2-39 in D.M. Finch, ed., Ecosystem disturbance and wildlife conservation in western grasslands: a symposium proceedings. USDA Forest Service, Rocky Mountain Experiment Station, General Technical Report RM-GTR-285. Fort Collins, CO.

Hulbert, L.C., 1988. Causes of fire effects in tallgrass prairie. Ecology 69, 46–58.

Joern, A. and K. Keeler. 1995. The Changing Prairie in North American Grasslands. Oxford University Press. New York. 241 pp.

King, W. B. 1985. Island birds: Will the future repeat the past? Pages 3–15 in P. J. Moors, ed., Conservation of Island Birds. International Council for Bird Preservation. Cambridge: Cambridge University Press

Knapp, A.K., and Seastedt, T.R., 1986. Detritus accumulation limits productivity of tallgrass prairie. Bioscience 36, 662–668.

Kucera, C.L., 1981. Grasslands and fire. Gen. Tech. Rep. WO-26. In: Mooney, H.A., Bonnicksen, T.M., Christensen, N.L., Lotan, J.E., Reiners, W.A. (Eds.), Proceedings of the Conference: Fire Regimes and Ecosystem Properties. U.S. Department of Agriculture, Forest Service, Washington, DC, pp. 90–111.

Lauenroth, W. K., and D. G. Milchunas. 1992. Shortgrass steppe, pp. 183-226. In: R. T. Coupland (ed.), Natural grasslands: Introduction and western hemisphere. Elsevier Scientific, Amsterdam.

Lauenroth, W.K., I.C. Burke, and J.A. Morgan. 2008. The shortgrass steppe, the region and research sites. Pages 3-13 in W.K. Lauenroth and I.C. Burke, eds. Ecology of the shortgrass steppe, a long-term perspective. Oxford University Press.

Natural Resources Conservation Service U.S. Department of Agriculture. 2007. Ecological site description system. Retrieved July 27, 2014 from, https://esis.sc.egov.usda.gov/.

Natural Resources Conservation Service, United States Department of Agriculture. 2012. Soil Survey Geographic (SSURGO) Database for Kiowa County, TX. Available online at http://soildatamart.nrcs.usda.gov . Accessed 04/24/2012.

Oesterheld, M., Loreti, J., Semmartin, M., Paruelo, J.M., 1999. Grazing, fire and climate effects on primary productivity of grasslands and savannas. In: Walker, L.R. (Ed.), Ecosystems of Disturbed Ground. Elsevier, New York, pp. 287–306.

Pellant, M., P. Shaver, D.A. Pyke, and J.E. Herrick. 2005. Interpreting indicators of rangeland health, version 4. Technical Reference 1734- 6. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO. BLM/ WO/ST-00/001+1734/REV05. 122 pp.

Scheintaub, M. R., J. D. Derner, E. F. Kelly, and A. K. Knapp. 2009. Response of the shortgrass steppe plant community to fire. Journal of Arid Environments 73:1136–1143.

Sherow, J. E. 1989. Utopia, reality, and irrigation: The plight of the Fort Lyon Canal Company in the Arkansas River Valley. The Western Historical Quarterly 20:162-184.Society for Range Management [SRM]. 1999. A glossary of terms used in range management. Society for Range Management. Denver, Colorado. 20p.

Smeins, F. E. 1980. The natural role of fire on the Edwards Plateau. Pages 4-16, Junction, Texas.

Soil Science Society of America. 1997. Glossary of soil science terms. Soil Science Society of America. Madison, Wisconsin. 138p.

Stevens, J.E., K. Forrest, S. Neid, and M. Fink. 2007. Bent's Old Fort National Historic Site: Vegetation Classification and Mapping. Natural Resource Technical Report NPS/SOPN/NRTR—2007/049. National Park Service, Fort Collins, Colorado.

Tilman, D., J. Knops, D. Wedin, P. Reich, M. Ritchie, and E. Sieman. 1997. The influence of functional diversity and composition on ecosystem processes. Science 277: 1300-1302.

Tilman, D. 1999. The ecological consequences of changes in biodiversity: a search for general principles. The Robert H. MacArthur Award Lecture. Ecology 80:1455-1474.

Vitousek, P.M. 1990. Biological invasions and ecosystem processes: towards an integration of population biology and ecosystem studies. Oikos 57: 7-13.

Wand, S.J.E., Midgley, G.F., Jones, M.H. and Curtis, P.S. 1999. Responses of wild C4 and C3 grass (Poaceae) species to elevated atmospheric CO2 concentration: a meta-analytic test of current theories and perceptions. Global Change Biology5: 723-741.

## 4.10. Exotic Plants

**Indicators/Measures**

- Prevalence of Exotic Plant (2 measures)
- Potential to Alter Native Plant Communities (2 measures)

**Condition – Trend - Confidence**



Moderate – Improving - High

### *4.10.1. Background and Importance*

Globalization of commerce, transportation, human migration, and recreation in recent history has introduced invasive exotic species to new areas at an unprecedented rate. Biogeographical barriers that once restricted the location and expansion of species have been circumvented, culminating in the homogenization of Earth's biota. Although only 10% of introduced species become established and only 1% become problematic (Williamson 1993; Williamson and Fitter 1996) or invasive, nonnative species have profound impacts worldwide on the environment, economies, and human health.

Invasive species have been directly linked to the replacement of dominant native species (Tilman 1999), the loss of rare species (King 1985), changes in ecosystem structure, alteration of nutrient cycles and soil chemistry (Ehrenfeld 2003), shifts in community productivity (Vitousek 1990), reduced agricultural productivity, and changes in water availability (D'Antonio and Mahall 1991) (Figure 4.10.1-1). The damage caused by these species to natural resources is often irreparable, and our understanding of the consequences incomplete. Invasive species are second only to habitat destruction as a threat to wildland biodiversity (Wilcove et al. 1998). Consequently, the dynamic relationships among plants, animals, soil, and water established over many thousands of years are at risk of being destroyed in a relatively brief period. For the NPS, the consequences of these invasions present a significant challenge to the management of the agency's natural resources "unimpaired for the enjoyment of future generations." National parks, like land managed by other organizations, are deluged by new exotic species arriving through predictable (e.g., road, trail, and riparian corridors), sudden (e.g., long-distance dispersal through cargo containers and air freight), and unexpected anthropogenic pathways (e.g., weed seeds in restoration planting mixes). Nonnative



NPS

**Figure 4.10.1-1. Cheatgrass (*Bromus tectorum*) can form dense, nearly single-species communities in grasslands.**

plants claim an estimated 4,600 acres of public land each year in the United States (Asher and Harmon 1995), significantly altering local flora. For example, exotic plants comprise an estimated 43% and 36% of the flora of the states of Hawaii and New York, respectively (Rejmanek and Randall 1994). Invasive plants infest an estimated 2.6 million acres of the 83 million acres managed by the NPS. Prevention and early detection are the principal strategies for successful invasive exotic plant management. While there is a need for long-term suppression programs to address high-impact species, eradication efforts are most successful for infestations of less than one hectare in size (Rejmanek and Pitcairn 2002).

### *4.10.2. Data and Methods*

In considering current condition and trend for exotic plants at Bent's Old Fort NHS, two indicators, with two measures each, were used to assess the overall impact an exotic has on the native plant communities throughout Bent's Old Fort NHS.

**Indicators/Measures**

Prevalence of Exotic Plant (2 measures)

As part of the Southern Plains Inventory and Monitoring Network (SOPN) exotic plants monitoring program, high priority vectors/blocks (e.g., roads and trails) were identified based on their potential risk for invasion by exotic plants. Sampling within these high priority blocks was conducted from June to July each year. The methodology used in this monitoring is described in detail in Folts-Zettner et al. (2011). The approach is based on a generalized linear model, where 50-meter blocks on both sides of the vector (right [R] and left [L]) are surveyed from a transect running along (e.g., trails) or adjacent to (e.g., along the mow strip of roads) the vector (Figure 4.10.2-1).

This effort is part of a sampling scheme that uses a three-year rotating panel design, whereby a new area is surveyed each year (a panel) for three years, after which the areas surveyed are repeated. It is important to emphasize that this sampling approach does not provide a complete survey of exotic plants throughout the Historic Site. Instead, it provides a repeated snapshot for a limited area with high potential (e.g., roads and trails) for new invasions. The full protocol also includes estimation of four density classes assigned to each block ranging from scattered plants to a dense matrix, as well as four distance classes used to determine the extent to which exotic plants are limited to the zone immediately adjacent to the vector.

The data used to assess the measures of proportion of high priority blocks infested and plant density were collected in 2011-2013 from plots shown in Figure 4.10.2-2

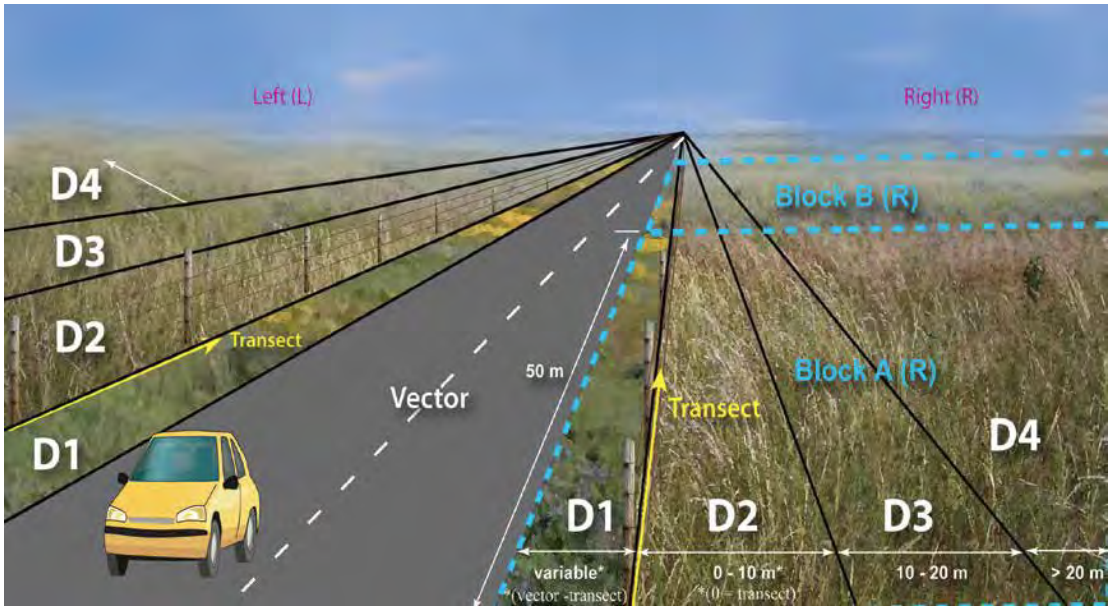



**Figure 4.10.2-1. Fifty meter blocks are sampled on each side of a high-risk vector (e.g., roads and trails).**

**Table 4.10.2-1. Number and percentage of exotic plant species detected in SOPN high priority monitoring blocks sampled in 2011 - 2013 at Bent's Old Fort NHS.**

| Species | No. Blocks | % (N=311) |
|---|---|---|
| *Kochia scoparia* | 247 | 79.42% |
| *Convolvulus arvensis* | 173 | 55.63% |
| *Salsola tragus* | 153 | 49.20% |
| *Bromus tectorum* | 61 | 19.61% |
| *Asparagus officinalis* | 55 | 17.68% |
| *Typha angustifolia* | 37 | 11.90% |
| *Lactuca serriola* | 29 | 9.32% |
| *Cirsium arvense* | 28 | 9.00% |
| *Tribulus terrestris* | 22 | 7.07% |
| *Bromus inermis* | 14 | 4.50% |
| *Tragopogon dubius* | 11 | 3.54% |
| *Rumex crispus* | 11 | 3.54% |
| *Tamarix ramosissima* | 11 | 3.54% |
| *Melilotus officinalis* | 9 | 2.89% |
| *Thinopyrum ponticum* | 9 | 2.89% |
| *Thinopyrum intermedium* | 9 | 2.89% |
| *Chenopodium album* | 8 | 2.57% |
| *Acroptilon repens* | 8 | 2.57% |
| *Cardaria draba* | 8 | 2.57% |
| *Sorghum halepense* | 7 | 2.25% |
| *Bromus commutatus* | 4 | 1.29% |
| *Eragrostis cilianensis* | 4 | 1.29% |
| *Elaeagnus angustifolia* | 3 | 0.96% |
| *Lactuca tatarica* | 3 | 0.96% |
| *Rumex obtusifolius* | 3 | 0.96% |
| *Taraxacum ramosissima* | 3 | 0.96% |
| *Ulmus pumila* | 3 | 0.96% |
| *Populus alba* | 2 | 0.64% |
| *Conium maculatum* | 1 | 0.32% |
| *Cynodon dactylon* | 1 | 0.32% |
| *Medicago sativa* | 1 | 0.32% |
| *Verbascum thapsus* | 1 | 0.32% |

Species highlighted are considered to be of highest, high, or moderate concern as shown in Table 4.10.4-1.

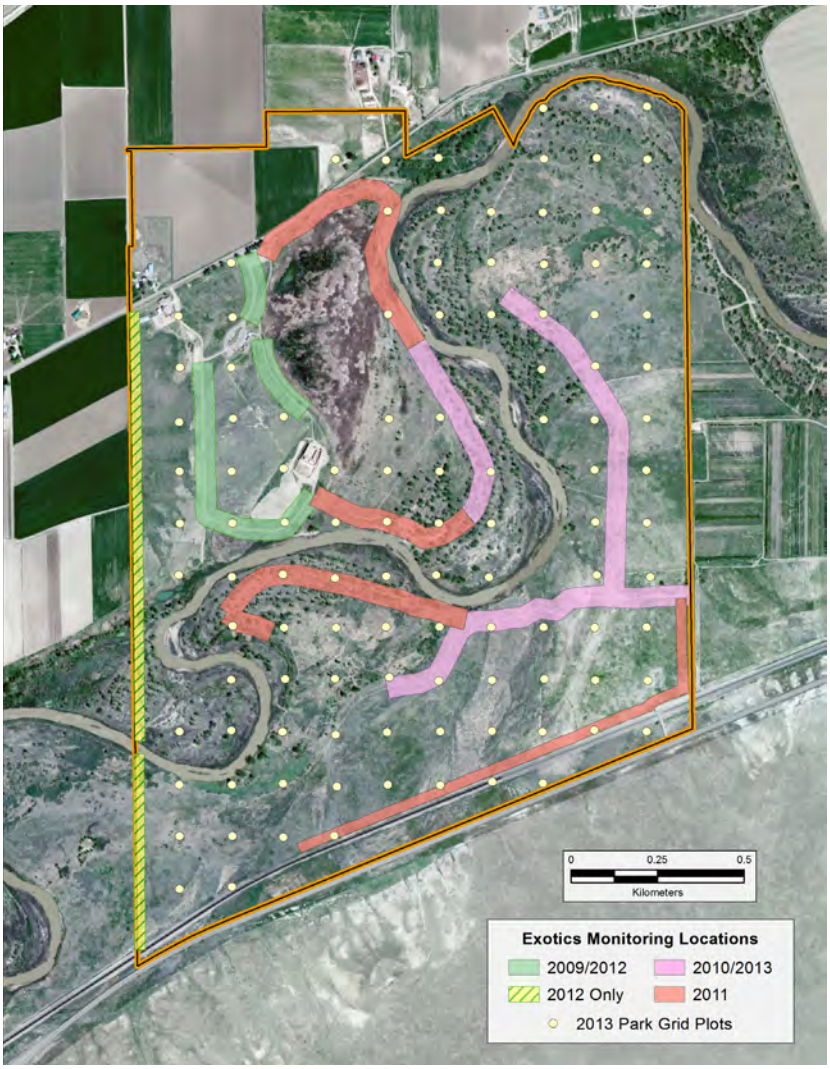



**Figure 4.10.2-2. Annual high priority blocks sampled in 2010 -2013 and one time rapid assessment Historic Site grid plots sampled in 2013 only.**

(Folts-Zettner and Sosinski 2012a,b; 2013). The proportion of blocks infested for each exotic species found is shown in Table 4.10.2-1 and the density for each exotic plant located within the first distance class (D1) only is shown in Figures 4.10.2-3, -4, -5, -6, -7, -8 and -9 and in Appendix F. Within the first distance class each observed exotic species was assigned to one of five density classes (including absent in a given distance class, which is not shown on the maps), which represents a range of occurrence from a small number of individual plants to a continuous matrix within the block for that species. These density classes are as follows:

- 0 = Not observed within that distance class
- 1 = 1-5 plants present within the distance class
- 2 = Scattered in patches within the distance class
- 3 = Scattered fairly evenly throughout a specific distance class
- 4 = Forming a matrix in the distance class (Folts-Zettner et al. 2011).

In addition to the annual SOPN exotic plants monitoring, a rapid assessment was

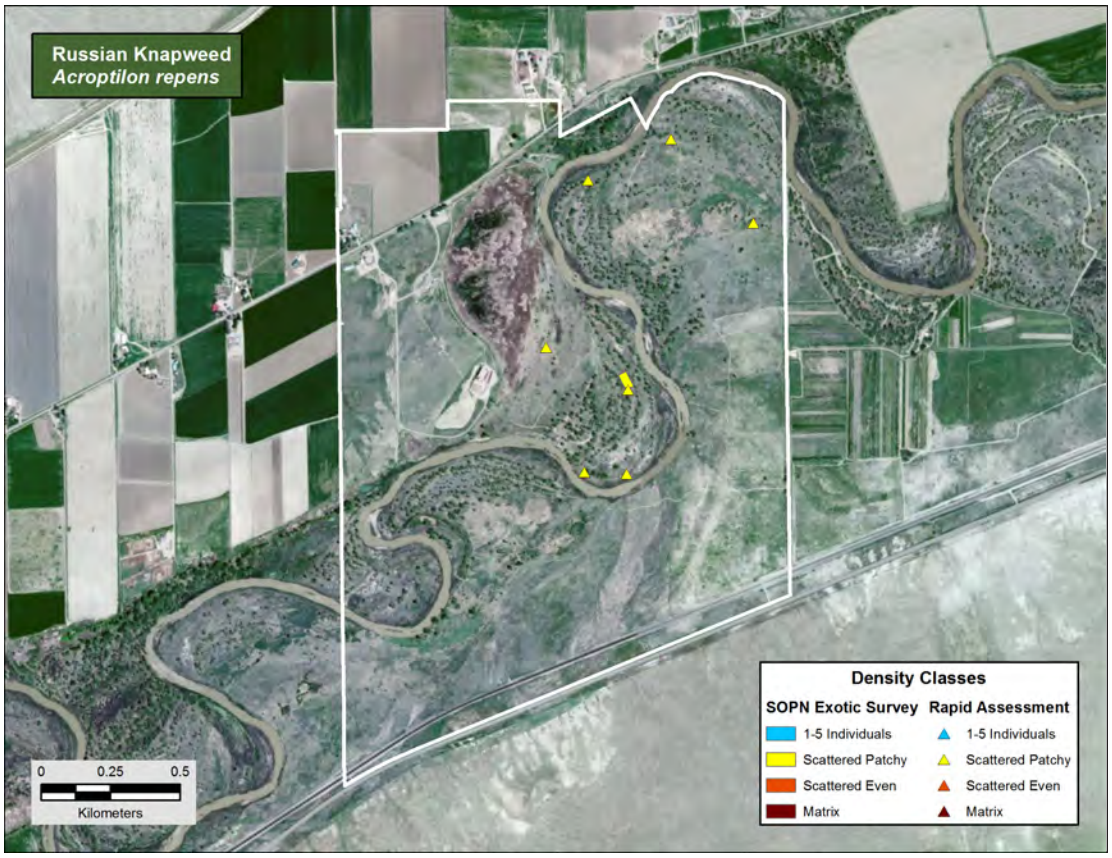



**Figure 4.10.2-3.** ***Acroptilon repens*** **plant density based on surveys conducted by SOPN monitoring efforts and 2013 rapid assessment.**

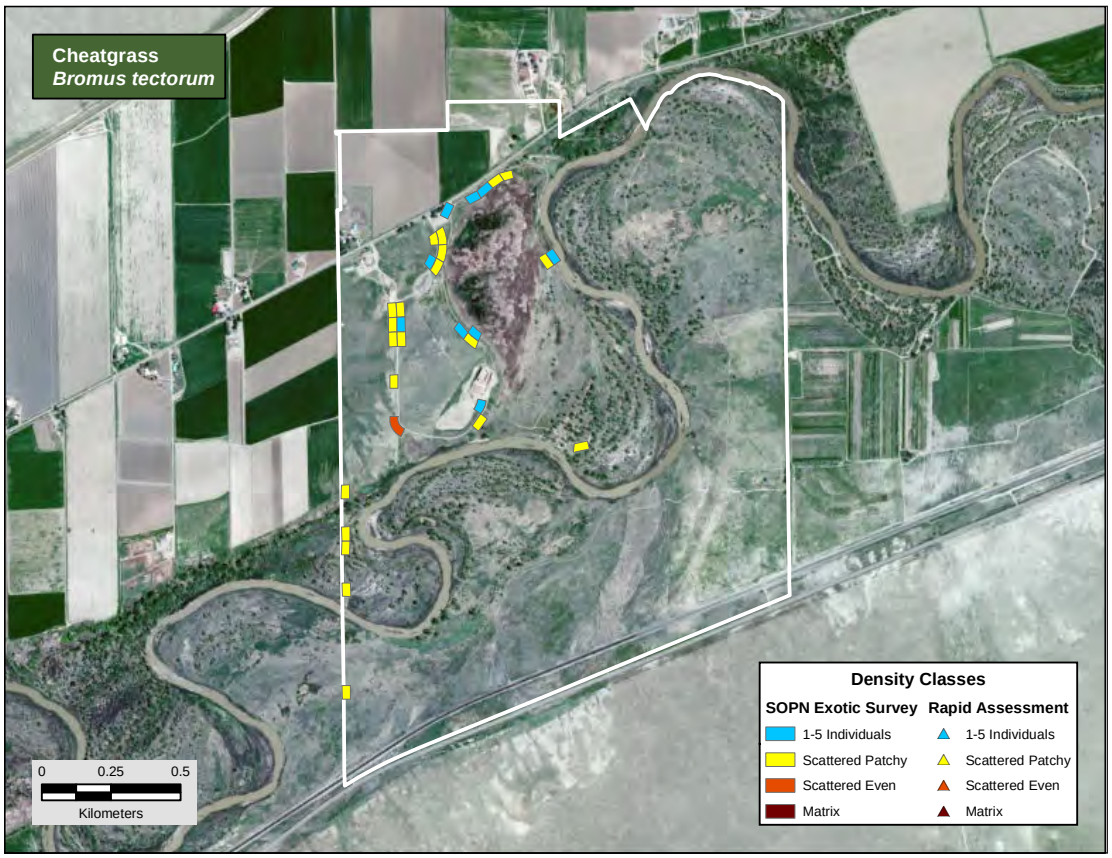



**Figure 4.10.2-4.** ***Bromus tectorum*** **plant density based on surveys conducted by SOPN monitoring efforts and 2013 rapid assessment.**

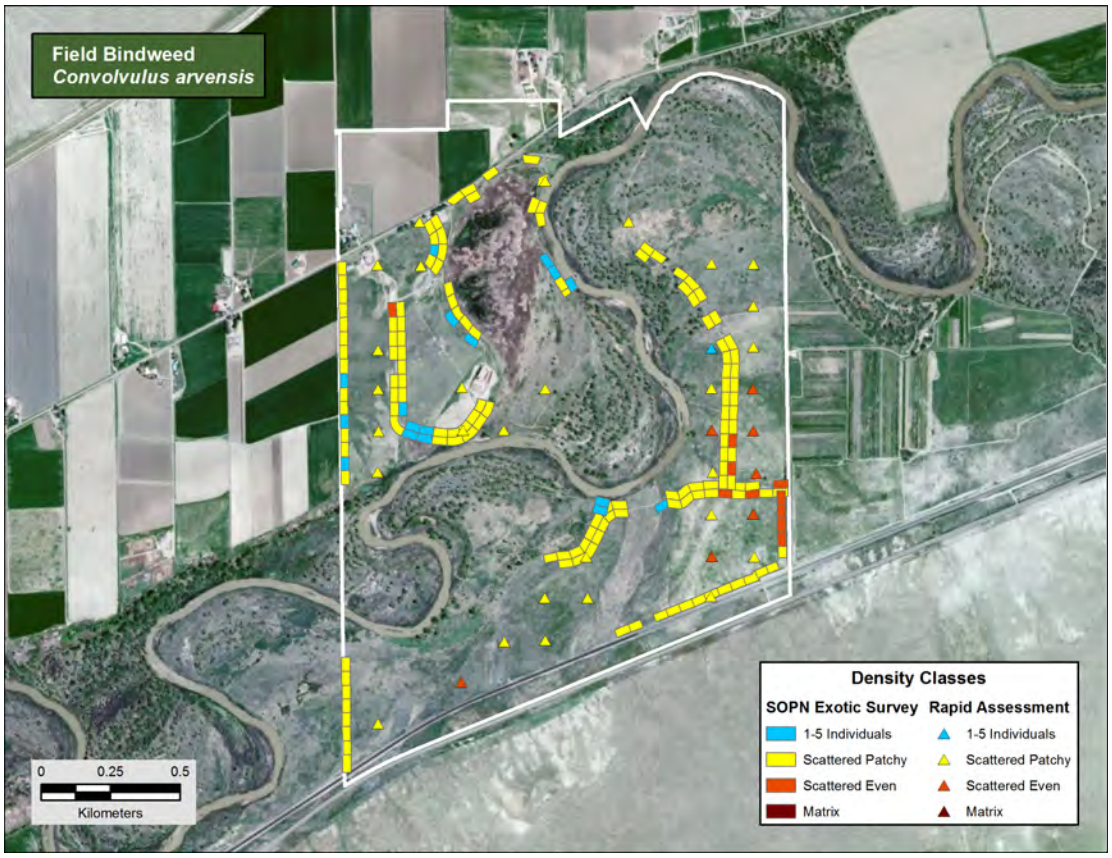



**Figure 4.10.2-5. *Convolvulus arvensis* plant density based on surveys conducted by SOPN monitoring efforts and 2013 rapid assessment.**

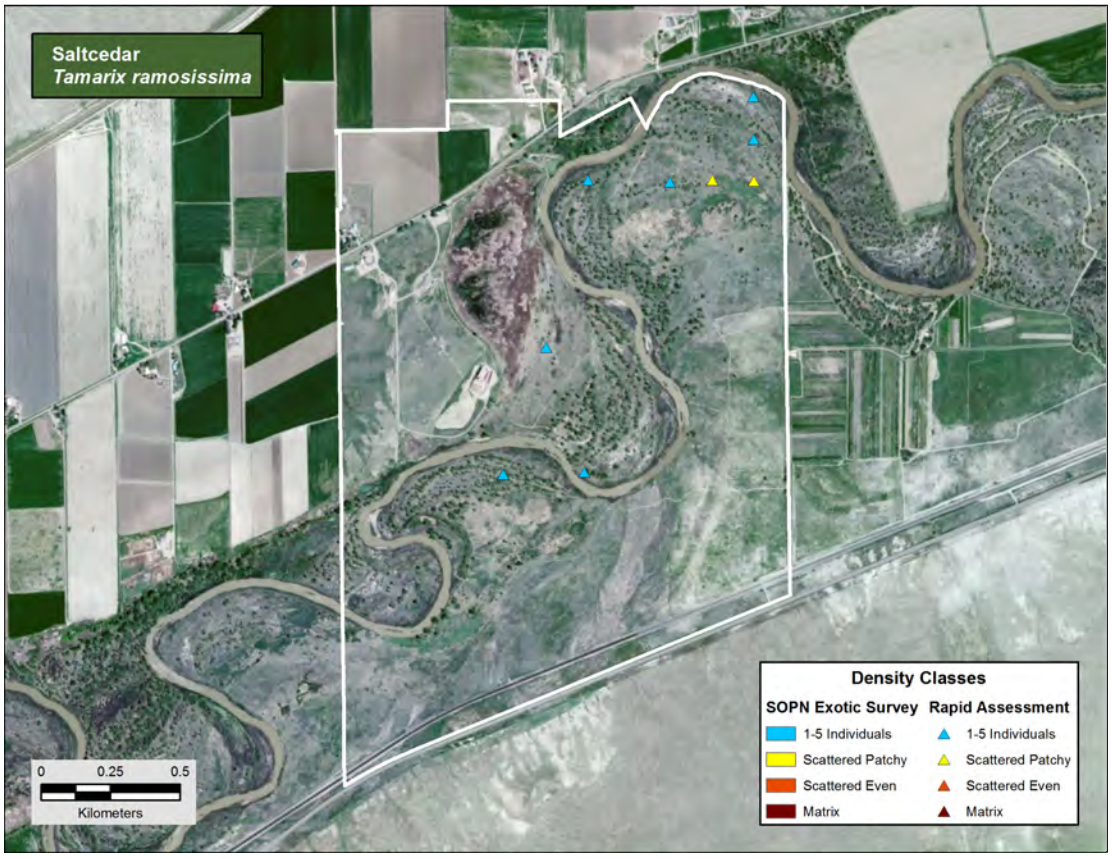



**Figure 4.10.2-6. *Tamarix ramosissima* plant density based on surveys conducted by SOPN monitoring efforts and 2013 rapid assessment.**

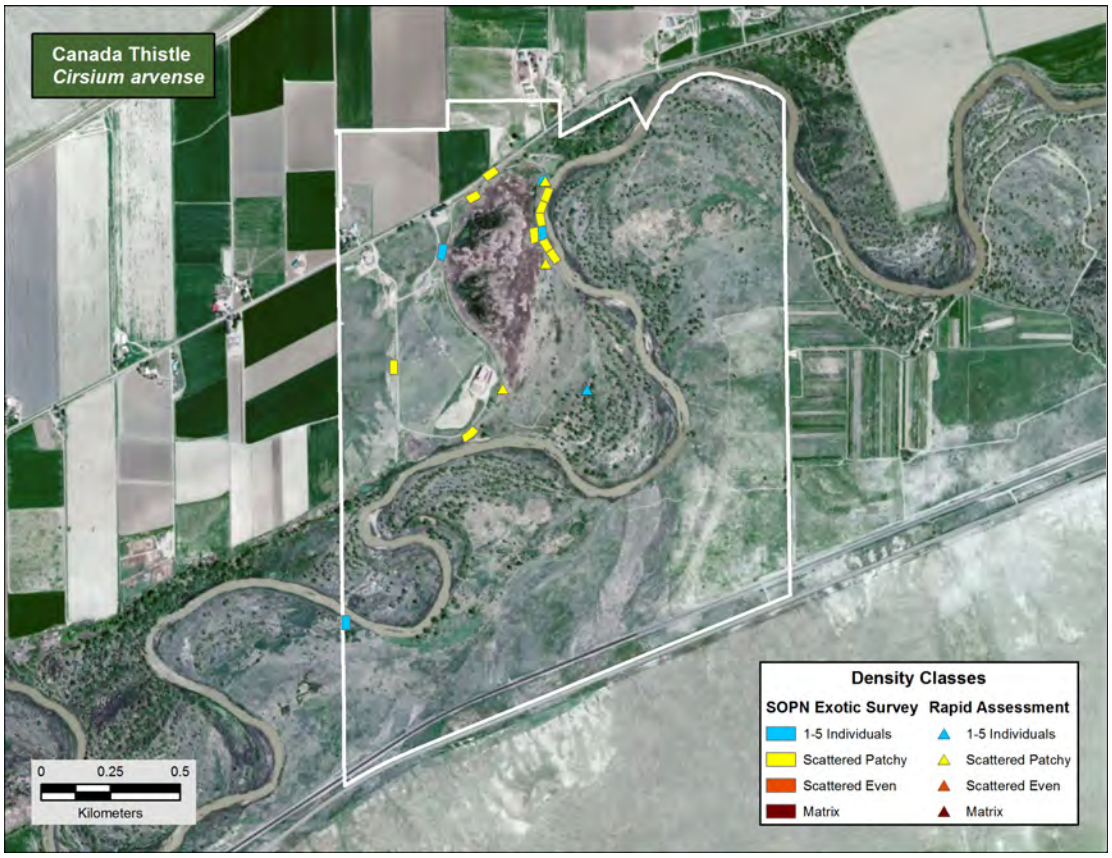



**Figure 4.10.2-7. *Cirsium arvense* plant density based on surveys conducted by SOPN monitoring efforts and 2013 rapid assessment.**

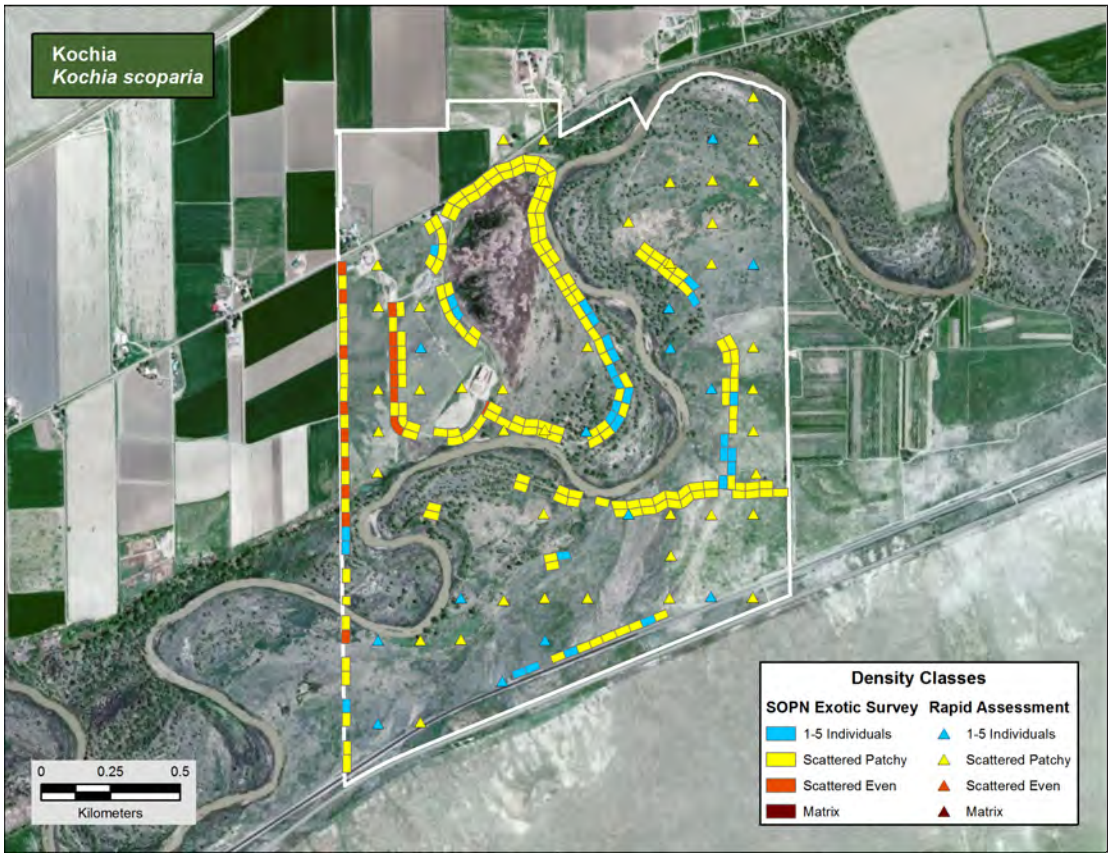



**Figure 4.10.2-8. *Kochia scoparia* plant density based on surveys conducted by SOPN monitoring efforts and 2013 rapid assessment.**

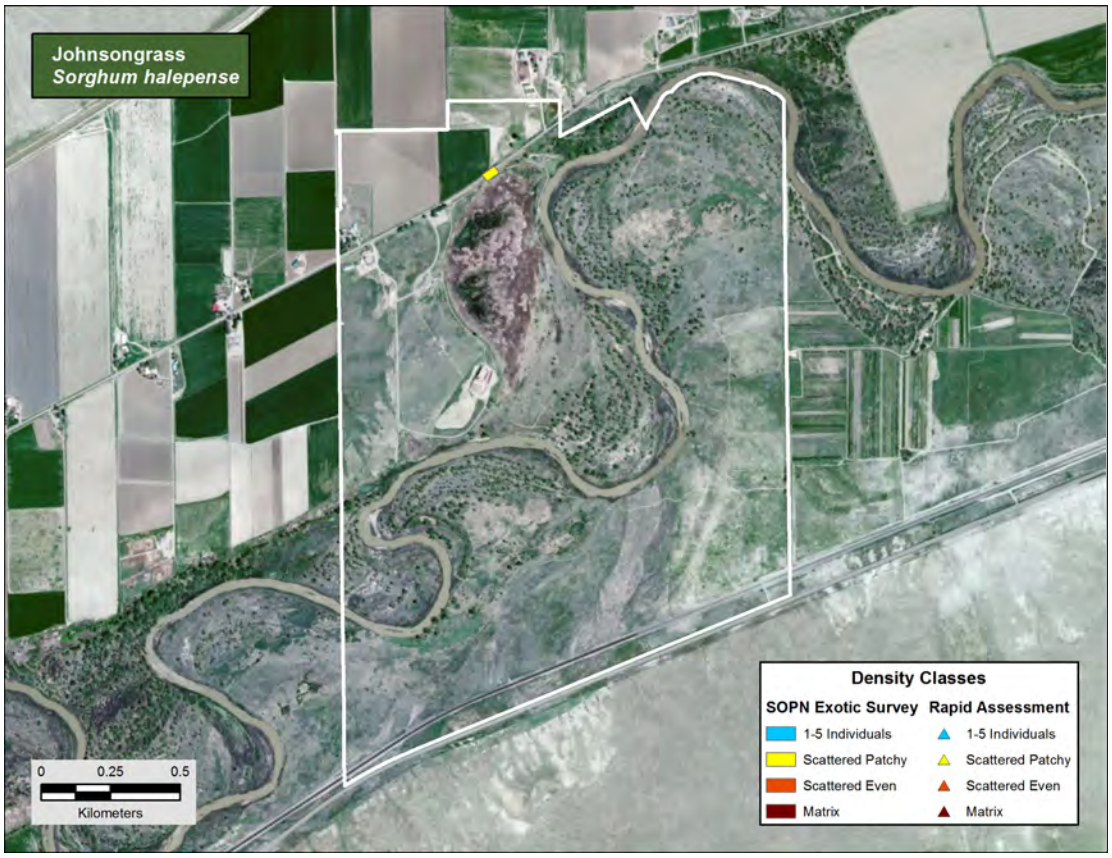



**Figure 4.10.2-9. *Sorghum halepense* plant density based on surveys conducted by SOPN monitoring efforts and 2013 rapid assessment.**

**Table 4.10.2-2. Number and percentage of exotic plant species detected throughout the Historic Site grid plots sampled in 2013.**

| Species | No. Blocks | % (N=111) |
|---|---|---|
| *Kochia scoparia* | 55 | 49.55 |
| *Salsola tragus* | 54 | 48.65 |
| *Convolvulus arvensis* | 36 | 32.43 |
| No plants detected | 16 | 14.41 |
| *Asparagus officinalis* | 10 | 9.01 |
| *Tamarix ramosissima* | 9 | 8.11 |
| *Acroptilon repens* | 7 | 6.31 |
| *Cirsium arvense* | 4 | 3.60 |
| *Chenopodium album* | 3 | 2.70 |
| *Rumex crispus* | 3 | 2.70 |
| *Bromus commutatus* | 2 | 1.80 |
| *Cardaria draba* | 2 | 1.80 |
| *Typha angustifolia* | 2 | 1.80 |
| *Lactuca serriola* | 1 | 0.90 |
| *Melilotus officinalis* | 1 | 0.90 |
| *Thinopyrum intermedium* | 1 | 0.90 |
| *Tragopogon dubius* | 1 | 0.90 |
| *Ulmus pumila* | 1 | 0.90 |

Species highlighted are considered to be of highest, high, or moderate concern as shown in Table 4.10.4-1.

conducted in 2013 as a one time occurrence for this condition assessment to determine the proportion and density of exotics measuredthroughout the entire Historic Site (Figure 4.10.2-2). Presence and density data for these supplemental points were recorded in the same way as in the standard monitoring blocks described above, except that these points will not be included in SOPN's permanent rotating panels. The results for proportion of plots occupied by a given exotic plant is shown in Table 4.10.2-2.

## Indicators/Measures

### Potential to Alter Native Plant Communities (2 measures)

The remaining measures, ecological impact and management difficulty, were derived using NatureServe's invasive species rankings, developed by Morse et al. (2004). The Nature Conservancy and National Park Service developed this ranking system to objectively and systematically evaluate the invasiveness of a plant species based upon four categories: two of which include ecological impact and management difficulty.

Each category is reported as either high, medium, low, insignificant, unknown or a combination of two categories (e.g., low/insignificant) and data can be accessed from http://www.natureserve.org/explorer/servlet/NatureServe?init=Species. These rankings for each exotic plant are shown in Table 4.10.2-3.

The ecological impact rank is based on the premise that exotic species with the largest negative impacts on native plant, animal, and other species populations, ecological communities, and ecosystems generally cause the most severe problems, particularly if they change ecosystem processes or harm native species, keystone species, or communities of conservation significance (Morse et al. 2004). NatureServe's management difficulty is based on the premise that a species that is difficult to manage (control or prevent from spreading) will have a greater chance of causing significant damage because it is more likely to persist and spread (Morse et al. 2004).

Both of these NatureServe rankings were considered when evaluating the overall significance of impact when combining all exotic plant measures. The results of the exotic species considered to be of highest, high, and moderate significance of impact will be discussed in the condition and trend section.

**Table 4.10.2-3. Ecological impact rank and management difficulty rank according to NatureServe (2013).**

| Species | NatureServe Rank (2013) | |
|---|---|---|
| | Ecological Impact | Management Difficulty |
| Highest Concern | | |
| *Acroptilon repens* | Medium/Low | High/Medium |
| *Bromus tectorum* | High | High/Medium |
| *Convolvulus arvensis* | Low/ Insignificant | High/Medium |
| *Tamarix ramosissima* | High | High |
| High Concern | | |
| *Cirsium arvense* | Medium/Low | High/Medium |
| *Kochia scoparia* | Low/ Insignificant | High/Medium |
| *Lepidium latifolium* | High | High/Medium |
| *Conium maculatum* | Low | Low/ Insignificant |
| *Sorghum halepense* | Medium/Low | High/Medium |
| Moderate Concern | | |
| *Lactuca serriola* | Insignificant | Unknown |
| *Melilotus officinalis* | NYA | NYA |
| *Salsola tragus* | NYA | NYA |
| *Thinopyrum intermedium and ponticum* | Low | Moderate |
| *Tragopogon dubius* | Low | Medium |
| *Tribulus terrestris* | NYA | NYA |

Species are grouped by concern level as shown in Table 4.10.4-1.

NYA = Not Yet Assessed

### *4.10.3. Reference Conditions*

The most desirable reference condition is the complete absence of exotic species. However, such a reference condition is probably not a realistic standard to which exotic plant species should be compared. We consider a more realistic reference condition to be the capability for the integrity of the primary communities (e.g., woodlands, shrublands, and grasslands) to be maintained. By this, we mean that the ecological attributes (e.g., species composition, structure, etc.) and natural processes remain within the natural variation for the community type. Therefore, the reference condition of "good" is that species are known to occur regionally or on adjacent lands, but have not yet been confirmed within Historic Site, or if species have been confirmed, distribution is sparse, limited in extent, and may vary from sparse individuals to dense patches. A "moderate" condition is when species have been found in the Historic Site in small, localized patches. Finding and controlling patches might prevent large-scale invasion, and distribution is somewhat limited in extent and may vary in intensity from sparse individuals to dense patches. A condition of significant concern is warranted when exotic plants threaten to alter these primary communities to the point where they no longer maintain these attributes or processes. For example, when exotic species dominate a community where key native species are expected for that community type, then the area would be considered as severely degraded. However,

significant concern is also warranted when the trend for a community is clearly toward such an degraded outcome rather than it actually having been realized.

### *4.10.4. Condition and Trend*

There are currently a total of 32 exotic species found within Bent's Old Fort NHS (Folts-Zettner and Sosinski 2012a,b; 2013). Fifteen of these species are considered to be the highest, high or of moderate concern based upon the significance of impact and are shown in Table 4.10.4-1. The remaining plants that do not fall into the previous three categories, but are still of concern, are located in Appendix G, along with species that have been previously but no longer present in the Historic Site.

Significance of Impact-Highest Concern

Based on combining the four measures-proportion of blocks/plots infested, plant densities, the ecological impact and the management difficulty, Russian knapweed (*Acroptilon repens*), Cheatgrass (*Bromus tectorum*), field bindweed (*Convulvulus arvensis*), and Saltcedar (*Tamarix chinensis/ ramosissima*) are considered to be of highest concern for significance of impact.

Exotic bromes are well known to dramatically change the character of an ecosystem, including such changes as major shifts in community composition and structure (Knapp 1996) as well as substantially altered fire regimes (Whisenant 1990). In many cases these changes have become, for all practical purposes, irreversible (Knapp 1996). From a standpoint of significance of impact to the Historic Site's native grassland community, we consider cheatgrass one of the highest exotic plant concerns.

Both field bindweed and Russian knapweed are not as ecologically impactful as cheatgrass, but they are very difficult to control once established. Currently, field bindweed is located in over 55% of the high priority blocks as well as over 32% of the parkwide plots, appearing to spread into native plant communities from corridors. Field bindweed thrives under drought conditions, which the Historic Site has been experiencing for over the last three years making it that much more significant in potential impact.

The bindweed is most often one of the only green plants observed amidst the brown dead plants (Tomye Folts-Zettner, personal communication, December 2012).

Significance of Impact-High Concern

Canada thistle (*Cirsium arvense*), Kochia (*Kochia scoparia*), Broadleaf pepperweed (*Lepidium latifolium)*, and Johnsongrass (*Sorghum halepense*) have a high potential for significance of impact at the Historic Site.

*Cirsium arvense* was found in 9% of the primary vector blocks but in only 4% of the parkwide plots. This perennial is considered a noxious weed in all surrounding states, spreading primarily vegetatively and secondarily by seed and resulting in displaced natives and a decrease in biodiversity. Its aggressive rhizomes require multi-year treatments to eradicate and it is a particular threat to both prairie and riparian ecosystems (Folts-Zettner and Sosinski 2012a).

Kochia grows in disturbed areas and is an indicator of changed soil chemistry, especially where organic matter has been added (i.e., barnyards, wood piles, old homestead sites). Kochia self perpetuates and continues to add organic matter into soil. It also sprouts early depending on the amount of rainfall and quickly grows and is persistent, easily out-competing for resources. It is the most widespread exotic growing throughout the Historic Site, with over 79% of the high priority blocks and over 49% of the parkwide plots containing Kochia. Several locations containing scattered to even patches are located along the western boundary providing a wind-driven seed source for future spread.

Both broadleaf pepperweed and Johnsongrass are currently abundant in the Historic Site and are considered to be of high concern.

Significance of Impact-Moderate Concern

Seven additional species that ranked relatively high in their significance of impact are considered to be of moderate concern for invading the Historic Site's native plant

**Table 4.10.4-1. Exotic species found within Bent's Old Fort National Historic Site that are considered to have the most impact to native habitats throughout the Historic Site based upon combined measures.**

| Scientific Name | Common Name | Noxious[1] | Rationale for Rating[2] |
|---|---|---|---|
| | | Highest Concern | |
| *Acroptilon repens* | Russian knapweed | N | This plant was found in over 6% of the parkwide plots, and while of medium to low ecological impact, the ability to control this exotic is highly difficult, especially once established. Currently, all known locations are considered to be scattered patchy. |
| *Bromus tectorum* (and *var tectorum*) | Cheatgrass | N | Cheatgrass is one of the highest ranked for both ecological impact and management difficulty. It is also found in almost 20% of the high priority vector plots, indicating that its current distribution is still limited to well travelled corridors. While relatively patchy, one location contains higher densities. |
| *Convolvulus arvensis* | Field bindweed | N | This plant is found in over 55% of the high vector plots and in over 32% of the parkwide plots. This is a difficult plant to manage once established, and even though not ranked as a high ecological risk, it has been observed quickly dominating an area throughout Southern Plains parks (Tomye Folts-Zettner, SOPN Biologist, pers. comm.). Several patches are considered to be scattered even, especially in the southeast area of the Historic Site. |
| *Tamarix chinensis/ ramosissima* | Saltcedar | N | While Historic Site staff efforts have effectively controlled this exotic, it is one of the most difficult plants to control and has a high ecological impact to riparian systems. It was found in over 8% of the parkwide plots and in over 3% of the high priority plots but in low densities. |
| | | High Concern | |
| *Cirsium arvense* | Canada thistle | N | Found in 9% of the high priority vectors and over 3% parkwide, this plant is considered to be difficult to manage once established but of medium ecological impact. The majority of densities are scattered patchy. |
| *Kochia scoparia* (aka *Bassia scoparia*) | Kochia | | Kochia can form monocultures that resist the establishment of preferred natives (Tomye Folts-Zettner, SOPN Biologist, pers. comm.). It is also found in the highest number of high priority and parkwide plots, indicating a wide distribution, although the densest patches are along the corridors, originating from the western boundary. Once established, it is difficult to control. |
| *Lepidium latifolium* | Broadleaf pepperweed | N | This is considered to be of high ecological impact and management difficulty, and is found scattered in the riparian area, particularly on the south side of the river. |
| *Sorghum halepense* | Johnsongrass | N | This was found in the high vector plots only and is very difficult to manage, with a moderate ecological impact. Currently, the one known location is scattered patchy. |
| | | Moderate Concern | |
| *Conium maculatum* | Poison Hemlock | N | While considered low in all measures, this plant has been observed to invade and dominate an understory (Tomye Folts-Zettner, SOPN Biologist, pers. comm.). |
| *Lactuca serriola* | Prickly lettuce | | Found in over 9% of the high vector plots, this plant is considered to be ecologically impactful and management difficulty is unknown but presence has been increasing throughout the monitoring period (Tomye Folts-Zettner, SOPN Biologist, pers. comm.). |
| *Melilotus officinalis* | Yellow Sweetclover | | During the summer of 2013, yellow sweetclover was observed in dense stands thoughout areas surrounding the park. It is persistent once established, is competative for resources, is a nitrogen fixer (which is not optimal for short-grass areas) and makes lot of seed. |
| *Salsola tragus* | Prickly Russian Thistle | | This plant is found in almost 50% of both the parkwide and high vector plants, indicating a widespread presence. A couple of plots have scattered even densities. Reintroduction of this plant will be a constant maintenance issue but is known to be manageable. |
| *Thinopyrum intermedium* | Intermediate Wheatgrass | | This is a large bunchgrass that is increasing on the south side of the river. While only found in a low percentage of the parkwide plots and in low densities. This is a large perennial bunchgrass that displaces natives and has a visual impact as it looks out-of-place. |
| *Tragopogon dubius* | Western salsify | | This plant was found in both high priority and parkwide plots, and although not considered to be of high ecological impact, its numbers have been increasing throughout the Historic Site, although still found as individual plants versus patches. |
| *Tribulus terrestris* | Puncturevine | N | This plant was found in slightly over 7% of the high vector plots and is one that easily spreads along pathways. Currently, it occurs in low densities, but it requires regular maintenance to prevent rapid spread. |

[1] N = Present on the Colorado state noxious status list (USDA NRCS 2013).

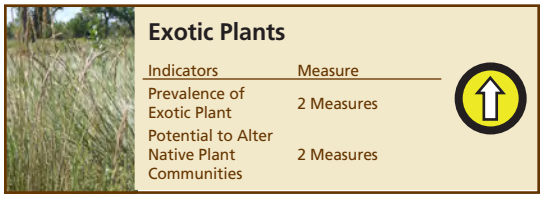
[2] The rationale is comprised of the four measures: proportion of high priority blocks and parkwide blocks occupied, density of plants, ecological impact, and management difficulty.

**Table 4.10.4-2. Indicator, measures, and their contributions to the overall exotic plants condition rationale.**

| Indicator of Condition | Measure | Condition | Rationale for Condition. |
|---|---|---|---|
| Prevalence of Exotic Plant | Proportion of High Priority and Parkwide Plots Infested | Moderate | Six exotic species were found in greater than 10% of the high priority sampling sites between 2011-2013. Two of these species are considered to be of highest concern, one of high concern, and one of moderate concern. |
| | Density of Exotic | Good | For the most part, most of the species warranting high, highest, or moderate concern occur in low densities throughout the Historic Site. Additionally, Historic Site staff proactively manage the exotic plants and have been successful in controlling one of the highest concern species, Saltcedar and considered to be in good condition. |
| Potential to Alter Native Plant Communities | Ecological Impact | Moderate | This measure is based on the premise that species with the largest negative impacts on native plant, animal, and other species populations, and ecosystems generally cause the most severe problems. Several species, particularly, *Bromus tectorum* and *Tamarix chinenesis* are considered to be extremely impactful to native communities, but many of the species with high ecological impact are relatively rare throughout the Historic Site, therefore, this we consider this measure to be of moderate condition. |
| | Management Difficulty | Significant Concern | All eight species (26%) of exotics considered to be the highest or high concern are considered to be very difficult to manage, therefore, we consider this measure to be of significant concern. |

communities. *Salsola tragus* is drought tolerant, making 1000s of seeds annually and once dry, breaks off tumbling across the prairie dispersing its seeds. It also thrives in highly disturbed areas, and appears to be spreading throughout the Historic Site.

Moist conditions will favor the seed dispersal of *Tragopogon dubius*, especially in a windy environment such as Bent's Old Fort NHS.




Overall Condition and Trend

For assessing the condition of exotic plants, we used two indicators and two measures that were not mutually exclusive but were intended to be different ways of capturing the essence of what we thought represented an exotic plant's potential for significance of impact to the native plant communities throughout the Historic Site.

Several factors contribute to an exotic's ability to threaten the integrity of a native ecosystem including its current abundance, density, and potential for ecological impact and management control based upon its life history. Also, the location where an exotic is found has implications pertaining to its establishment and potential control measures. Thus, our measures for this resource were intended to capture different aspects of these contributing factors, and a summary of how they contributed to the overall exotic plants condition is summarized in Table 4.10.4-2. We consider the overall condition for exotic plants at Bent's Old Fort NHS to be moderate with an improving trend.

Level of Confidence/Key Uncertainties

The exotic plants monitoring program is designed to occur during a time of year when early spring plants are still identifiable and rosettes are present for fall blooming plants. This strategic timing ensures the highest degree of detection. In addition with the three year rotation cycle, SOPN staff feel confident that they will identify new plants before they become established even if the plant is introduced right after the rotation cycle has been completed. Overall, we are very confident that at least 85-90% of the exotic plants have been identified throughout the Historic Site.

A key uncertainty is knowing how a given exotic plant species will respond to localized conditions. What may be considered a non-threatening plant in one region may become

a nuisance in a different region. But as stated above, annual monitoring of exotic plants helps identify changes to assist with early detection and rapid response.

Another key uncertainty is that many of the species currently absent have a high potential for reestablishing, especially since several respond to flooding and fire events, which both occur at the Historic Site. Once again, annual monitoring helps identify these new introductions before plant establishment and impact to native plant communities occur.

### *4.10.5. Sources of Expertise*

Surveys for exotic plants at Bent's Old Fort NHS were conducted by the SOPN exotic plants monitoring team well trained in species identification and methods. Our confidence is very high regarding the reliability of their surveys.

Tomye Folts-Zettner is a biologist/botanist with the SOPN and is also the project lead for monitoring exotic plants and grasslands in parks of the SOPN.

Jonathin Horsley is a biological technician for both the Chihuahuan Desert Network and the Southern Plains Network. He is the crew leader for their exotic plant monitoring crews. To the exotics section under sources of expertise.

### *4.10.6. Literature Cited*

Asher, J. A., and D. W. Harmon. 1995. Invasive exotic plants are destroying the naturalness of U.S. Wilderness areas. International Journal of Wilderness 1:35–37.

D'Antonio, C. M., and B. E. Mahall. 1991. Root profiles and competition between the invasive, exotic perennial, *Carpobrotus edulis*, and two native shrub species in California coastal scrub. American Journal of Botany 78:885–894.

Ehrenfeld, J. G. 2003. The effects of exotic plant invasions on soil nutrient cycling processes. Ecosystems 6:503–523.

Folts-Zettner, T., R. Bennetts, K. Gallo, S. Studd, M. Powell, K. Beaupre, and H. Sosinski. 2011. Multi-Network Exotic Plant Monitoring Protocol and Standard Operating Procedures : A collaboration among the Southern Plains, Chihuahuan Desert and Sonoran Desert Networks Natural Resource Technical Report NPS/SOPN/NRTR—2011/XXX. National Park Service, Fort Collins, Colorado.

Folts-Zettner, T. , and H. Sosinski. 2012a. Exotic plant monitoring in the Southern Plains Network: project report 2011. Natural Resource Technical Report NPS/SOPN/NRTR—2012/XXX. National Park Service, Fort Collins, Colorado.

Folts-Zettner, T., and H. Sosinski. 2012b. Exotic plant monitoring in the Southern Plains Network: project report 2012. Natural Resource Technical Report NPS/SOPN/NRTR— 2012/655. National Park Service, Fort Collins, Colorado.

Folts-Zettner, T., and H. Sosinski. 2013. Exotic plant monitoring in the Southern Plains Network: project report 2013. Natural Resource Technical Report NPS/SOPN/NRTR— 2013/xxx. National Park Service, Fort Collins, Colorado.

King, W. B. 1985. Island birds: Will the future repeat the past? Pages 3–15 in P. J. Moors, ed., Conservation of Island Birds. International Council for Bird Preservation. Cambridge: Cambridge University Press.

Knapp, P. A. 1996. Cheatgrass (*Bromus tectorum* L.) dominance in the Great Basin Desert: history, persistence, and influences to human activities. Global Environmental Change 6:37–52.

Morse, L.E., J.M. Randall, N. Benton, R. Hiebert, and S. Lu. 2004. An Invasive Species Assessment Protocol: Evaluating Non-Native Plants for Their Impact on Biodiversity. Version 1. NatureServe, Arlington, Virginia.

NatureServe. 2013. NatureServe explorer. Available at http://www.natureserve.org/explorer/servlet/NatureServe (accessed October 23, 2013).

Rejmanek, M., and M. J. Pitcairn. 2002. When is eradication of exotic pest plants a realistic goal? Pages 249–253 in C. R. Veitch and M. N. Clout, eds., Turning the tide: The eradication of invasive species. IUCN SSC Invasive Species Specialist Group. Gland, Switzerland and Cambridge, U.K.: IUCN.

Rejmanek, M., and J. M. Randall. 1994. Invasive alien plants in California: 1993 summary and comparison with other areas in North America. Madrono 41:161–177.

Tilman, D. 1999. The ecological consequences of changes in biodiversity: A search for general principles. Ecology 80:1455–1474.

USDA-NRCS. 2013. Colorado state listed noxious weeds. Available at http://plants.usda.gov/java/noxious?rptType=State&statefips=08 (accessed June 13, 2013).

Vitousek, P. M. 1990. Biological invasions and ecosystem processes: towards an integration of population biology and ecosystem studies. Oikos 57:7–13.

Whisenant, S. 1990. Changing fire frequencies on Idaho's Snake River plains: ecological and management implications. From Proceedings from the Symposium on Cheatgrass Invasion, Shrub Dieoff and Other Aspects of Shrub Biology and Management. US Forest Service Gen.:. Tech. Rep. INT -276, pp.4–10

Wilcove, D. S., D. Rothstein, J. Dubow, A. Phillips, and E. Losos. 1998. Quantifying threats to imperiled species in the United States. Bioscience 48:607–615.

Williamson, M. 1993. Invaders, weeds and risk from genetically modified organisms. Experientia 49:219–224.

Williamson, M., and A. Fitter. 1996. The varying success of invaders. Ecology 77:1661–1666.

## 4.11. Breeding Landbirds

**Indicators/Measures**

- Species Occurrence (3 Measures)

**Condition – Trend – Confidence**



Good - Insufficient Data - High

### *4.11.1. Background and Importance*

The National Park Service's mission is to manage park resources "unimpaired for future generations." Protecting and managing some of our nation's most significant natural resources requires basic knowledge of the condition of ecosystems and species that occur in national parks. Landbirds are a conspicuous component of many ecosystems (Figure 4.11.1-1) and have high body temperatures, rapid metabolisms, and occupy high trophic levels. As such, changes in landbird populations may be indicators of changes in the biotic or abiotic components of the environment upon which they depend (Canterbury et al. 2000; Bryce et al. 2002). Relative to other vertebrates, landbirds are also highly detectable and can be efficiently surveyed with the use of numerous standardized methods (Bibby et al. 2000; Buckland et al. 2001).

Changes in landbird population and community parameters can be an important element of a comprehensive, long-term monitoring program, such as that being implemented for the SOPN parks. Birds select habitat based on the presence of behavioral cues triggered by the environment (Hutto 1985; Alcock 2005). In some environments, however, especially those that vary unpredictably, habitat may not be saturated and changes in resources may not always be tracked by changes in animal populations (Wiens 1985). In these situations, relating changes in bird populations to environmental features can be complex, especially when confounded by time lags that are characteristic of site-tenacious bird species. Additional complications occur if birds respond more sensitively to environmental change than we can detect, and when cyclical environmental changes result in erratic changes in population size that are ultimately inconsequential. However, the utility of monitoring landbirds is strengthened by concurrent monitoring of a broad suite of environmental parameters (Dale and Beyeler 2001) that may assist with elucidating changes in the bird community to other environmental factors. Such a broad-based approach is now being undertaken by the SOPN program (NPS 2008) and other monitoring approaches (e.g., Ringold et al. 1996; Stevens and Gold 2003; Barrows et al. 2005).

Perhaps the most compelling reason to monitor landbird communities in SOPN parks is that birds themselves are inherently valuable. The high aesthetic and spiritual values that humans place on native wildlife are acknowledged in the agency's Organic Act: "to conserve . . . the wildlife therein . . . unimpaired for the enjoyment of future generations." Bird watching, in particular, is a popular, longstanding recreational pastime in the United States and forms the basis of a large and sustainable industry (Sekercioglu 2002).



© ROBERT SHANTZ

**Figure 4.11.1-1 Blue Grosbeak, found in both grassland and riparian habitat at Bent's Old Fort NHS.**

### *4.11.2. Data and Methods*

In 2009, Rocky Mountain Bird Observatory (RMBO) began systematic surveys of birds at Bent's Old Fort NHS as part of the SOPN Monitoring program. Although these data will enable quantitative evaluation of trends in birds in the future (e.g., in occupancy), it is premature to use them in such a context at the present with only four years of data. Rather, for this assessment, we focus on species occurrence (presence/absence), focusing on what species are, or are not, observed at Bent's Old Fort NHS. The most recent data we have for occurrence of birds at the Historic Site are the RMBO surveys. With the use of additional data sources, we evaluated species occurrence in three contexts: (1) a temporal context (i.e., changes over time), (2) a spatial context (i.e., comparison with surrounding region), and (3) a conservation context (i.e., the occurrence and status of species of conservation concern). We describe each of these below, followed by descriptions of the data sources used to support the comparisons.

#### Indicators/Measures
Species Occurrence

Temporal Context – Changes over Time

To evaluate birds in a temporal context, we compared the occurrence of species detected during 2009-2012 RMBO surveys at Bent's Old Fort NHS (described below) to 2001 and 2002 inventories for birds at the Historic Site conducted by the Colorado Natural Heritage Program (Gionfriddo and Stevens 2003). This analysis compares information from 2001-2002 to 2009-2012- a time span of seven to eleven years.

Our analysis is not intended as a rigorous or quantitative comparison given the limitations of the available information; rather, it is intended as a crude qualitative indicator of major changes over time. To do this in the most meaningful way, we needed the sources to be as comparable as possible. For example, the recent RMBO surveys were conducted during the breeding season; thus it is not reasonable to compare these results with species that occur at the Historic Site during other seasons. The 2001 CNHP inventory was conducted in August, while the 2002 inventory was conducted in May. The RMBO surveys were conducted during the breeding season primarily in June. We focused our comparisons on those species for which Bent's Old Fort NHS is within their normal breeding range. We made this determination based primarily on the Birds of North America (BNA) species accounts (Cornell Lab of Ornithology 2013). Given the potential for us to have made errors in determining whether the Historic Site was within the normal breeding range from online and hard copy maps (GIS data were not available), we included for consideration species outside of their normal breeding range but within 100 miles of their breeding range edge. Unlike field guides that are often written by persons with general knowledge of birds, the BNA accounts for each species are written by persons that have extensive experience and knowledge working with that particular species. Consequently, these accounts constitute a comprehensive summary of our current knowledge for a given species (including range) written by experts for that species. Note that by "normal breeding range" we mean the area designated by the BNA accounts where a species is known to consistently breed. Some birds may breed in small numbers outside of these areas, however.

We further refined our comparisons to species for which reasonably suitable breeding habitat exists at the Historic Site (since comparisons are based on the breeding season). We assigned each species to one of three breeding habitat classes (Table 4.11.2-1) based on the BNA accounts in combination with local knowledge.

Spatial Context – Comparisons with Surrounding Region

We also evaluated species occurrence in a spatial context. Again, this is intended only as a qualitative indicator rather than a rigorous quantitate estimate (which will be possible in the future). For this assessment, we compared the recent RMBO surveys at the Historic Site to regional surveys (described below) conducted by RMBO in similar habitats within the surrounding area over the approximate same period of time;

**Table 4.11.2-1. Breeding habitat classes assigned to each species that has been reported to occur at Bent's Old Fort NHS and is within or near its reported breeding range.**

| Breeding Habitat Class | Class Description |
|---|---|
| Exists | This class was assigned when the habitat at the Historic Site is characteristic of habitats where a given species might be expected to breed. |
| Possibly Exists | This class was assigned when it was unlikely that the habitat at the Historic Site would support consistent or widespread breeding, but does not preclude some breeding in limited numbers. |
| Limited to None | This class was assigned when it is unlikely that the habitat at the Historic Site would support breeding by that species. This does not imply that the species would not occur at the Historic Site in limited numbers or during other seasons, but rather that it would be unlikely to breed there. |

**Table 4.11.2-2. Classes assigned to species of concern regarding the potential for Bent's Old Fort NHS to play a role in their conservation.**

| Potential for Conservation | Conservation Class Description |
|---|---|
| High | These are species for which the Historic Site is within the normal breeding range or in proximity to the edge of that range. They are also species for which we considered the Historic Site to have good breeding habitat. We assigned species to this class if we believed, based on the evidence, that the potential for breeding was good, regardless of whether they currently occur at the Historic Site in substantial numbers. |
| Moderate | These are the species for which the Historic Site is within the normal breeding range or in proximity to the edge of that range, and for which there is some habitat at the Historic Site that might support occurrence or even some breeding in limited numbers. |
| Low to None | These are the species that are either outside of their normal breeding range and/or for which the habitat at the Historic Site is unlikely to support breeding. This does not preclude limited occurrences of the species, but the potential for the Historic Site to play any significant role in the conservation of that species is very limited. |

the regional surveys serve as a general spatial reference for species occurrence within the region. As with the temporal comparison, we focused our comparisons on those species for which the Historic Site is within their normal breeding range, but we also considered species outside of but within 100 miles of their normal breeding range. We used the regional RMBO surveys for the basis of our comparison because their methods are similar to those used in the annual RMBO surveys at the Historic Site. We also used the Breeding Bird Surveys, described below, as supporting information for the comparison.

Conservation Context – The Occurrence and Status of Species of Conservation Concern

Our intent for this context was to determine which species that occur at Bent's Old Fort NHS are considered species of concern at either national or local scales, to assess the current status (occurrence) of those species at the Historic Site, and to evaluate the potential for the Historic Site to play a role in their conservation. For the latter, we assigned each species of conservation concern to one of three classes representing the potential for the Historic Site to play a role in its conservation during the breeding season (Table 4.11.2-2). This was based primarily on whether or not the Historic Site was within the normal breeding range of the species and the availability of breeding habitat at the Historic Site.

To develop a candidate list for species of conservation concern, we used the lists developed by several organizations. There have been a number of such organizations that focus on the conservation of bird species. Such organizations may differ, however,

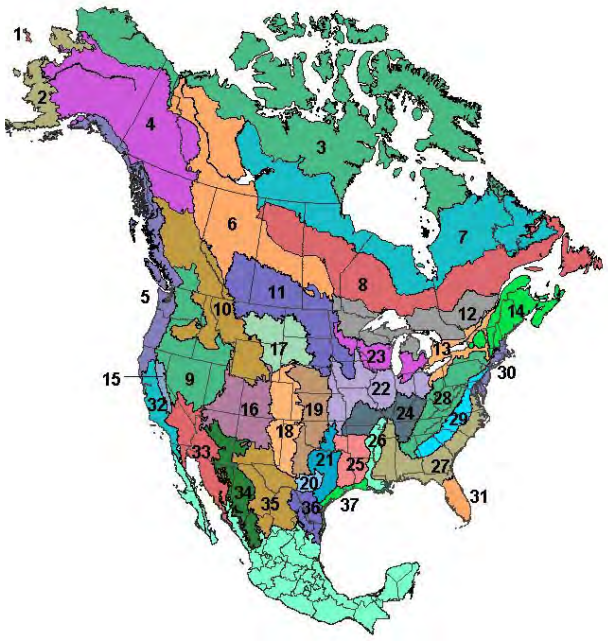



**Figure 4.11.2-1. Bird Conservation Regions in North America.**

in the criteria they use to identify and/or prioritize species of concern based on the mission and goals of their organization. They also range in geographic scale from global organizations, such as the International Union for Conservation of Nature (IUCN), who maintains a "Red List of Threatened Species," to local organizations or chapters of larger organizations. This has been, and continues to be, a source of confusion, and perhaps frustration, for managers that need to make sense of and apply the applicable information. In recognition of this, the U.S. North American Bird Conservation Initiative (NABCI) was started in 1999; it represents a coalition of government agencies, private organizations, and bird initiatives in the United States working to ensure the conservation of North America's native bird populations. Although there remain a number of sources at multiple geographic and administrative scales for information on species of concern, several of which are presented below, the NABCI has made great progress in developing a common biological framework for conservation planning and design.

One of the developments from the NABCI was the delineation of Bird Conservation Regions (BCRs) (U.S. North American Bird Conservation Initiative 2013). Bird Conservation Regions are ecologically distinct regions in North America with similar bird communities, habitats, and resource management issues (Figure 4.11.2-1). Bent's Old Fort NHS lies within the Short Grass Prairie Unit (BCR-18) (Figure 4.11.2-2).

*Conservation Organizations Listing Species of Conservation Concern*

Below we identify some of the organizations/efforts that list species of conservation concern; these are the listings we used for the condition assessment. Appendix H presents additional details on each of the organizations/efforts.

- U.S. Fish & Wildlife Service: Under the Endangered Species Act, the U.S. Fish and Wildlife Service (USFWS) lists species as threatened, endangered, or candidates for listing.
- State of Colorado: Under the authority of the Nongame, Endangered, or Threatened Species Conservation Act, the State of Colorado, through the Division of Wildlife (CDOW) (now Colorado Parks and Wildlife) maintains listings of species considered as threatened or endangered, as well as State special concern (although the latter is not a statutory category) (Colorado Parks and Wildlife 2012).
- USFWS: This agency also developed lists of birds of conservation concern according to: the Nation, USFWS Region, and BCR.
- The National Audubon Society (NAS) and American Bird Conservancy (ABC): These groups combined efforts to produce a "Watch List," based on, but not identical to, the Partners in Flight approach to species assessment (see below). The 2007 WatchList has two primary levels of concern: a "Red Watchlist," which identifies what these organizations consider as species of highest national concern; and a "Yellow WatchList," which is made up of species that are somewhat less critical.
- Partners in Flight (PIF): This is a cooperative effort among federal, state, and local government agencies, as well as private organizations. PIF has adopted BCRs as the geographic scale for updated regional bird conservation

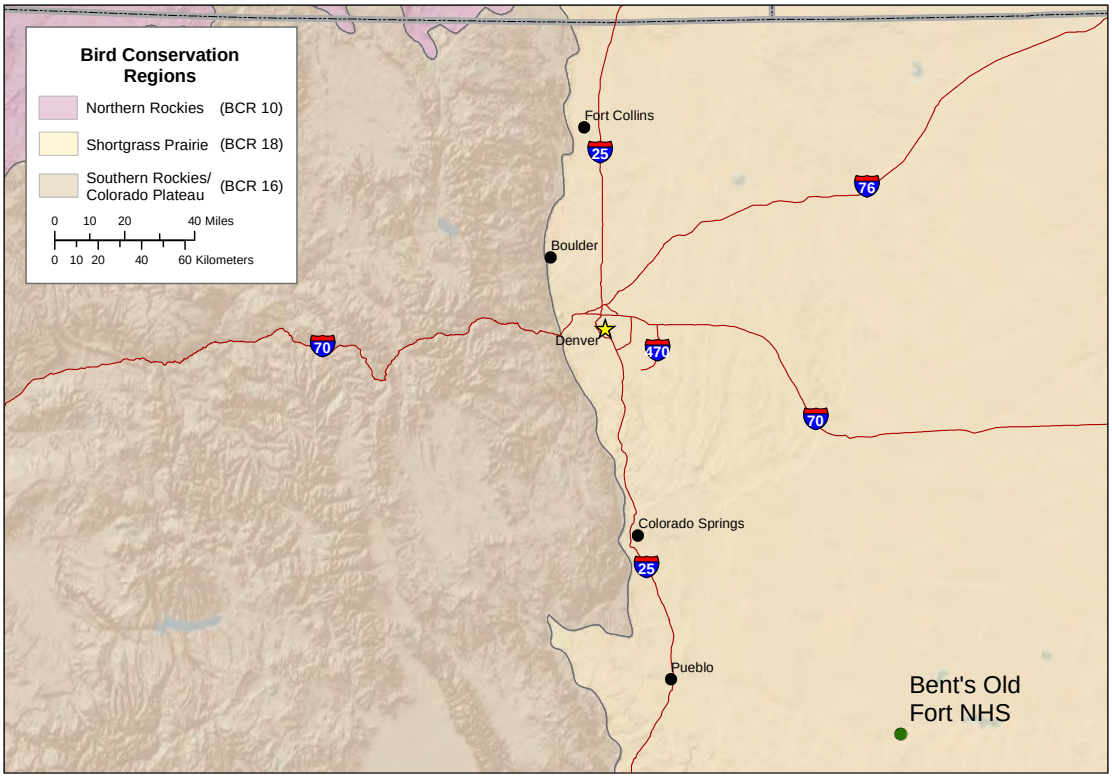



**Figure 4.11.2-2. Bird Conservation Regions in the vicinity of Bent's Old Fort NHS.**

assessments. At the scale of the individual BCRs, there are species of Continental Importance (Continental Concern [CC] and Continental Stewardship [CS]) and Regional Importance (Regional Concern [RC] and Regional Stewardship [RS]).

- State of Colorado: In addition to listing threatened and endangered species, the State developed a Comprehensive Wildlife Conservation Strategy, also known as a Wildlife Action Plan (CDOW 2006), that identifies species and conservation needs for what they consider the Species of Greatest Conservation Need (SGCN). The strategy reflects a basic goal of securing wildlife populations so that they do not require protection through federal or state listing regulations (CDOW 2006).

Primary Data Sources

Data used as part of the condition assessment include: surveys conducted by RMBO at Bent's Old Fort NHS in 2009-2012; two biological surveys/inventories conducted by the CNHP in 2001 and 2002 (Gionfriddo et al. 2002 and Gionfriddo and Stevens 2003); and surveys conducted by RMBO in the surrounding region in 2008-2012. Data were also collected from Breeding Bird Surveys (BBS), and these data were used as supporting information (i.e., secondary sources). Bird species lists for the Historic Site were also reviewed and are mentioned in the report where applicable. Each of the primary sources are described below, and the secondary sources are described in the subsequent section.

*RMBO Surveys at the Historic Site in 2009-2012*

RMBO used point-transect surveys (Buckland et al. 2001) during the breeding season to estimate and monitor landbird population parameters at Bent's Old Fort NHS (Lock et al. 2012). A total of about 61 unique points in riparian (cottonwood bottom; n=23) and grassland (shortgrass prairie; n=38) habitats were sampled three times each in 2009-2012 (Figure 4.11.2-3) (Lock et al. 2012). All birds detected at a given point were recorded. Observers spent six minutes at each point along the transect or grid and used a rangefinder to estimate the linear distance to each bird or group detected. This protocol of spending six minutes per site is consistent with other efforts being conducted by RMBO. After counts were completed, observers used

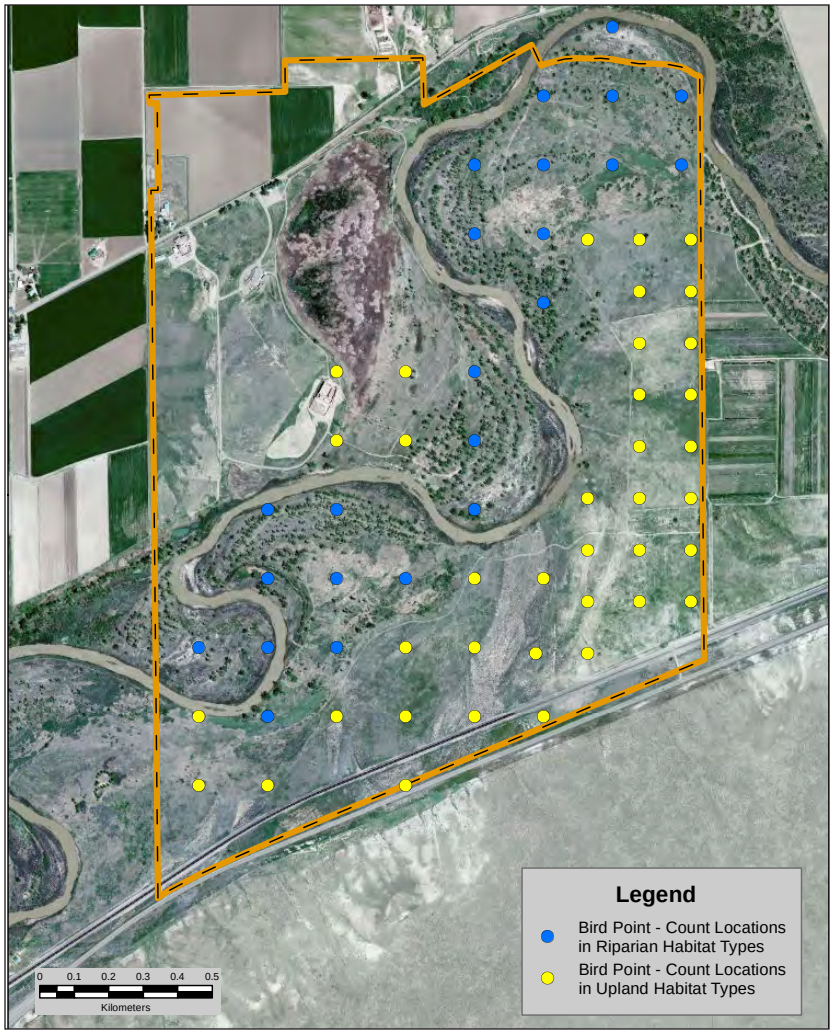



**Figure 4.11.2-3. Survey points sampled by the Rocky Mountain Bird Observatory at Bent's Old Fort NHS in 2009-2012.**

a handheld GPS (Global Positioning System) unit to locate successive survey points. While walking between points, observers noted only species that were not recorded during the count period; sometimes these represented species that had not been previously reported for the Historic Site.

*Regional RMBO Surveys*

Within the surrounding region, RMBO conducts additional surveys as part of the Integrated Monitoring in Bird Conservation Regions program (White et al. 2012). The following paragraph, taken from the RMBO website (RMBO 2013a), describes sampling under the program:

- "Using the intersection of BCRs and state boundaries as the primary level of stratification, substrata are defined by IMBCR partners based on areas to which inferences are needed, for example, an individual National Forest. Spatially balanced samples are selected within each substratum using a generalized random tessellation stratification algorithm (Stevens and Olsen 2004). This sampling design allows direct comparison of density and occupancy estimates among geographic areas and across spatial scales. Birds are surveyed from a grid of points within each sample unit during a six minute period. Observers record distances to each bird and the one-minute interval during which each bird was detected. These data are used to estimate occupancy rates at two spatial scales (Pavlacky et al. 2012) and density using distance sampling theory (Buckland et al. 2001)."

We used data from the IMBCR program to conduct our spatial comparison. We compared species observed during the IMBCR sampling (2008-2012) to those observed during surveys at the Historic Site (2009-2012). Note, however, that during the regional surveys some points were sampled in 2008-2012, but others were only surveyed in one or two of these years. Using the RMBO Avian Data Center (i.e., RMBO 2013b), we selected five sampling sites in riparian, grassland, and light agricultural areas in the vicinity of the Historic Site for our comparison (Figure 4.11.2-4). Data were downloaded from the RMBO website.

*CNHP Inventories/Surveys*

In 2001, the CNHP conducted vertebrate inventories that included birds (Gionfriddo et al. 2002). Field sampling for the vertebrates occurred from August 6-18. Birds were inventoried primarily by visual encounter surveys (VES; by foot and vehicle), but also using fixed-point auditory surveys. Fifty-five hours of VES were conducted.

In the spring of 2002, a supplementary survey was conducted by CNHP to focus on breeding birds, particularly in the wetlands of the Historic Site, and breeding frogs and toads (Gionfriddo and Stevens 2003). Some terrestrial habitats (woodlands

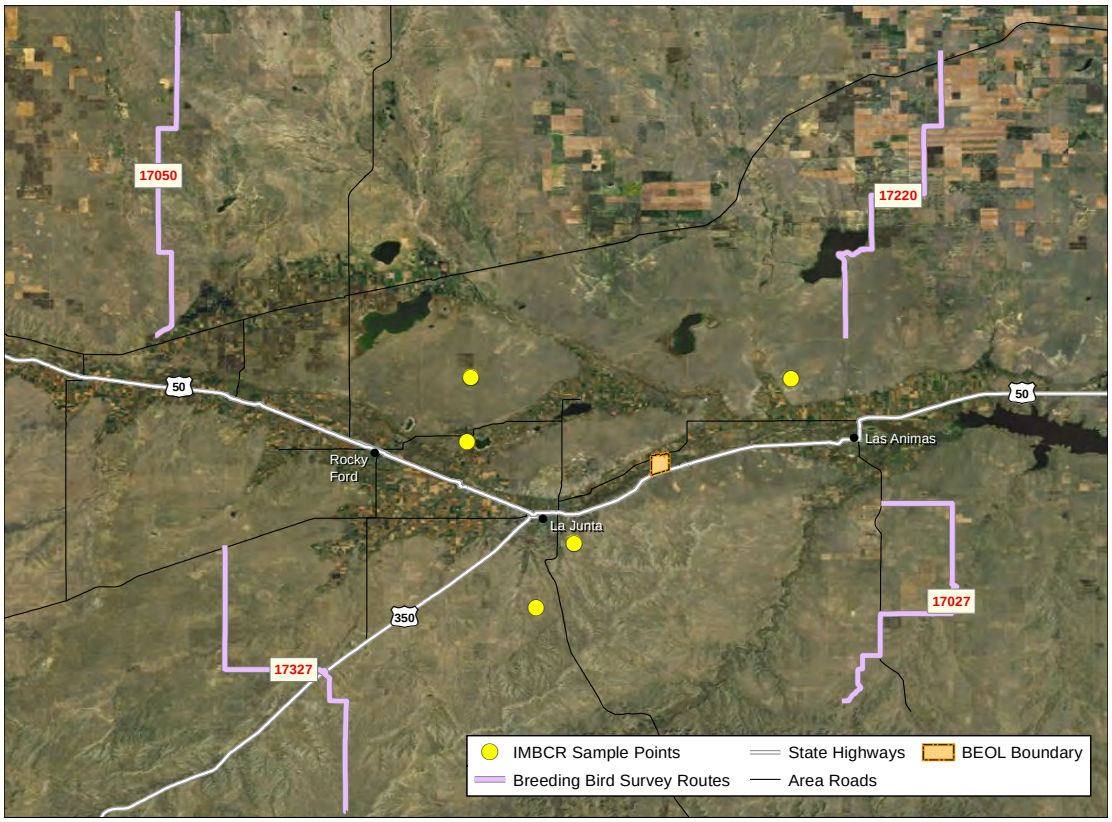



**Figure 4.11.2-4. Five IMBCR sampling sites (in yellow; primary data source) and four BBS routes (in purple; secondary data source) used for the regional comparison of landbird species occurrence.**

and grasslands) were also searched. Field sampling was conducted from May 20-25 and included 50.9 hours of bird surveys. Birds were surveyed by observing wetlands from suitable vantage points and through the use of VES on foot and by vehicle.

Secondary Data Sources

*BBS Routes*

Breeding Bird Surveys are conducted on over 4,100 survey routes located across the continental U.S. and Canada (http://www.pwrc.usgs.gov/BBS/). Each year during the height of the avian breeding season, participants skilled in avian identification sample birds along roadside survey routes. Each survey route is 24.5 miles long with stops at 0.5-mile intervals. At each stop, a 3-minute point count is conducted. During the count, every bird seen within a 0.25-mile radius or heard is recorded. Surveys start one-half hour before local sunrise and take about 5 hours to complete. There are four BBS routes in the general vicinity of Bent's Old Fort NHS (Figure 4.11.2-4). We used data from these four BBS routes for 2009-2012 as a secondary source of information for the spatial comparison of species occurrence.

*Check Lists*

In 2006, the Western National Parks Association (WNPA) published *A Checklist of the Birds of Bent's Old Fort National Historic Site, Colorado*, which was compiled by NPS staff. We used the list on a case by case basis as supporting information for particular species.

## *4.11.3. Reference Conditions*

Temporal Reference Condition for Species Occurrence

The first bird monitoring or inventory effort at Bent's Old Fort NHS was that made by CNHP in 2001 and 2002 (i.e., Gionfriddo et al. 2002 and Gionfriddo and Stevens 2003). A total of 72 species was recorded during the two inventories; Appendix I shows which species were recorded and whether they were recorded in one or both inventories.

We compared the species list from the 2001 and 2002 surveys/inventories to the list of species that have been detected during the 2009-2012 RMBO surveys to see if there were

**Table 4.11.3-1. Reference conditions used to assess the current condition of breeding landbird species occurrence in temporal and spatial contexts.**

| Occurrence Indicator | Significant Concern | Moderate Concern | Good |
|---|---|---|---|
| Temporal Context | We considered condition to be of significant concern if several species of birds that are within their normal breeding range and have existing habitat at the Historic Site were detected in the 2001-2002 surveys but not in recent RMBO surveys, particularly if those species had previously been considered common at the Historic Site. | We considered condition to be of moderate concern if a few bird species that were detected during 2001-2002 surveys that are within their normal breeding range and have breeding habitat at the Historic Site were not detected during recent RMBO surveys. | We considered condition to be good if all, or nearly all, birds that were detected during 2001-2002 surveys that are within their normal breeding range and have breeding habitat at the Historic Site were detected during recent RMBO surveys. |
| Spatial Context | We considered condition to be of significant concern if several species of birds that are within their normal breeding range and have breeding habitat at the Historic Site were detected during regional surveys but not during recent RMBO surveys. | We considered condition to be of moderate concern if a few bird species that were detected during regional surveys and are within their normal breeding range and have breeding habitat at the Historic Site were not detected during recent RMBO surveys. | We considered condition to be good if all, or nearly all, birds that were detected during regional surveys and are within their normal breeding range and have breeding habitat at the Historic Site were detected during recent RMBO surveys. |

any differences. Differences in the two lists may represent changes over time. Specifically, we looked at species that were not observed during 2009-2012 RMBO surveys that had been documented in 2001-2002. We "refined" the list of species where there were differences by excluding those species that were outside of their normal breeding range (and more than 100 miles from the edge of their normal breeding range). Although this analysis is a crude measure and only spans a relatively short time differential, it does potentially provide some insights as to major shifts that might have occurred at the Historic Site. Table 4.11.3-1 summarizes the qualitative condition classes we assigned for the temporal and spatial indicators.

Spatial Reference Condition for Species Occurrence

In a spatial context, we compared the species observed during recent RMBO surveys (2009-2012) at Bent's Old Fort NHS to the regional IMBCR surveys conducted by RMBO (2008-2012); as noted previously, for the IMBCR data we chose points located in habitats comparable to those at the Historic Site (riparian, grassland, and light agricultural areas). Both surveys were conducted during the breeding season.

Reference Condition for Species of Concern

This aspect of the assessment is somewhat different than the other two in that the focus is on the avian species for which the Historic Site can play a role in their conservation. From the list of species detected at the Historic Site during recent RMBO surveys, we identified the species that occurred on one or more of the lists of species of conservation concern. Those considered as having the greatest potential for conservation at the Historic Site are those within their breeding range and for which breeding habitat exists at the Historic Site. In our analysis, we also considered several species that were not detected in recent RMBO surveys but were reported during the 2001-2002 CNHP inventories.

### *4.11.4. Condition and Trend*

There have been a total of 103 bird species reported at Bent's Old Fort NHS (Appendix I). These species were detected during the 2001 and/or 2002 CHNP inventories (the list is the same as the Historic Site's Certified

**Table 4.11.4-1 Species reported in 2001 and/or 2002 by CNHP (Gionfriddo et al. 2002, Gionfriddo and Stevens 2003) at Bent's Old Fort NHS that were not observed during the 2009-2012 RMBO surveys. Also shown is the range status based on Birds of North America species accounts, and breeding habitat class for birds within (or within 100 miles of) their normal breeding range.**

| Common Name | Range Status | Breeding Habitat Class |
|---|---|---|
| Black-billed Magpie | Year-round | Possibly Exists |
| Grasshopper Sparrow | Breeding (on western edge of) | Possibly Exists |
| Lark Bunting | Breeding | Possibly Exists |
| Loggerhead Shrike | Year-round | Possibly Exists |
| Ferruginous Hawk | Year-round | Limited to None |
| Rock Wren | Breeding | Limited to None |
| Violet-green Swallow | Breeding | Limited to None |
| American Avocet [1] | Breeding | ---- |
| American Coot [1] | Breeding and Wintering | ---- |
| Black Tern [1] | Breeding | ---- |
| Black-crowned Night-Heron [1] | Breeding | ---- |
| Blue-winged Teal [1] | Breeding | ---- |
| Forster's Tern [1] | Outside Normal Breeding Range | ---- |
| Northern Shoveler [1] | Year-round | ---- |
| Sora [1] | Breeding | ---- |
| Spotted Sandpiper [1] | Breeding | ---- |
| White-faced Ibis [1] | Outside but <100 mi from Local Breeding | ---- |
| American Bittern [2] | Outside Normal Breeding Range [3] | Possibly Exists |
| Yellow-headed Blackbird [2] | Breeding | Possibly Exists |

1 = Wetland species not expected to be observed on RMBO Surveys (although its occurrence/detection is possible). No breeding habitat class is provided for these species.

[2] = Wetland species, but observations could be expected on RMBO Surveys because survey points are close to potential breeding habitat.

[3] = But within 100 miles of breeding range edge.

Species List from NPSpecies), the 2009-2012 RMBO point-count surveys, and/or recorded incidentally to surveys (only a few species).

Species Comparisons using 2001 and 2002 CNHP Inventories (Temporal Context)

A total of 72 species of birds were observed at Bent's Old Fort NHS in the 2001 and 2002 CNHP surveys (Appendix I). Of these 72 bird species, 19 were not observed on recent (2009-2012) RMBO surveys (Table 4.11.4-1). However, 10 of these species (designated with a "1" in the table) are primarily associated with wetlands, so they would not be expected to be observed during RMBO surveys that are conducted in grassland and riparian (cottonwood) habitat classes. Two additional species (designated with a "2") are also associated with wetlands, but potential breeding habitat exists for them in close proximity to RMBO survey points. Of the remaining seven species, all are within or within but on the edge (Grasshopper Sparrow) of their normal breeding ranges. However, all fall into the "possibly exists" or "limited to none" breeding habitat classes; none are in the "exists" class, in which the habitat at the Historic Site is characteristic of the habitat(s) where they might be expected to breed. Of these seven species, the 2006 WNPA checklist for the Historic Site lists four as uncommon breeders or residents, two as migrants (one common and one uncommon),

**Table 4.11.4-2 Birds species detected in 2008-2012 IMBCR regional surveys by RMBO in the vicinity of Bent's Old Fort NHS that were not detected at the Historic Site during the 2009-2012 RMBO point-count surveys. Species that were detected during surveys by CNHP in 2001 and/or 2002 are noted (with a "1").**

| Common Name | Range Status | Breeding Habitat Class: Exists, Probably Exists, Limited to None |
|---|---|---|
| House Finch | Year-round | Possibly Exists |
| Song Sparrow | Wintering, and Just outside breeding range [2] | Possibly Exists (along river) |
| Vesper Sparrow | Breeding (but on edge of breeding range) | Possibly Exists |
| Band-tailed Pigeon | Outside Normal Breeding Range [2] | Limited to None |
| Bank Swallow | Breeding | Limited to None |
| Common Raven | Year-round (but on eastern edge) | Limited to None (breeding habitat) |
| Olive-sided Flycatcher | Outside Normal Breeding Range [2] | Limited to None |
| Scaled Quail | Year-round | Limited to None |
| Western Scrub-Jay | Year-round (but on edge of year-round range) | Limited to None |
| Yellow-rumped Warbler (Audubon's) | Outside Normal Breeding Range [2] | Limited to None |
| Black-billed Magpie [1] | Year-round | Possibly Exists |
| Grasshopper Sparrow [1] | Breeding (but on western edge) | Possibly Exists |
| Lark Bunting [1] | Breeding | Possibly Exists |
| Ferruginous Hawk [1] | Year-round | Limited to None |
| White-faced Ibis [1] | Outside Normal Breeding Range [2] | Wetland species not expected during RMBO surveys at the Historic Site |

1 = Species detected during surveys by CNHP in 2001 and/or 2002.
2 = But within 100 miles of its breeding range edge.

and one as a resident that is present in some years and absent in others.

A different set of species (26) was detected in the 2009-2012 surveys but not in the 2001 or 2002 inventories (e.g., Bell's Vireo, Brewer's Blackbird, Burrowing Owl, Cliff Swallow, Indigo Bunting, Mississippi Kite, Red-eyed Vireo, and Say's Phoebe; see Appendix I). Of the 26 species, 19 were on the 2006 Bird Checklist (WNPA 2006), six were not on the list (Bell's Vireo, Chimney Swift, Great Crested Flycatcher, Ladder-backed Woodpecker, White-eyed Vireo, and Willow Flycatcher), and one was on the list but noted as "extirpated" (Burrowing Owl).

From the comparison of species detected in 2001-2002 to 2009-2012, we do not have any particular concerns for species occurrence at the Historic Site.

Species Comparisons to Surrounding Region (Spatial Context)

Fifteen species were detected during the 2008-2012 regional (IMBCR) surveys that were not detected during the 2009-2012 RMBO surveys at Bent's Old Fort NHS (Table 4.11.4-2). Of these 15 species, five were recorded at the Historic Site during the 2001 and/or 2002 CNHP surveys (designated with a "1" in the table). Of the 15 species, eight have limited to no breeding habitat at the Historic Site. One additional species is a wetland species, so it would not be expected to be observed during RMBO surveys at the Historic Site; it is also outside of its normal breeding range.

The six remaining species fall into the "possibly exists" breeding habitat class, meaning that while some breeding may occur in limited numbers, it is unlikely that the

habitat at the Historic Site would support consistent or widespread breeding. The six species in the "possibly exists" class are Black-billed Magpie, Grasshopper Sparrow, House Finch, Lark Bunting, Song Sparrow, and Vesper Sparrow. All of these species were counted in small numbers in the regional surveys, except for the Lark Bunting, which had a total count of 71 individuals. Also note that some of the six species and some of the other species discussed are on the edge of, or are outside of but less than 100 miles from the edge of, their normal breeding ranges. Additionally, although the 2006 WNPA list includes all six species, four are noted as "uncommon" at the Historic Site.

A review of the BBS data from nearby survey routes indicated that from 2008-2012, only seven of the 15 species mentioned above were recorded on the four routes, and a few of the seven bird species were observed in very low numbers. We also compared the complete list of species detected at the Historic Site in 2009-2012 by RMBO to the summary list from the four BBS routes for the period 2008-2012. Eleven additional bird species were observed on the four BBS routes but not at Bent's Old Fort NHS. However, the absence of the species does not raise any concerns (e.g., because they are typical of habitats not occurring at the Historic Site, or they are usually observed in low numbers).

Given the status of their ranges and habitat preferences, we do not have any particular concerns with this list of 15 (and 11 additional) species. Therefore, based on the spatial comparison, a concern for bird species occurrence is not justified at this time.

Species of Conservation Concern

There are 18 species that have been detected at Bent's Old Fort NHS during 2009-2012 RMBO surveys that are listed as species of conservation concern on one or more of the lists described in Section 4.11.2 and Appendix I (Table 4.11.4-3). Additionally, there are six species that were detected in 2001 and/or 2002 surveys that are considered species of conservation concern, which we will also address in this section.

- USFWS / Listed Species: There are no bird species listed by the USFWS as endangered or threatened that are known to occur at Bent's Old Fort NHS (USFWS 2013). Although there is one species considered a candidate for listing (i.e., Yellow-billed Cuckoo) and one species proposed for listing as threatened (Horned Lark [Streaked Horned Lark]; USFWS 2012), both listings apply only to birds in other parts of the western U.S. (Table 4.11.4-3).
- State of Colorado / Listed Species: There are no bird species that occur at the Historic Site that are listed as endangered by the state of Colorado; however, there is one species, the Burrowing Owl, that is listed as threatened (Colorado Parks and Wildlife 2012). Additionally, two species are listed as special concern by the state--Ferruginous Hawk (detected only by CNHP in 2001/2002) and Yellow-billed Cuckoo.
- USFWS / Birds of Conservation Concern: There are 13 species that have been detected at the Historic Site that have been identified by the USFWS as having the greatest conservation need at a National, USFWS Regional, or BCR geographic scale (U.S. Fish and Wildlife Service 2008). This includes five species that were not detected during recent RMBO surveys but during 2001 or 2002 CNHP surveys at the Historic Site.
- NAS / ABC: There are seven species that occur or have occurred at Bent's Old Fort NHS that have been listed on the NAS/ABC 2007 WatchList. Three species, Bell's Vireo, Black Rail, and Lewis's Woodpecker, are listed on their Red List. The other four species are on the Yellow List, three because of population declines and one because it is rare. Only one of these seven species (Lark Bunting) was not detected during recent RMBO surveys but during the 2001-2002 CNHP surveys.
- PIF: Twenty of the 24 birds in Table 4.11.4-3 are listed by PIF in one or more of its categories (i.e., CC, RC, CS, RS). This includes four species that were detected in 2001/2002 surveys but not in recent RMBO surveys at the Historic

**Table 4.11.4-3. Summary of species detected during 2009-2012 RMBO surveys (or 2001/2002 inventories only*) (excluding the exotic Ring-necked Pheasant) at Bent's Old Fort NHS of conservation concern, as listed by government agencies and non-governmental organizations.**

| Common Name | Listed Species | | Species of Conservation Concern Lists | | | | | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Federal[1] | State[2] | US Fish & Wildlife Service | | | NAS/ ABC[3] | Partners in Flight National Conservation Strategy[4] | | | | |
| | USFWS | CPW (CDOW) | National | Region 6 | BCR 18 | 2007 Watch List | BCR 18® CC | BCR 18® RC | BCR 18® CS | BCR 18® RS | |
| American Bittern * | | | | ● | | | | | | | * Species detected in 2001 and/or 2002 only. |
| Bell's Vireo | | | ● (a) | ● (a) | ● (a) | ● | ● | ● | | | (a) Non-listed subspec. or population of T or E species. |
| Black Rail | | | ● | ● | | ● | | | | | |
| Brown Thrasher | | | | | | | | | ● | | |
| Burrowing Owl | | ST | | ● | ● | | | ● | | ● | |
| Cassin's Sparrow | | | | | | | | ● | ● | ● | |
| Chihuahuan Raven | | | | | | | | | | ● | |
| Common Nighthawk | | | | | | | | ● | | | |
| Dickcissel | | | ● | | | | | | ● | | |
| Ferruginous Hawk * | | SC | | ● | | | | ● | | ● | |
| Grasshopper Sparrow * | | | | ● | | | | ● | ● | ● | |
| Horned Lark | PT [B] | | B | | | | | | | ● | [B] Listings with "B" are only for a subspecies that does not occur in CO (but PIF RS listing applies). |
| Lark Bunting * | | | | | ● | ● | | ● | ● | ● | |
| Lewis's Woodpecker | | | ● | ● | ● | ● | | ● | ● | | |
| Loggerhead Shrike * | | | ● | ● | | | | | | | |
| Mississippi Kite | | | | | | | | | ● | | |
| Northern Harrier | | | | | | | | ● | | | |
| Red-headed Woodpecker | | | ● | ● | | ● | ● | | | | |
| Swainson's Hawk | | | ● | | | ● | | | | ● | |
| Western Meadowlark | | | | | | | | ● | | ● | |
| Willow Flycatcher | | | ● (a) | ● (a) | ● (a) | ● | | | | | (a) Non-listed subspec. or population of T or E species. |
| Yellow-billed Cuckoo | C [D] | SC | D | | | | | ● | | | [D] Listings with "D" are for a sub-population that does not occur east of the Rockies, but other listings apply. |
| Yellow-headed Blackbird * | | | | | | | | | ● | | |

[1] **Federal Listed Species Codes**
T = Threatened C= Candidate
E = Endangered PT = Proposed Threatened

[2] **State Listed Species Codes**
ST = Threatened SC = Special Concern
SE = Endangered

[3] **NAS/ABC - 2007 Watchlist**
● = Red List
● = Declining or Rare

[4] **PIF NCS Categories**
CC = Continental Concern RC = Regional Concern
CS = Continental Stewardship RS = Regional Stewardship

Site. Note that the Ring-necked Pheasant (which is not shown in the table) is on the PIF list, but because it is an introduced species, it will not be addressed further in this analysis.

- Colorado Species of Greatest Conservation Need: Five species that were detected at the Historic Site during the 2009-2012 RMBO surveys (and four that were detected during 2001-2002 surveys) are considered Tier 1 Species of Greatest Conservation Need in the State's Comprehensive Wildlife Conservation Strategy (CDOW 2006). All nine of these Tier 1 species already appear in Table 4.11.4-3 and are addressed, as appropriate, in the *Summary* section below. These Tier 1 species are: American Bittern, Burrowing Owl, Cassin's Sparrow, Ferruginous Hawk, Lark Bunting, Lewis's Woodpecker, Loggerhead Shrike, Swainson's Hawk, and Yellow-billed Cuckoo. Tier 2 species, which are relatively lower-priority Species of Greatest Conservation Need, are also listed in the Colorado plan.

Summary of Species Listed as Birds of Conservation Concern (Conservation Context)

For this summary, we emphasize species for which Bent's Old Fort NHS has the greatest potential to positively impact their conservation during the breeding season, based on their habitat and range. We do not mean to imply that other seasons are not important for the conservation of birds, they are. Rather, we have limited this assessment to the breeding season because that is the only season for which we have current information. We also recognize that there is considerable uncertainty and subjectivity in our assessment. Thus, we do not mean to imply that the classes we assigned are the only "correct" categories. Rather, this represents our interpretation from the available evidence, but we fully expect that other interpretations might be appropriate.

Of the 23 species listed by one or more organization as being of conservation concern (Table 4.11.4-3, excluding the Ring-necked Pheasant and including the six species observed by CNHP in 2001-2002), we believe that five have sufficient habitat at the Historic Site to be considered as having high conservation potential (Table 4.11.4-4). These are the species that are within their normal breeding range and sufficient habitat exists at the Historic Site to support breeding. All of these five species have been observed on recent (2009-2012) RMBO surveys. Furthermore, all of the species have been observed during all four years of surveys (Table 4.11.4-5). One of the species, Western Meadowlark, has been observed in relatively high numbers. It was the most abundant species at the Historic Site in 2012, accounting for 23% of the birds counted during the breeding season; in the other three survey years, Western Meadowlark was the second or third most abundant species.

Four species are considered to have moderate potential for the Historic Site to contribute to their conservation. These are the Burrowing Owl, Black Rail, Northern Harrier, and Yellow-headed Blackbird.

The Burrowing Owl is a State-threatened species and is recognized by both USFWS and PIF conservation lists. The Burrowing Owl was detected only in 2009 and 2011 during recent RMBO surveys at the Historic Site. It was observed in the prairie dog colony on the south side of the river. This species prefers low grass structure and burrows, such as those provided by prairie dogs. As discussed in the Prairie Dog chapter of this NRCA, the sylvatic plague decimated the prairie dog colony at the Historic Site and adjacent land in late 2011/early 2012. As of 2013, the status of prairie dogs at the Historic Site remains unchanged.

In summary, all species of conservation concern that are within their normal breeding range and have "existing" breeding habitat at the Historic Site (i.e., high potential species) have been observed during recent (2009-2012) RMBO surveys. Based on this, we consider the condition for species of conservation concern to be good.

**Table 4.11.4-4. Species detected at Bent's Old Fort NHS during 2009-2012 surveys (and/or 2001 or 2002 CNHP inventories) that have also been identified as species of concern on one or more watch list. Species are organized by whether they have high, moderate, or low potential for the Historic Site to contribute to their conservation.**

| Common Name | Detected During | | Range Status | Breeding Habitat Class |
|---|---|---|---|---|
| | 2009-2012 RMBO Surveys | 2001 or 2002 Survey/ Inventory | | |
| High Potential | | | | |
| Brown Thrasher | • | • | Breeding | Exists |
| Common Nighthawk | • | • | Breeding | Exists |
| Red-headed Woodpecker | • | • | Breeding | Exists |
| Western Meadowlark | • | • | Year-round | Exists |
| Yellow-billed Cuckoo | • | • | Breeding | Exists |
| Moderate Potential | | | | |
| Black Rail | • | | Outside Normal Breeding Range, but <100 mi from local breeding/ summer records [4] | Possibly Exists [4] |
| Burrowing Owl | • | | Breeding | Possibly Exists [2] |
| Northern Harrier | • | • | Year-round | Possibly Exists |
| Yellow-headed Blackbird | | • | Breeding | Possibly Exists |
| Low to No Potential | | | | |
| American Bittern | | • | Outside Normal Breeding Range [1] | Possibly Exists |
| Bell's Vireo | • | | Outside Normal Breeding Range [1] | Possibly Exists |
| Cassin's Sparrow | • | • | Breeding | Possibly Exists [3] |
| Chihuahuan Raven | • | | Year-round | Possibly Exists [3] |
| Dickcissel | • | • | Outside Normal Breeding Range but <100 mi from peripheral breeding range; species breeds & summers sporadically in area | Possibly Exists |
| Ferruginous Hawk | | • | Year-round | Limited to None |
| Grasshopper Sparrow | | • | Breeding (on western edge of) | Possibly Exists [3] |
| Horned Lark | • | | Year-round | Possibly Exists [3] |
| Lark Bunting | | • | Breeding | Possibly Exists [3] |
| Lewis's Woodpecker | • | • | Year-round | Possibly Exists [3] |
| Loggerhead Shrike | | • | Year-round | Possibly Exists [3] |
| Mississippi Kite | • | | Breeding (on edge) | Possibly Exists [5] |
| Swainson's Hawk | • | • | Breeding | Limited to None |
| Willow Flycatcher | • | | Outside Normal Breeding Range [1] | Possibly Exists |

[1] Outside Normal Breeding Range, but within 100 miles of breeding range edge.

[2] Habitat for the Burrowing Owl is located in the black-tailed prairie dog town, which is now inactive.

[3] Species for which some breeding may occur, but the potential for the Historic Site to play a significant role in its conservation is limited (e.g., due to low quality or small area of breeding habitat).

[4] Breeding/summer records are available for the Historic Site and nearby (near Pueblo; Ross Lock, RMBO, personal communication). The Historic Site represents one of the few known locations with breeding/summer records in the state (making the breeding habitat within the Historic Site locally important).

[5] Species is in the lowest category of conservation potential, meaning that the Historic Site is unlikely to play a significant role in its conservation. However, a very small area of Colorado is considered within the breeding range of the species, and the Historic Site is within this small area (making the breeding habitat within the Historic Site locally important).

**Table 4.11.4-5. The number of individuals of species with highest conservation potential detected at Bent's Old Fort NHS during recent RMBO surveys.**

| Species | 2009 Survey | 2010 Survey | 2011 Survey | 2012 Survey | Total |
|---|---|---|---|---|---|
| Brown Thrasher | 15 | 20 | 15 | 18 | 68 |
| Common Nighthawk | 7 | 5 | 3 | 25 | 40 |
| Red-headed Woodpecker | 13 | 20 | 27 | 34 | 94 |
| Western Meadowlark | 167 | 316 | 182 | 521 | 1,186 |
| Yellow-billed Cuckoo | 11 | 1 | 3 | 22 | 37 |

**Table 4.11.4-6. Summary of the breeding landbirds indicator/measures and their contributions to the overall landbirds condition.**

| Indicator | Measure | Condition | Condition Rationale |
|---|---|---|---|
| Species Occurrence | Temporal Context | Good | Seventy-four percent of 72 species observed in 2001-2002 bird inventories were observed in 2009-2012 RMBO bird surveys at the Historic Site. Half of the birds not observed during recent surveys are primarily associated with habitat not surveyed in 2009-2012. Additionally, 26 species were observed in the 2009-2012 RMBO surveys that were not observed in 2001-2002. In a temporal context, the condition of breeding landbirds at the Historic Site is good. Data are available for a relatively small number of years, so no trend information is available at this time. |
| | Spatial Context | Good | In a comparison of RMBO bird surveys outside of (but in the vicinity of) the Historic Site to RMBO surveys within the Historic Site, there were 15 species that were not observed at the Historic Site from 2009-2012. However, of these 15 species, more than one-half have limited to no breeding habitat at the Historic Site, and all but one of the remaining species were observed only in small numbers in the region. Based on this comparison, the condition of breeding landbirds is good. Because data are available for a relatively small number of years, no trend information is available at this time. |
| | Conservation Context | Good | There are 23 species that have been observed during 2009-2012 and/or 2001-2002 surveys that are listed by one or more organization as being of conservation concern. We believe that five of these species have high conservation potential at the Historic Site. These are species that are within their normal breeding range and sufficient habitat exists at the Historic Site to support breeding. All of these species have been observed on recent RMBO surveys (each in all four years). Therefore, we consider the condition of species of conservation concern at the Historic Site to be good. We do not have sufficient data to justify a trend in the condition at this time. |




## Overall Condition

For assessing the condition of landbirds, we used one indicator with three measures that assessed landbird occurrence. This indicator is summarized in Table 4.11.4-6.

Although our assessment is based on limited data, we found no justification to warrant concern for landbird occurrence at Bent's Old Fort NHS at this time.

From the comparison of species detected in 2001 and 2002 to 2009-2012, we do not have any particular concerns for species occurrence. The temporal comparison found 19 species that were not detected during recent RMBO surveys. However, 10 of these species are primarily associated with wetlands, so they would not be expected to be observed during RMBO surveys in grassland

and riparian areas; two additional species are wetland dependent, but potential breeding habitat is in close proximity to survey points. None of the remaining seven species fall into the "existing" habitat class; they fall into the "possibly exists" or "limited to none" categories.

Furthermore, 26 different (new) species were observed in recent RMBO surveys but not in the 2001-2002 inventories.

Similarly, there was nothing particularly surprising or alarming when comparing species observed during recent RMBO surveys to the species observed during 2008-2012 regional RMBO surveys (IMBCR program). Fifteen species were observed that have the potential to occur at the Historic Site that were not detected during the 2009-2012 RMBO surveys. Of these 15 species, five were recorded at the Historic Site during the 2001 and/or 2002 CNHP surveys. Eight of the 15 species have limited to no breeding habitat at the Historic Site, and an additional species would not be expected to be observed because it is primarily associated with wetlands. The remaining species fall into the "possibly exists" breeding habitat class only; all but one were counted in small numbers in the regional surveys, and some of the species are on the edge of or are outside of their normal breeding ranges. A review of BBS data from nearby routes likewise raised no concerns for species occurrence.

We found five species that we believe have relatively high conservation potential at Bent's Old Fort NHS, and all of these have been observed numerous times at the Historic Site during recent years.

With the exception of slight concern for the Burrowing Owl (which was only observed in two of the four RMBO sampling years, but not since prairie dogs have disappeared from the Historic Site), based on the evidence presented here, we consider the condition of breeding landbirds at the Historic Site to be good. Unfortunately, we do not have sufficient data to justify a trend in that condition, although ongoing monitoring should provide such an estimate for future assessments.

Level of Confidence/Key Uncertainties

The key uncertainties related to this assessment are the overall lack of data (i.e., four years of recent data and two years of prior data) and subjectivity with respect to assigning individual species to range, habitat, or conservation classes. Although we are currently collecting data that will provide for a quantitatively rigorous analysis in the future, at the present time we relied primarily on qualitative indicators to assess the condition of landbirds.

We determined the breeding ranges primarily from the BNA species accounts and had to judge from online and hard copies whether or not the Historic Site was within those ranges. We tried to account for this uncertainty by also including species that were on the edge of their ranges (i.e., less than 100 miles from the breeding range edge). Similarly, there is considerable subjectivity in our assignment of habitat classes. We based this assessment on a combination of the BNA accounts, as well as our own and local knowledge of the species in question.

Although the RMBO regional data used for the spatial comparison were not as comprehensive as we would have preferred (not all of the five sampling sites were surveyed in each of the years from 2008-2012), we supported our analysis by also using data from the BBS covering 2009-2012.

### *4.11.5. Sources of Expertise*

Ross Lock, a wildlife biologist with RMBO, provided consultation and reviewed Tables 4.11.4-1, 4.11.4-2., and 4.11.4-4.

### *4.11.6. Literature Cited*

Alcock, J. 2005. Animal behavior: An evolutionary approach. Sunderland, Mass., Sinauer Associates.

Barrows, C. W., M. B. Swartz, W. L. Hodges, M. F. Allen, J. T. Rotenberry, B. L. Li, T. A. Scott, and X. W. Chen. 2005. A framework for monitoring multiple-species conservation plans. Journal of Wildlife Management 69:1333–1345.

Bibby, C. J, N. D. Burgess, D. A. Hill, and S. Mustoe. 2000. Bird census techniques. Second ed. London: Academic Press.

Bryce, S. A., R. M. Hughes, and P. R. Kaufmann. 2002. Development of a bird integrity index: Using bird assemblages as indicators of riparian condition. Environmental Management 30:294–310.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: Estimating abundance of biological populations. Oxford, U.K.: Oxford University Press.

Canterbury, G. E., T. E. Martin, D. R. Petit, L. J. Petit, and D. F. Bradford. 2000. Bird communities and habitat as ecological indicators of forest condition in regional monitoring. Conservation Biology 14:544–558.

Colorado Division of Wildlife (CDOW). 2006. Colorado's Comprehensive Wildlife Conservation Strategy and Wildlife Action Plans. Available online (http://wildlife.state.co.us/WildlifeSpecies/ColoradoWildlifeActionPlanPages/ColoradoWildlifeActionPlan.aspx).

Colorado Parks and Wildlife. 2012. Colorado Endangered, Threatened and Species of Special Concern. Accessed July 1, 2013. Available online (http://wildlife.state.co.us/WildlifeSpecies/SpeciesOfConcern/Birds/Pages/BirdsOfConcern.

Cornell Lab of Ornithology. 2013. The birds of North America. Online. (http://bna.birds.cornell.edu/bna/). Last accessed June 21, 2013.

Dale, V. H., and S. C. Beyeler. 2001. Challenges in the development and use of ecological indicators. Ecological Indicators 1:3–10.

Gionfriddo, J.P., D.R. Culver, and J. Stevens. 2002. Biological survey of Bent's Old Fort National Historic Site, Otero County, Colorado. Report submitted to the National Park Service by the Colorado Natural Heritage Program, Colorado State University.

Gionfriddo, J.P., and J. Stevens. 2003. Survey of Bent's Old Fort Natinal Historic Site for Breeding Birds and Anurans, May 2002. Report submitted to the National Park Service by the Colorado Natural Heritage Program, Colorado State University.

Hutto, R. L. 1985. Habitat selection by nonbreeding, migratory, land birds. Pages 455–476 in M. L. Cody, ed., Habitat selection in birds. Orlando, Fla.: Academic Press.

Lock, R., R.E. Bennetts, and H. Sosinski. 2012. Landbird monitoring in the Southern Plains Network: annual report, 2011. Natural Resource Technical Report NPS/SOPN/NRTR—2012/522. National Park Service, Fort Collins, Colorado.

National Park Service, Southern Plains Inventory and Monitoring Network (SOPN). 2008. Southern Plains Network Vital Signs Monitoring Plan. Natural Resource Report NPS/SOPN/NRR-2008/028. National Park Service, Fort Collins, Colorado.

Pavlacky, D. C., Jr., J. A. Blakesley, G. C. White, D. J. Hanni, and P. M. Lukacs. 2012. Hierarchical multi-scale occupancy estimation for monitoring wildlife populations. Journal of Wildlife Management 76:154-162, as cited in RMBO 2013.

Ringold, P. L., J. Alegria, R. L. Czaplewski, B. S. Mulder, T. Tolle, and K. Burnett. 1996. Adaptive monitoring design for ecosystem management. Ecological Applications 6:745–747.

Rocky Mountain Bird Observatory (RMBO). 2013a. Integrated monitoring in bird conservation regions (IMBCR). Available at http://rmbo.org/v3/OurWork/Science_/BirdPopulationMonitoring/IntegratedMonitoringinBCRs(IMBCR).aspx. Accessed June 27, 2013.

Rocky Mountain Bird Observatory (RMBO). 2013b. The Rocky Mountain Bird Observatory Avian Data Center. [web application]. Brighton, CO. http://rmbo.org/v3/avian/ExploretheData.aspx. Accessed: June 24, 2013.

Sekercioglu, C. H. 2002. Impacts of birdwatching on human and avian communities. Environmental Conservation 29:282–289.

Stevens, L. E., and B. D. Gold. 2003. Monitoring for adaptive management of the Colorado River Ecosystem in Glen and Grand Canyons. Pages 101–134 *in* D. E. Busch and J. C. Trexler, eds., Monitoring ecosystems: Interdisciplinary approaches for evaluating ecoregional initiatives. Washington, D.C.: Island Press.

Stevens, D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99:262-278, as cited in RMBO 2013.

U.S. Fish and Wildlife Service. 2008. Birds of Conservation Concern 2008. United States Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, Virginia. 85 pp. [Online version available at <http://www.fws.gov/migratorybirds/>].

U.S. Fish and Wildlife Service. 2012. Endangered and Threatened Wildlife and Plants; Listing Taylor's Checkerspot Butterfly and Streaked Horned Lark and Designation of Critical Habitat. DOI, USFWS, 50 CFR Part 17. Federal Register, Vol. 77, No. 197, Thursday, October 11, 2012. Proposed Rules.

U.S. Fish & Wildlife Service. 2013. Listings and occurrences for Colorado. http://ecos.fws.gov/tess_public/pub/stateListingAndOccurrenceIndividual.jsp?state=CO. Accessed July 1, 2013.

U.S. North American Bird Conservation Initiative. 2013. Main page. Online. (http://www.nabci-us.org). Accessed January 8, 2013.

Western National Parks Association (WNPA). 2006. A checklist of the birds of Bent's Old Fort National Historic Site, Colorado. Compiled by National Park Service Staff.

White, C. M., N. J. Van Lanen, D.C. Pavlacky Jr., J. A. Blakesley, R. A. Sparks, J. A. Fogg, M. F. McLaren, J. J. Birek and D. J. Hanni. 2012. Integrated Monitoring in Bird Conservation Regions (IMBCR): 2011 Annual Report. Rocky Mountain Bird Observatory. Brighton, Colorado.

Wiens, J. A. 1985. Habitat selection in variable environments: Shrub-steppe birds. Pages 191–226 in M. L. Cody, ed., Habitat selection in birds. Orlando, Fla.: Academic Press.

## 4.12. Black-tailed Prairie Dog (*Cynomys ludovicianus*)

**Indicators/Measures**

- Prairie Dog Occurrence (Area occupied and Density of prairie dogs)

**Condition – Trend - Confidence**



Significant Concern – Unchanging - High

### *4.12.1. Background and Importance*

Prairie dogs, which occur only in North America, are burrowing rodents that belong to the squirrel family. Prairie dogs are diurnal and live in colonies, or towns, which sometimes contain thousands of individuals and extend for miles. There are five species of prairie dogs, all of which may be considered rare (Hoogland 2006a). The black-tailed prairie dog (*Cynomys ludovicianus*) (Figure 4.12.1-1), the most abundant, widespread, and conspicuous of the five species, occurred at Bent's Old Fort NHS until the winter-spring of 2011-2012. At that time, the prairie dog colony on the Historic Site was decimated by sylvatic plague. As of September 2013, prairie dogs have not yet returned to the Historic Site. However, because of the significant ecological role that prairie dogs play in the landscape (described below), including at the Historic Site, their status as a management issue for the Historic Site, and because prairie dogs may, on their own, eventually return to their once-inhabited town at Bent's Old Fort NHS, they are included in this NRCA.

Prairie dogs are an important component of the ecosystems they inhabit. They directly and indirectly influence grasslands through their grazing and burrowing and as prey (Kotliar et al. 2006). Through their foraging and clipping of vegetation to maintain their habitat, as well as the mixing of subsoil and topsoil during excavations, prairie dogs affect the redistribution of minerals and nutrients, encourage penetration and retention of moisture, and affect plant species composition (Kotliar et al. 2006). Although they reduce the biomass of vegetation, they often also enhance the digestibility, protein content, and productivity of grasses and forbs at colony-sites (especially young colony-sites) that are preferred by large herbivores. Prairie dog colony-sites may extend for miles and contain hundreds of mounds that surround their burrow entrances. Black-tailed prairie dog mounds may be as high as 2.5 feet (0.75 meters), with a diameter up to 7 feet (2 meters; Hoogland 2006b). Because black-tailed prairie dogs eat or clip grasses and other plants that grow taller than about 12 inches (30 centimeters), vegetation at colony-sites is relatively short (Hoogland 2006b). Prairie dog burrows and colony-sites provide shelter and nesting habitat for a variety of animals (only some of which have been reported at Bent's Old Fort NHS), including insect and arachnid species, Burrowing Owls (*Athene cunicularia*), Mountain Plovers (*Charadrius montanus*), Horned Larks (*Eremophila alpestris*), and federally-endangered black-footed ferrets (*Mustela nigripes*; which do not occur at the Historic Site). Among the animals that consume prairie dogs are black-footed ferrets, American badgers (*Taxidea taxus*), long-tailed weasels (*Mustela frenata*),



PHOTO: JOHN GOOD

**Figure 4.12.1-1 Black-tailed Prairie Dog (*Cynomys ludovicianus*), the most abundant and widespread of the prairie dog species.**

bobcats (*Felis rufus*), coyotes (*Canis latrans*), Ferruginous Hawks (*Buteo regalis*), Golden Eagles (*Aquila chrysaetoes*), Prairie Falcons (*Falco mexicanus*), bull snakes (*Pituophis melanoleucus*), and prairie rattlesnakes (*Crotalus viridis*) (see Figure 4.12.1-2 for photos of some of these species). Additional species use prairie dog towns (see Sovell et al. 2008).

Within colonies, prairie dogs live in family groups called coteries. The size of a coterie ranges from 1 to 26 individuals, but a coterie generally consists of 1 breeding male, 2-3 adult females, and 1-2 yearling offspring of each gender (Hoogland 2006a). Most black-tailed prairie dogs reach sexual maturity and mate in the second February-March following their birth. Female prairie dogs have one litter of young per year, with the most common litter size being three. Breeding takes place in late January through early March, and gestation length is typically 34-35 days. On average, young emerge from the natal burrow 41 days after birth.

Black-tailed prairie dogs are thought to have once occupied 74 million acres from Canada to Mexico (Proctor et al. 2006), including parts of eleven states (Hoogland 2006b). Estimates for the species' occurrence in Colorado ranged from 3 million to 7 million acres (Clark 1989, Knowles 1998, Sovell 2008). However, after 200 years of shootings, poisonings, conversion of habitat, and more recently sylvatic plague, prairie dog numbers are a fraction of what they once were (Hoogland 2006b). Sylvatic plague, caused by the bacterium *Yersinia pestis*, is a disease transmitted by fleas; it can be contracted by various mammals and may kill nearly all prairie dogs in an infected colony (U.S. Geological Survey [USGS] 2008). Today, the black-tailed prairie dog's overall range is similar to its historic range, but it occupies only about 1.2 to 2.1 million acres (Proctor et al. 2006). An estimate for 2003 for Colorado was 631,578 acres occupied (Luce et al. 2006). In 2004, it was estimated that black-tailed prairie dogs inhabited about 6,900 acres of land managed by the NPS in the western United States (including Bent's Old Fort NHS; Sidle et al. 2006).

Prairie dog populations vary over time and space due to factors such as available forage, climate, predation, and disease (Hoogland 2006a). The first count of prairie dog burrows at Bent's Old Fort NHS was recorded in 1987 (Real West Natural Resource Consulting [RWNRC] 2001). One colony with 79 burrows that covered approximately 3.7 acres (1.5 ha)



PHOTO: ROB BENNETTS



PHOTO: BRYAN HARRY



PHOTO: BRYAN HARRY



PHOTO: ROBERT SHANTZ

**Figure 4.12.1-2 Species that benefit from black-tailed prairie dogs,clockwise from top left: Burrowing Owl (*Athene cunicularia*); Coyote (*Canis latrans*); Ferruginous Hawk (*Buteo regalis*); and American badger (*Taxidea taxus*).**

was reported south of the Arkansas River. Five years later, two colonies were reported south of the river with a combined 1,310 burrows and coverage of about 55 acres (22.3 ha). Prairie dogs were observed north of the river for the first time in 1997 (only one animal), and 31 burrows were reported there in 1999. To minimize management conflicts (e.g., to protect human health by minimizing visitor/prairie dog contact, and to prevent potential damage to archaeological resources), the prairie dogs on the north side of the river were translocated to the south colony in 1999 (RWNRC 2001; Fran Pannebaker, Bent's Old Fort NHS, pers. comm. 2013).

The colony south of the river has now been monitored on a regular basis for a number of years (e.g., see Figure 4.12.1-3), and monitoring details are provided in Section 4.12.4, "Condition and Trend." Prairie dog density at the Historic Site was estimated for the first time in 2000 (Fran Pannebaker, Bent's Old Fort NHS, pers. comm.), at an estimated 14.3 prairie dogs per hectare (5.8 per acre) using visual counts. Density estimates in 2009 were 79 prairie dogs per hectare (32 per acre) in June using visual counts, and 27.6 prairie dogs per hectare (11 per acre) in June using mark-recapture estimates (Pigg and Cully 2010). Animal species associated with prairie dog towns that have been recorded at Bent's Old Fort NHS include Burrowing Owls (but only in two years), Ferruginous Hawks, Horned Larks, and coyotes (Gionfriddo et al. 2002, Appendix I), as well as American badgers, bobcats, and Red-tailed Hawks (*Buteo jamaicensis*) (Fran Pannebaker, Bent's Old Fort NHS, pers. comm.).

Management of the black-tailed prairie dog varies substantially across its range; some states consider it a species of special concern, other states consider it a small game species, and still others consider it a vertebrate pest (USGS 2009). Because prairie dogs are both an important component of the ecosystem and, in some cases, damaging to other resources within and adjacent to parks, their management is important and complex. The policy of the National Park Service is to conserve and recover the black-tailed prairie dog wherever possible (RWNRC 2001, Sovell 2008). The NPS can control prairie dogs on its property only to protect human health and safety, for good neighbor relations, and to manage conflicts with other Historic Site objectives, such as the preservation of cultural resources.

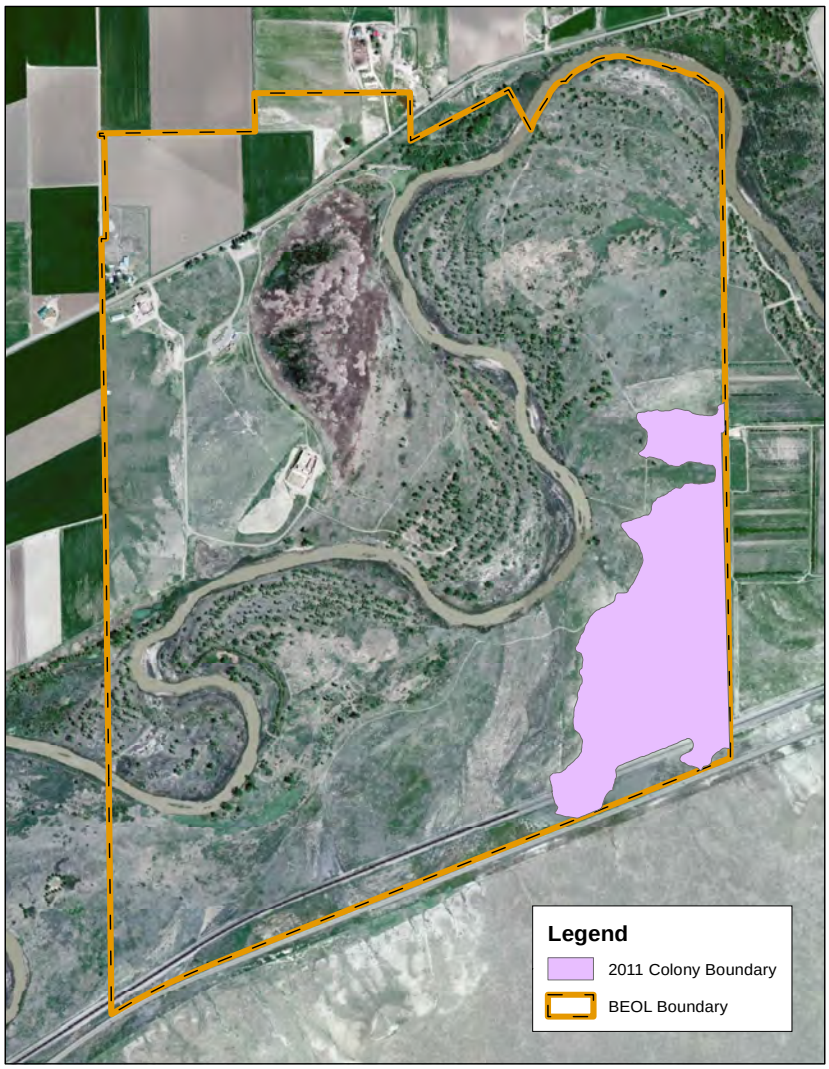



**Figure 4.12.1-3 Areal coverage of Black-tailed prairie dog colony in 2011, prior to the sylvatic plague event. (Source: annual surveys at the Historic Site.) Digital data from NPS Intermountain Region; collected in 2011 by Kansas State University.**

Bent's Old Fort NHS developed a *Prairie Dog Management Plan and Environmental Assessment* in 2001 (i.e., RWNRC 2001). The plan "provides for continued restoration of the site on the north side of the river to reflect conditions that were present in 1846" and allows for "natural expansion and contraction of the colony south of the Arkansas River. Consideration of control measures may be necessary if the colony expands into adjacent

private lands or if they expand onto identified archaeological sites." The management plan discusses potential management options for controlling prairie dogs, including: use of visual exclusion/planting methods; chemical methods only when necessary; and manual trapping and relocation from the north to the south side of the river. The plan includes annual monitoring to provide data over the long term.

### 4.12.2. Data and Methods

This assessment is based on all of the information on the prairie dog colonies at Bent's Old Fort NHS that is available. In some cases, the information presented is not easily comparable because prairie dog occurrence was sampled using varying methods. This is one of the reasons that the assessment is qualitative in nature. The primary information sources used for the assessment are described immediately below and consist of: 1) the Historic Site's *Prairie Dog Management Plan and Environmental Assessment* (RWNRC 2001); 2) a study on the prairie dog populations at Bent's Old Fort NHS (and three other small NPS units) (Pigg and Cully 2010); and 3) a continuation of the study reported in Pigg and Cully (2010) that is presented in Goldberg (2012). As available, we also used information collected by NPS personnel at Bent's Old Fort NHS as part of the Prairie Dog Management Plan (including digital maps depicting colony locations/areal coverage, and annual density estimates using visual counts). This description of primary information sources is followed by a discussion of the indicators/measures we used to determine the condition of prairie dogs at the Historic Site.

Primary Data Sources

*Prairie Dog Management Plan and Environmental Assessment (RWNRC 2001)*
The management plan includes a description of the known presence of black-tailed prairie dogs at the Historic Site for a number of years up to about 2000, and it provides summaries of studies and management actions that have been conducted at the Historic Site. We used the first component mentioned to describe the occurrence of prairie dogs at the Historic Site, and we reproduced details in a table in Section 4.12.4, "Condition and Trend." As described above, we also used data that were collected during monitoring under the Plan (~2000-2011). From 2002 onward, visual surveys were conducted in August using the protocol of Plumb et al. (2001).

*Study of Prairie Dogs at Bent's Old Fort NHS (Pigg and Cully 2010, and Goldberg 2012)*
Because additional information was needed on the prairie dog populations at Bent's Old Fort NHS (and other parks), such as on their dispersal to adjacent lands, a project (*Status and Management of Black-tailed Prairie Dogs on Small Cultural National Parks of the Western Great Plains*) was devised to collect information over multiple years. At Bent's Old Fort NHS, trapping was conducted from June 5-11 and from July 25-29, 2009. The report contains prairie dog density estimates based on the sampling, a report on the number and type of burrows counted, and some information on prairie dog movements from radio telemetry work. The authors used two methods to estimate prairie dog density. One method used the protocol of Plumb et al. (2001) for visual counts, and the other used capture data and models in program CAPTURE. We mention both abundance estimates in our assessment.

The 2009 study continued in 2010 and 2011, and relevant information was collected on prairie dog dispersal and estimating abundance (Goldberg 2012). The researchers estimated prairie dog abundance using visual counts (Plumb et al. 2001 protocol) and mark-recapture and mark-resight methodologies. One of the project's objectives was to compare the various methods used; we do not present many details on this comparison in the condition assessment, so we refer the reader to Goldberg (2012) for more information, if desired, on that topic.

**Indicator/Measures**
Prairie Dog Occurrence: (Area occupied and Density of prairie dogs)

Estimates of prairie dog populations are usually based on the amount of occupied habitat, rather than on the number of

individual animals (U.S. Fish and Wildlife Service [USFWS] 2009). However, density of prairie dogs (number of prairie dogs per unit of area) may also be estimated, and its use appears to be on the rise (e.g., Goldberg 2012). Because we have some information on each of these metrics, as well as the number of prairie dog burrows, we present all of the available information in this assessment (except for some abundance estimates for methods comparison by Goldberg [2012]).

We assessed prairie dog occurrence, area occupied and density of prairie dogs, by looking at changes in the area occupied/ density of prairie dogs over time. These qualitative assessments were conducted using the primary data sources described above.

### 4.12.3. Reference Conditions

Reference conditions for prairie dogs are complex and highly dependent on the perspective from which they are taken. For example, a landowner that makes his or her living from production needs to consider the decreased plant biomass associated with prairie dog colonies, as well as the potential for injury of stock animals. Thus, from their perspective the condition of the resource may be best when prairie dogs are in very low numbers or entirely absent. In contrast, from an ecological perspective, prairie dogs have a pronounced impact on their ecosystem (Kotliar et al. 2006). As discussed in Section 4.12.1, prairie dogs increase habitat diversity and contribute to grassland ecosystem processes. Prairie dogs clip the vegetation and maintain open habitats preferred by some animals, such as the Horned Lark and Burrowing Owl. Many species, such as the American badger, prairie rattlesnake, Burrowing Owl, and the federally endangered black-footed ferret, prey on prairie dogs or use their burrows for shelter. Thus, from an ecological standpoint, having a healthy population of prairie dogs may be viewed positively, especially when considering the suite of other species that may benefit from their presence. However, even from an ecological perspective, having an overabundance of prairie dogs may have detrimental consequences to the vegetation.

In this condition assessment, we focus on the prairie dog's ecological role in the grassland ecosystem. We do, however, acknowledge that prairie dogs in a national park also pose difficulties to management, particularly with regard to adjacent land owners who do not value prairie dogs on their property, and the damage that prairie dog excavations can cause to important cultural resources that the park must protect.

### 4.12.4. Condition and Trend

Prairie dog occurrence: Area occupied and Density of prairie dogs

*Area Occupied*

Black-tailed prairie dogs did not inhabit land on the north side of the Arkansas River at Bent's Old Fort NHS for long. They were first observed there in 1997, and while their town was estimated to cover about 0.5 acres (0.20 ha) in 1999 (Table 4.12.4-1), they were trapped and relocated to the south side of the river to avoid conflicts with archaeological resources and visitors. Prairie dogs have not occurred north of the river since that time.

Information on the prairie dog colony south of the river is available for a period of about 25 years. In 1987, the colony occupied about 3.7 acres (1.5 ha); the coverage fluctuated over the years, and the coverage increased from about 10 acres (4 ha) in 2001 to 68.2 acres (27.6 ha) in 2011 (Table 4.12.4-1). In late 2011 to early 2012, the sylvatic plague swept through the colony and appeared to have resulted in 100% mortality. The acreage occupied by prairie dogs in the south colony of Bent's Old Fort NHS dropped to 0 acres in 2012 (and remained at 0 in 2013) (Fran Pannebaker, Bent's Old Fort NHS, pers. comm.). In the summer of 2013, a few individual prairie dogs were observed in the vicinity of the southern portion of the previous colony, between the railroad tracks and Highway 50 (Fran Pannebaker, Bent's Old Fort NHS, pers. comm). At this time, however, it is not known whether the individuals will inhabit the previous colony or move off-site, or whether their numbers will grow.

**Table 4.12.4-1. Area occupied, estimated densities, and number of burrows of black-tailed prairie dogs at Bent's Old Fort NHS from various studies and surveys.**

| Colony | Year | Area Occupied in Acres (and Hectares) | Density of prairie dogs in Hectares (and Acres) | Other Information | Source |
|---|---|---|---|---|---|
| South | 1987 | ~ 3.7 acres (1.5 ha) | No Data | 79 burrows counted | Reported in RWNRC (2001) |
| South, 2 colonies | 1992 | ~ 55 acres (22.3 ha) total | No Data | 205 prairie dogs observed; 1,310 burrows counted | Survey by Historic Site personnel; reported in RWNRC (2001) |
| South | 1995 | No Data | No Data | <100 prairie dogs observed | Reported in RWNRC (2001) |
| South | 1999 | ~2.0 acres (0.8 ha) | No Data | 236 burrows counted; a small colony was also present adjacent to the Historic Site on land managed by CDW | Reported in RWNRC (2001) |
| South | 2000 | 13.7 acres (5.5 ha) | 14.3 prairie dogs/ha (5.8/acre) | ----- | NPS [1] |
| South | 2001 | 9.97 acres (4 ha) | No Data | ---- | NPS [1] |
| South | 2002 | 38.2 acres (15.4 ha) | 23.6 prairie dogs/ha (9.5/acre) | ---- | NPS [1] |
| South | 2003 | 48.3 acres (19.5 ha) | 28.6 prairie dogs/ha (11.6/acre) | ---- | NPS [1] |
| South | 2005 | 51.2 acres (20.7 ha) | 27.4 prairie dogs/ha (11.1/acre) | ---- | NPS [1] |
| South | 2007 | No Data | 28.0 prairie dogs/ha (11.3/acre) | ---- | NPS [1] |
| South | 2009 | 53.8 acres (21.8 ha) [1] | 79 per ha (32 per acre) in June, and 82 per ha (33 per acre) in July; measured with visual counts | density = 27.6 per ha (11 per acre) in June, and 65.8 per ha (27 per acre) in July using CAPTURE analysis | Pigg and Cully (2010) (for density estimates) |
| South | 2010 | 65.98 acres (26.7 ha) total [1] | 67.5 per ha (27 per acre) in April / May, and 35 per ha (14 per acre) in July / Aug; measured with visual counts [2] | Study site was 4 ha (9.9 acres) in size. Author also reported density estimates (not presented here) using other other methods | Goldberg (2012) (for density estimates) |
| South | 2011 | 68.2 acres (27.6 ha) [1] | 42.5 per ha (17 per acre) in April / May, and 60 per ha (24 per acre) in July / Aug; measured with visual counts [2] | Study site was 4 ha (9.9 acres) in size. Author also reported density estimates (not presented here) using other other methods | Goldberg (2012) (for density estimates) |
| | | | | | |
| North | 1997 | No Data | No Data | One prairie dog observed | Reported in RWNRC (2001) |
| North | 1999 | ~0.5 acres (0.20 ha) | No Data | No prairie dogs observed. 31 burrows counted. A total of 15 prairie dogs had been trapped and relocated to the south colony | Reported in RWNRC (2001) |

RWNRC (2001) = Prairie Dog Management Plan and draft Environmental Assessment, prepared by Real West Natural Resource Consulting.

[1] Source is annual monitoring survey by NPS personnel. Data on area occupied obtained from NPS Intermountain Region; data on density from F. Pannebaker, Bent's Old Fort NHS. Density estimates from visual surveys in August from 2002-2007.

[2] Goldberg (2012) presented abundance estimates, for 4-ha study sites, rather than density estimates. We converted abundance estimates (taken from Figure 3.1 of Goldberg [2012]) to densities by dividing by 4 ha.

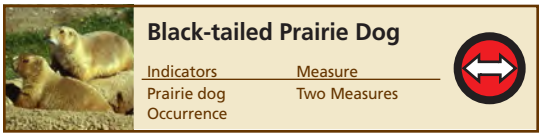
**Table 4.12.4-2. Indicators and measures of black-tailed prairie dog condition, their corresponding assigned condition class(es), and the rationale for assigning the condition class(es).**

| Indicator | Measures | Condition | Rationale for Condition |
|---|---|---|---|
| Prairie dog occurrence | Area occupied | Significant Concern | Acreages occupied were estimated in many years from 1987-2011. Area occupied by prairie dogs increased from about 10 acres (4 ha) in 2001 to 68.2 acres (27.6 ha) in 2011. However, in late 2011/early 2012, the area occupied dropped to 0 acres due to the sylvatic plague. The former colony remains unoccupied to date. Therefore, the condition of prairie dogs is of significant concern. It should be noted, however, that in the summer of 2013 a few individual prairie dogs were observed in the vicinity of the southern portion of the previous colony (between the railroad tracks and Highway 50), but it is not known if they will move into the previous colony or whether their numbers will grow. |
| | Prairie dog density | Significant Concern | Density (prairie dogs per unit area) was estimated in a number of years from 2000-2011. After several years of similar density estimates from visual surveys, there was an increase from August 2007 to July 2009. Using the density estimates from visual surveys, densities may have declined somewhat from 2009 to 2011 (based on a crude comparison of estimates from June 2009 to April/May 2011 and July 2009 to July/August 2011). Whether or not there was an actual decline over these later years, there was a crash in the density by late 2011/early 2012, when the density reached 0 due to the sylvatic plague. Therefore, based on density, the condition of prairie dogs is of significant concern. Also see last sentence above. |

*Prairie Dog Densities*

Prairie dog densities were estimated using visual counts for the first time in 2000, when 14.3 individuals per hectare (5.8 per acre) were estimated in the colony south of the river. From 2000 to 2007, estimated densities (in August) remained below 30 prairie dogs per hectare (12.1 per acre). However, in 2009, the estimated density using visual counts increased to 79 per hectare (32 per acre) in June and 82 per hectare (33 per acre) in July (Table 4.12.4-1). Two estimates are presented for each year in 2009-2011, because estimates are often made for the period before juveniles emerge from the burrows (sampling period of April/May), and after juveniles emerge (sampling period of July/August; Goldberg 2012). For all three years from 2009-2011, the table shows density estimates using visual counts. Although Goldberg (2012) reported that other methods of estimation are more precise (mark-resight), or may be preferable when certain types of information are needed (mark-recapture), we present the data from visual counts (protocol of Plumb et al. 2001), because it is the method called for in the Historic Site's Monitoring Plan (and used 2000-2007), and there are data for 2009-2011 using the method. Additionally, Goldberg (2012) pointed out that under certain conditions (prairie dog colony is on level ground with good visibility), visual counts using the Plumb et al. (2001) protocol may be the most cost-effective, quickest, and easiest method.

In a very crude comparison of the density estimates from 2009 to 2011 (i.e., June 2009 to April/May 2011 and July 2009 to July/August 2011), the prairie dog density appears to have potentially declined somewhat. Whether or not there was a fluctuation or decline from 2009-2011, there definitely was a decline by late 2011/early 2012; due to the sylvatic plague event that occurred at Bent's Old Fort NHS and the adjacent area, prairie dog densities dropped to zero.




Overall Condition and Trend

Based on the information available at this time, and using the ecological reference condition stated in Section 4.12.3, the condition of the black-tailed prairie dog at Bent's Old Fort NHS is of significant concern. This indicator

is summarized in Table 4.12.4-2. The trend is unchanging at this time; the condition deteriorated in late 2011-early 2012, when the prairie dog population was reduced to zero. Both area occupied and density of prairie dogs dropped to zero. The population can not deteriorate further from that point, and there is no evidence of an increase at this time (except for the few individual prairie dogs that were observed at the southern edge of the NHS in July of 2013). As discussed in the next section, however, the prairie dog population at the Historic Site could increase in the future (although this is an area of high uncertainty). Prior to the 2011-2012 plague event, sylvatic plague had not been recorded in the immediate vicinity of the Historic Site (Fran Pannebaker, Bent's Old Fort NHS, pers. comm.).

Although prairie dogs provide numerous ecological benefits, they are also known for potentially causing damage to resources on national parks (e.g., cultural or archaeological sites) and concern to adjacent landowners who do not want prairie dogs on their land. As described previously, the Historic Site had developed a prairie dog management plan for the Historic Site to minimize such potential problems. At least for the time being, prairie dog management efforts at Bent's Old Fort NHS are not needed.

Level of Confidence/Key Uncertainties

According to the best available information, prairie dogs within Bent's Old Fort NHS suffered 100% mortality by late 2011/early 2012, and prairie dogs on the state-owned property adjacent to the Historic Site disappeared as well (Fran Pannebaker, Bent's Old Fort NHS, pers. comm.). After realizing that the Historic Site's prairie dog population had been hit by the sylvatic plague, F. Pannebaker conducted driving surveys to determine whether prairie dog colonies in the surrounding area had been affected. She found that: a large colony about eight miles from the Historic Site (west and north) along Highway 109 had collapsed; a colony about 10 miles west of the Historic Site (west of La Junta) had collapsed; and a colony two miles west of the Historic Site on the south side of the river had suffered mortalities, although there were some survivors. Effects on colonies east and south of the Historic Site were undetermined because of their inaccessibility. There is a possibility that prairie dogs could recolonize, on their own, the Historic Site in the future. It is possible that the few individuals spotted in July 2013 between the railroad tracks and Highway 50 could lead to more individuals returning. This is an area of uncertainty.

Factors influencing recolonization would include whether 100% mortality of prairie dogs adjacent to the Historic Site actually occurred; the distance from the Historic Site to the closest active prairie dog town(s), and the habitat in between (i.e., would the land between be conducive to prairie dog movements); and dispersal distances of prairie dogs. Although these questions cannot be answered at this time, there are some data available.

Some information on black-tailed prairie dog recolonization rates is available from studies involving control of prairie dog populations. For instance, Knowles (1986) found that it took three-five years for colonies receiving a 95% population reduction (using zinc phosphide) to obtain pretreatment numbers. Similarly, Crosby and Graham (1986) estimated that a black-tailed prairie dog population reduced by 77% or less would likely attain pre-control levels within three years (so a population reduced by more than 77% would take longer than three years to recover). A study of a prairie dog colony whose abundance was reduced by 95% due to plague (and the colony area was reduced by 89%) found that more than half of the surviving individuals had antibodies to *Yersinia pestis* (Pauli et al. 2006). The authors pointed out that although others have suggested that colony growth after a plague event is probably due to recolonization by prairie dogs dispersing from other colonies (Antolin et al. 2002), plague survivors may be critical in repopulating the colony.

Two other recent studies provide some information on dispersal rates and distances of prairie dogs. One study, using nearly 150 VHF collars and a handful of GPS collars, observed eight intercolony dispersal events

over the three-year study (Goldberg 2012). Yearling males, adult females, and yearling females were the most likely to disperse from the colony. Three kilometers (1.9 miles) was the longest confirmed dispersal distance, although a few dispersals of up to 6.5 kilometers (4 miles) may have occurred. Another study found that related individuals were found up to 60 kilometers (37.3 miles) distant from one another, although it may have taken more than one generation to disperse the distance (Wisely et al. 2012).

### *4.12.5. Sources of Expertise*

For this assessment, we relied on previous reports and publications, and personal communications with Fran Pannebaker at Bent's Old Fort NHS.

### *4.12.6. Literature Cited*

Antolin, M.F., P. Gober, B. Luce, D.E. Biggins, W.E. Van Pelt, D.B. Seery, M. Lockhart, and M. Ball. 2002. The influence of sylvatic plague on North American wildlife at the landscape level, with special emphasis on black-footed ferret and prairie dog conservation. Transactions of the North American Wildlife and Natural Resources Conference 67:104-127, as cited in Pauli et al. (2006).

Clark, T.W. 1989. Conservation biology of the black-footed ferret, *Mustela nigripes*. Wildlife Preservation Trust Special Scientific Report No. 3. Wildlife Preservation Trust International. Philadelphia, Pennsylvania. 175 pp, as cited in Sovell (2008).

Crosby, L.A., and R. Graham. 1986. Population dynamics and expansion rates of black-tailed prairie dogs. Proceedings of the Twelfth Vertebrate Pest Conference. Paper 18. http://digitalcommons.unl.edu/vpc12/18.

Gionfriddo, J.P, D.R. Culver, and J. Stevens. 2002. Biological survey of Bent's Old Fort National Historic Site, Otero County, Colorado. Report submitted to the National Park Service by the Colorado Natural Heritage Program, Colorado State University.

Goldberg, A.R. 2012. Apparent survival, dispersal, and abundance of black-tailed prairie dogs. M.S. Thesis, Kansas State University, Manhattan, Kansas.

Hoogland, J. 2006a. Social behavior of prairie dogs. Pps 7-26, In Hoogland, J. (ed.) Conservation of the black-tailed prairie dog: Saving North America's Western grasslands. Island Press, Washington.

Hoogland, J. 2006b. Introduction: Why care about prairie dogs? Pps 1-6, In Hoogland, J. (ed.) Conservation of the black-tailed prairie dog: Saving North America's Western grasslands. Island Press, Washington.

Knowles, C.J. 1986. Population recovery of black-tailed prairie dogs following control with zinc phosphide. Journal of Range Management 39(3):249-251.

Knowles, C.J. 1998. Availability of black-tailed prairie dog habitat for black-footed ferret recovery. U.S. Fish and Wildlife Service. Unpublished report. 12 pp., as cited in Sovell (2008).

Kotliar, N., B. Miller, R. Reading, and T. Clark. 2006. The prairie dog as a keystone species. Pps 53-64, In Hoogland, J. (ed.) Conservation of the black-tailed prairie dog: Saving North America's Western grasslands. Island Press, Washington.

Luce, R., R. Manes, and B. Van Pelt. 2006. A multi-state plan to conserve prairie dogs. Pps 210-217, In Hoogland, J. (ed.) Conservation of the black-tailed prairie dog: Saving North America's Western grasslands. Island Press, Washington.

Pauli, J.N., S.W. Buskirk, E.S. Williams, and W.H. Edwards. 2006. A plague epizootic in the black-tailed prairie dog (Cynomys ludovicianus). Journal of Wildlife Diseases 42(1):74-80.

Pigg, R., and J. Cully. 2010. Status and management of black-tailed prairie dogs on small cultural parks of the Western Great Plains. Status Report 2009. Kansas

Cooperative Fish and Wildlife Research Unit, and Kansas State University.

Plumb, G.E., G.D. Wilson, K. Kallin, K. Shinn, and W.M. Rizzo. 2001. Black-tailed prairie dog monitoring protocol for seven prairie parks. Northern Prairie Wildlife Research Center Inventory and Monitoring Program, U.S. Deparment of Interior and U.S. Geological Survey.

Proctor, J., B. Haskins, and S.C. Forrest. 2006. Focal areas for conservation of prairie dogs and the grassland ecosystem. Pps 232-247, In Hoogland, J. (ed.) Conservation of the black-tailed prairie dog: Saving North America's Western grasslands. Island Press, Washington.

Real West Natural Resource Consulting (RWNRC). 2001. Bent's Old Fort National Historic Site prairie dog management plan and draft environmental assessment. Prepared for Bent's Old Fort NHS, La Junta, Colorado by RWNRC, Laramie, Wyoming.

Sidle, J., G. Schenbeck, E. Lawton, and D. Licht. 2006. Role of federal lands in the conservation of prairie dogs. Pps 218-231, In Hoogland, J. (ed.) Conservation of the black-tailed prairie dog: Saving North America's Western grasslands. Island Press, Washington.

Sovell, J. 2008. Sand Creek Massacre National Historic Site: Draft prairie dog management plan and environmental assessment. Natural Resource Report NPS/SOPN/NRR-2008/001. National Park Service, Fort Collins, Colorado.

Sovell, J., J. Bell, and S. Neid. 2008. Sand Creek Massacre National Historic Site rare vertebrate species inventory. Natural Resource Report NPS/SOPN/NRTR-2008/001. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

U.S. Fish and Wildlife Service (USFWS). 2009. Black-tailed prairie dog. Information on endangered species of the Mountain-Prairie Region, USFWS, obtained online at http://www.fws.gov/mountain%2Dprairie/species/mammals/btprairiedog/. Accessed February 2, 2009.

U.S. Geological Survey (USGS). 2008. Protecting black-footed ferrets and prairie dogs against sylvatic plague. Two-page Fact Sheet, 2008-3087, October 2008, available at http://www.nwhc.usgs.gov/disease_information/sylvatic_plague/publications/protecting_black-footed_ferrets.pdf.

U.S. Geological Survey (USGS). 2009. Black-tailed prairie dog facts. Available online at http://www.mesc.usgs.gov/resources/spotlight/prairiedogs/pdog_facts.asp. Last accessed February 4, 2009.

Wisely, S.M., J. Cully, and C. Lee. 2012. Patterns and processes of dispersal of black-tailed prairie dogs in a heavily managed landscape of the Great Plains Landscape Conservation Cooperative. Kansas State University, Manhattan, Kansas, for U.S. Fish and Wildlife Service.

## 4.13. Fish

**Indicators/Measures**

- Species Occurrence

**Condition – Trend - Confidence**



Insufficient Data - Insufficient Data - Low

### *4.13.1. Background and Importance*

Bent's Old Fort National Historic Site (NHS) is situated along 2.2 miles (3.5 km) of the Arkansas River and contains seven wetlands (Vana-Miller et al. 2010). Sampling to document presence of fish species occurred in the Arkansas River, Arch Wetland, and Day Pond.

### *4.13.2. Data and Methods*

This limited assessment is based on four fish surveys that were conducted at the Historic Site-three specifically for the Site and one for Colorado Parks and Wildlife (Nesler et al. 1999, Gionfriddo et al. 2002, Tisdale-Hein 2006, and Foutz et al. (2012 unpub. dataset)). The indicator used for this assessment is presence or absence of fish species.

**Indicators/Measures**
Species Occurrence

Fish species observed by Nesler et al. (1999), were reported in Tisdale-Hein (2006). Nesler et al. (1999) surveyed the reach along the Historic Site's boundary and beyond (Tisdale-Hein 2006). Species observed are listed in Table 4.13.2-1.

Gionfriddo et al. (2002) sampled for fish only at Day Pond and the Arch Wetland and detected four species (Table 4.13.2-1). They directly observed and used dip and seine nets to identify fish species for a total of eight hours between August 6-18, 2001.

Tisdale-Hein (2006) detected 11 species of fish, eight of which were new species from September 12-15, 2005 (note they report 12 species detected but the Mosquito fish, *Gambusia affinis*, was accounted for twice since it was found at both sampling locations). They sampled in the Arch Wetland and the Arkansas River using baited traps at both locations as well as dip and seine nets in the Arkansas River.

Foutz et al. (unpub. dataset) sampled for fish in the Arkansas River only (Figure 4.13.1-1) on August 10, 2012 and detected ten species,



FOUTZ ET AL. (2012)

**Figure 4.13.1-1. The Arkansas River reach where Foutz et al. (2012) conducted fish sampling within the Historic Site.**

**Table 4.13.2-1. Fish species detected during inventories.**

| Scientific Name | Common Name | Nesler et al. (1999) | Gionfriddo et al. (2002) | Tisdale-Hein (2006) | Foutz et al. (2012) |
|---|---|---|---|---|---|
| | | Areas Surveyed | | | |
| | | Arkansas River[1] | Day Pond and Arch Wetland | Arkansas River and Arch Wetland | Arkansas River |
| *Ameiurus sp* | Bullhead catfish | | | • | |
| *Campostoma anomalum* | Stoneroller | • | | | |
| *Catostomus catostomus*[2] | Longnose sucker | • | | | |
| *Catostomus commersonii* | White sucker | • | | | • |
| *Culaea inconstans* | Brook stickleback | | | • | |
| *Cyprinus carpio*[2] | Common Carp | • | • | | |
| *Dorosoma cepedianum* | Gizzard shad | • | | | • |
| *Fundulus zebrinus* | Plains Killifish | • | • | • | • |
| *Gambusia affinis*[2] | Mosquitofish | | • | • | • |
| *Hybopsis gracilis (Platygobio gracilus)*[SC] | Flathead chub | | | • | • |
| *Ictalurus punctatus* | Channel catfish | | | • | • |
| *Lepomis cyanellus* | Green Sunfish | • | • | | |
| *Lepomis humilis* | Orangespotted sunfish | • | | | |
| *Lepomis macrochirus*[2] | Bluegill | | | • | |
| *Micropterus salmoides*[2] | Largemouth bass | • | | | |
| *Notropis lutrensis* | Red shiner | | | • | • |
| *Notropis stramineus* | Sand shiner | | | • | • |
| *Perca flavescens*[2] | Yellow perch | • | | | |
| *Phenacobius mirabilis*[SE] | Suckermouth minnow | | | • | • |
| *Pimephales promelas* | Fathead minnow | | | • | • |
| *Pomoxis annularis*[2] | White crappie | • | | | |
| *Pomoxis nigromaculatus*[2] | Black crappie | • | | | |
| *Rhinichthys cataractae* | Longnose dace | Listed in NPSpecies Certified Species List retrieved on August 23, 2013 but not listed in any of the studies shown above. | | | |

[1]Nesler et al. (1999) surveyed a reach that continued to extend beyond the Historic Site's boundary.

[2]Non-native species

[SC] State Special Concern (not a statutory category) and [SE] State Endangered (Colorado Parks and Wildlife 2011).

Note: *Sander vitreus x Sander canadense was* only observed in Nesler et al. (1999) study which may have been beyond the Historic Site's boundary. This species is not listed in NPSpecies Certified Species List retrieved on August 23, 2013

on August 10, 2012 and detected ten species, with two representing new species (Table 4.13.2-1).

In total, 22 species of fish were detected through the inventory efforts, with eight representing non-native species. An additional species listed in the Historic Site's NPS Certified Fish Species List (2013), Longnose dace (*Rhinichthys cataractae*), was included in Table 4.13.2-1, for a total of 23 species.

### *4.13.3. Reference Conditions*

No reference conditions were developed for this resource topic.

### *4.13.4. Condition and Trend*

The fish habitat found in the Arkansas River compared to the habitat in the Arch Wetland and Day Pond are different, therefore, most likely support different species of fish (Tisdale-Hein 2006). Only one species, mosquitofish, which is non-native, was detected in both the Arkansas River and Arch Wetland between

**Table 4.13.4-1. Indicator and measure of fish condition.**

| Indicator of Condition | Measure | Condition | Rationale for Condition. |
|---|---|---|---|
| Species Occurrence | Presence/absence of fish | Insufficient Data | To date, a total of 23 fish species have been detected at the Historic Site, with 8 species (34.8%) representing non-natives. No subsequent monitoring has occurred to document the current presence or absence of these species, therefore, condition status is currently unknown. |

the inventories conducted by Gionfriddo et al. (2002) and Tisdale-Hein (2006). Five fish species were detected by Gionfriddo et al. (2002) in the Arch Wetland, and these same species were detected by Nesler et al. (1999) in the Arkansas River (Tisdale-Hein 2006).

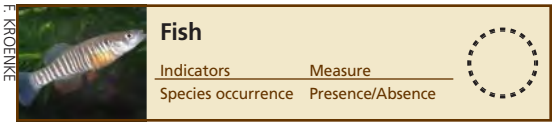
Both Foutz et al. (2012) and Nesler et al. (1999) conducted their inventories in the Arkansas River only, 13 years apart. Only three of the same species were reported by both efforts.

In addition to identifying fish species occurrence at the Historic Site, a secondary objective of the fish sampling conducted by Tisdale-Hein (2006) was to document the presence of individuals or habitat of the state-threatened Arkansas darter (*Etheostoma cragini*). They surveyed the Arch Wetland and the Arkansas River but did not find any present. They indicated that the darter prefers "habitat in shallow, clear streams with sandy substrate and abundant emergent vegetation, with the only apparent darter habitat component missing from the Arkansas River at this site being the lack of in-river emergent vegetation" (Tisdale-Hein 2006).

Two species with Colorado state status, Flathead chub (*Hybopsis gracilis*/*Platygobio gracilus*) and the Suckermouth minnow (*Phenacobius mirabilis*) were identified by Tisdale-Hein (2006) and most recently by Foutz et al. (2012).

The Flathead chub (*Hybopsis gracilis*/*Platygobio gracilus*) is a species of concern in Colorado and state threatened in Kansas but stable throughout the remainder of its North American range (USGS 2012). The Flathead chub is found in the plains area of the Arkansas River Basin and has been eliminated from upstream of Florence, Colorado (USGS 2012). Barriers such as dams and grade control structures may impede movement and migration, especially during spawning, which may be contributing to its decline (USGS 2012).

The Suckermouth minnow (*Phenacobius mirabilis* is endangered in Colorado and stocking efforts into the Arkansas River above John Martin Reservoir in the vicinity of the Rocky Ford and Oxbow State Wildlife Areas were made in November 2011 by Colorado Parks and Wildlife (Colorado Division of Wildlife 2011). The stocked minnows were offspring from adults collected from the Colorado wild where small populations existed ( Colorado Division of Wildlife 2011).



F. KROENKE

Overall Condition and Trend

Four fish inventories have been conducted at the Historic Site to document the occurrence of species. To date, a total of 23 species were detected, with 8 species (34.8%) representing non-natives, one species listed in the NPSpecies Certified Species List but not in the studies. No subsequent monitoring has occurred to document the continued presence or absence of these species, therefore, condition status and trend is currently unknown. Refer to Table 4.13.4-1 for the indicator and condition summary.

## *4.13.5. Sources of Expertise*

This section is based on the three fish inventory reports/data specifically collected for the Historic Site: Gionfriddo et al. 2002, Tisdale-Hein 2006, and Foutz et al. (unpub. dataset) and one report Nesler et al. (1999) conducted for Colorado Parks and Wildlife that included the reach of Arkansas River flowing through the Historic Site.

### *4.13.6. Literature Cited*

Colorado Division of Wildlife. 2011. Rare minnows restored to the Arkansas River. Available at http://wildlife.state.co.us/Newsapp/press.asp?PressId=7487 (accessed September 17, 2013).

Colorado Parks and Wildlife. 2011. Threatened and endangered list. Available at http://wildlife.state.co.us/WildlifeSpecies/SpeciesOfConcern/ThreatenedEndangeredList/Pages/ (accessed August 22, 2013).

Foutz et al. 2010. Warmwater stream survey, unpublished data.

Gionfriddo, J. P., D. R. Culver, and J. Stevens. 2002. Biological Survey of Bent's Old Fort National Historic Site, Otero County, Colorado. Colorado Natural Heritage Program, Fort Collins, CO.

Nesler, T.P., C. Bennett, J. Melby, G. Dowler, and M. Jones. 1999. Inventory and Status of Arkansas River Native Fishes in Colorado. Colorado Division of Wildlife.

Tisdale-Hein, Rinda E. 2006. Survey of fish and plant species in Arch Wetland and Arkansas River at Bent's Old National Historic Site. Unpublished Report. Bent's Old Fort National Historic Site, La Junta, CO.

Vana-Miller, D., C. Moore, J. Hughes and K. Noon. 2010. Water resources information and issues overview report: Bent's Old Fort National Historic Site. Natural Resource Report NPS/NRPC/WRD/NRR—2010/258. National Park Service, Fort Collins, Colorado.

United States Geological Survey (USGS). 2012. Spawning-related movements of Flathead chub in a prairie stream. Available at http://www.fort.usgs.gov/Research/research_tasks.asp?TaskID=2396 (accessed September 17, 2013).



KIM STRUTHERS

**NRCA meeting at Bent's Old Fort NHS.**

# Chapter 5: Discussion of Natural Resource Condition Assessment Findings and Considerations for Park Planning

## 5.1. Introduction

The primary purpose of the Natural Resource Condition Assessment (NRCA) Chapter 5 is to provide a "big picture" - broader application of resource condition findings (Albright 2010). We will fulfill this purpose by:

- creating a framework that connects the natural resource findings to Bent's Old Fort National Historic Site's purpose, significance, and fundamental resource and value statements

- delivering completed *State of the Park* natural resource condition summary tables and resource briefs for each of the topics assessed; and

- providing resource narratives for each assessed topic indicating data gaps, and highlighting potential management and project considerations, if applicable.

These Chapter 5 reporting pieces are *value added* products that can be used by park managers for a variety of resource planning and comprehensive park management purposes (Jeff Albright, NRCA Program Coordinator, pers. comm. August 23, 2013). Additionally, efficiencies are gained by providing these "ready to use products" because they deliver information to park staff that directly meet other reporting requirements, such as those for the *State of the Park* report, or they provide information that can be easily modified as needed (re: resource narratives) to be used for PMIS proposals as background information and problem statements, for other funding proposals, priority setting, or for interpretive purposes.

## 5.2. Connecting Natural Resource Condition Assessment Findings to Park Purpose, Significance, and Fundamental Resources & Values

Managing the natural resources at Bent's Old Fort NHS is inextricably tied to its historic purpose, significance and fundamental resources and values (FRVs). It is most often within this interdisciplinary perspective that managers consider potential actions and alternatives when addressing resource issues or needs. As such, we have created a table (Table 5.2-1) where natural resource topic relevance is presented within a framework of

**Table 5.2-1. Summary of natural resource topic relevance (denoted by black dots) as it relates to Bent's Old Fort National Historic Site's purpose, significance, and fundamental resources and values as identified in NPS (2013).**

| Natural Resource Condition Assessment Topics | Viewshed | Night Sky | Sound-scape | Air Quality | Geology | Water Quality | Ground-water | Riparian Habitat | Grassland | Exotic Plants | Landbird | Prairie Dog | Fish |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I. Park Purpose | | | | | | | | | | | | | |
| Commemorate the historic role Bent's Old Fort trading post played in the opening of the West. | | | | | | | | | | | | | |
| Develop, maintain and preserve the national historic site for visitor education and enjoyment. | ● | | ● | | | | | ● | ● | ● | ● | | |
| Interpret the significance of the Santa Fe Trail and the impact it had on the U.S., Mexico and Southern Plains tribes. | | | | | | | | | | | | | |
| II. Park Significance | | | | | | | | | | | | | |
| Westward Expansion | | | | | | | | | | | | | |
| Economy/Commerce | | | ● | | | | | | | | | | |
| Fort/Bent's Role as an Agent of Change | | | | | | | | | | | | | |
| Santa Fe Trail | ● | | | | | | | ● | ● | | | | |
| Reconstructed Fort/Historic Setting | ● | | ● | | | | ● | ● | ● | ● | ● | | |
| III. Fundamental Resources and Values | | | | | | | | | | | | | |
| Reconstructed Fort | | | ● | | ● | | ● | ● | | | | | |
| Historic Setting | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Living History | | | ● | | | | | | ● | | | | |
| Santa Fe Trail | ● | | | | | | | ● | ● | | | | |
| Archeology and Artifacts | | | | | | | | ● | | | | | ● |
| Cultural Traditions | | ● | ● | | | | | | | | | | |

Literature Cited: National Park Service. 2013. Foundation document Bent's Old Fort National Historic Site. 40pp.

the Historic Site's purpose, significance, and FRVs statements (NPS 2013). This provides a "snapshot" look at how each natural resource condition ties into the Historic Site's primary reasons for establishment.

The resource condition highlights for each resource topic, if applicable, will be presented in the *State of the Park* resource brief (section 5.3). Condition findings relative to potential resource issues/data gaps, opportunities and management considerations will be presented in the resource narratives section 5.4.

## *5.3. State of the Park* Reporting

As part of the stewardship of national parks for the American people, the NPS has begun to develop *State of the Park* reports to assess the overall status of each park's resources. The NPS will use the *State of the Park* report information to improve park priority setting and to synthesize and communicate complex

park condition information to the public in a clear and simple way (NPS 2012).

The key purposes of each *State of the Park* report are to:

- Provide to visitors and the American public a snapshot of the status and trend in the condition of a park's priority resources and values.
- Summarize and communicate complex scientific, scholarly, and park operations factual information and expert opinion using non-technical language and a visual format.
- Highlight park stewardship activities and accomplishments to maintain or improve the State of the Park.
- Identify key issues and challenges facing the park to help inform park management planning.

The format for relevant state of the park content in sections 5.4-5.16 will integrate resource condition findings into the required format for the Historic Site's *State of the Park* report, such that relevant pieces can easily be used for such reports. This includes an overall natural resource summary table showing the resource topic condition and rationale for overall condition ratings. A summary of the Status and Trend symbols for condition ratings can be found in Chapter 3, Table 3.2.3-1. We then present each natural resource topic individually, including all indicators and/or measures by which resource topics were assessed. Finally, a resource brief summarizing the condition rationale, will follow the condition table and include any significant condition highlights.

**Table 5.3-1 *State of the Park* Natural Resource Summary Table**

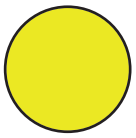
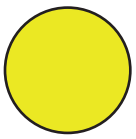
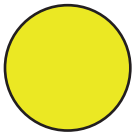
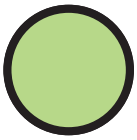
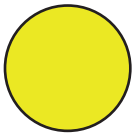
| Priority Resource or Value | Condition Status/Trend | Summary of Overall Condition Rating |
|---|---|---|
| **Natural Resources** | | |
| Viewshed |  | Views to the north and west have been moderately developed and non-contributing features are relatively conspicuous. In contrast, the views to the south and east are relatively intact with few conspicuous non-contributing features. Our overall assessment of a moderate condition for viewshed reflects the balance between these views. |
| Night Sky |  | Quantitative modeling of sky brightness (all-sky anthropogenic light ratio) and a qualitative assessment of sky quality (the Bortle Dark Sky Scale) were used to assess the condition of the night sky. The overall condition of the Historic Site's night sky is moderate, based on the more reliable ALR reading and the significant influence from nearby light domes. |
| Soundscape |  | The majority of noises heard was generated outside the Historic Site's boundary and included vehicles traveling along the highways, airplanes, and trains. While the locations where sounds were heard were mostly consistent with designated uses, the percent time audibility of noises always exceeded 50% of the time. The modeled impact sound level for the Historic Site ranged between 4.1-9.2 dBA (Mennitt et al. 2013). As a result of weighing all indicators and measures, we consider the overall soundscape condition to be of moderate concern, with an unknown trend. |
| Air Quality |  | Air quality monitoring is multifaceted and includes visibility, ozone, and wet deposition for total nitrogen and total sulfur. Three of the four air quality condition indicator values warranted moderate concern. Only wet deposition of sulfur was considered to be within a level to warrant a good condition rating. Levels of nitrate in precipitation decreased significantly from 2000-2009, while there were no significant trends for ammonium and sulfate. As a result, there is considered to be no significant trend in total wet nitrogen or sulfur deposition. |

***Table 5.3-1 State of the Park Natural Resource Summary Table (continued)***

| Priority Resource or Value | Condition Status/Trend | Summary of Overall Condition Rating |
|---|---|---|
| Geology |  | A geologic resource evaluation report was completed in 2005. There are no geologic concerns, and relative to this resource, the Historic Site is considered in good condition. |
| Surface Water |  | A long-term surface water monitoring program of the Arkansas River within the Historic Site began in 2012. Consistent with Colorado State water quality monitoring efforts, selenium and specific conductance measures greatly exceed state water standards. Even though the condition of the water quality measures are mixed, the persistently high selenium concentrations have resulted in section 303(d) listing for several years. Because of this and the high specific conductance levels, we consider the Arkansas River water quality to be of significant concern. |
| Groundwater |  | Water table elevation was used to assess condition of groundwater and based upon the 2013 condition of riparian habitat, the groundwater level is considered to be good from an ecological perspective. However, throughout the region, the water table has risen and has even flooded the historic Fort-one of the Historic Site's most significant resources. As a result, we consider the groundwater resource to be of moderate concern. |
| Riparian Habitat |  | A proper functioning condition for riparian areas requires integration between water flow and floodplain characteristics, vegetation types and amounts, and erosion and sediment deposition processes. All of these aspects are properly functioning throughout the Historic Site's riparian habitat and supports the system's resiliency. The overall condition is good for this resource. |
| Grasslands |  | Grasslands at Bent's Old Fort NHS are within the region generally characterized as short grass prairie, although there is considerable variation among specific locations. The grasses themselves are largely native species, but non-native forbs have been increasing at several locations. Historic land uses, prairie dogs, and drought have all contributed to moderate concerns about grassland condition. However, Historic Site staff have been actively engaged in prairie restoration and the resulting outlook is for continued improvement. |
| Exotic Plants |  | In 2013, 31 exotic plant species were found throughout the Historic Site, with eight (26%) of these considered to be of the highest or of high concern due to either their management difficulty or ecological impact (or both). An additional seven species are considered to be of moderate concern based on impact to the Historic Site's native habitats. Only six of the exotic species were found in >10% of the high priority monitoring sites and three species >10% were found throughout the entire Historic Site. Based upon the relative number of high impact species present, and their wide distribution throughout the Historic Site, we consider the overall condition of exotic plants to warrant moderate concern, with an improving trend. |
| Breeding Landbirds |  | We used one indicator, species occurrence (presence/absence), in three separate contexts (or measures; temporal, spatial, and conservation), to assess the condition of breeding landbirds at the Historic Site. For each measure, we found the current condition of breeding landbirds to be good. We do not have sufficient data to justify a trend in the condition at this time. |
| Prairie Dog |  | We used one indicator, prairie dog occurrence, with two measures, area occupied and density, to assess the condition of black-tailed prairie dogs at the Historic Site. Based on the indicator/measures, and from an ecological standpoint, the current condition of prairie dogs is of significant concern. In late 2011/early 2012, the sylvatic plague decimated the colony in (and adjacent to) the Historic Site. The trend is unchanging, as there is no evidence of an increase at this time. |
| Vertebrates-Fish |  | Four fish inventories have been conducted at or along the Historic Site to document the occurrence of species. To date, a total of 23 species were detected, with 8 species (34.8%) representing non-natives and two species of concern/state threatened in Colorado. No subsequent monitoring has occurred to determine long-term information on presence and absence of fish species. The condition of fish is unknown at this time. |

## 5.4. Viewshed Resource Brief and Narrative

### *5.4.1. Noteworthy Highlights*

One of the interpretive themes for Bent's Old Fort emphasizes " its location along the Arkansas River within the shortgrass prairie ecosystem, illustrating the intimate connections between natural setting and human endeavor". Views both from and toward the Fort can help to emphasize the connection between the Fort and its surrounding landscape. The surrounding lands provided the materials from which the Fort is built, plants and animals used for food, fuel for heat and cooking, and many other materials used in day to day life. Each of these can be visualized through the various views and can help to transport visitors back in time.

### *5.4.2. Condition Rationale*

In the recent draft Foundation Document for Bent's Old Fort NHS (NPS 2013), the viewshed was listed as fair to good. We agree with that assessment in that to the south and east, there is little development visible in the views, and what development exists is relatively inconspicuous. In contrast, there is a moderate degree of development, both housing and agriculture to the west and north. This development is primarily associated with highway 194 which runs along the Historic Site boundary and is relatively conspicuous within the primary views from the Fort. Although rural landscapes are often perceived positively by observers, this development does contrast somewhat from the historic setting and sense of place. It should also be noted that Bent's Old Fort NHS was established as a National Park unit within an established rural community. Our condition ranking of moderate reflects the balance between views that are relatively good with views that are fair in the context of its historic and natural setting (Table 5.4.2-1).

### *5.4.3. Management and Project Considerations and Narrative*

In its recent draft Foundation Document (NPS 2013), issues and management considerations relevant to the viewshed were identified. Most notably the Historic Site identified:

- Removal of NPS "stuff" from the viewshed.
- Consideration of what might be needed to maintain the viewshed and sense of place.
- Coordination with the county's land use planning board to monitor surrounding land management trends that may impact the viewshed.

**Table 5.4.2-1. Summary of overall viewshed condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site.**

| **Viewshed** | |  | |
|---|---|---|---|
| Indicators of Condition | Specific Measures | Condition Status/Trend | Rationale |
| Scenic and Historic Integrity | Intactness of View |  | Views to the south and east are relatively intact with few non-contributing features; whereas, to the west and north, there is a moderate degree of development. The moderate ranking for this measure reflects these differing conditions. |
| | Conspicuousness of noncontributing features |  | Non-contributing features to the west and north are relatively conspicuous; whereas, the limited development within view to the south and east are relatively inconspicuous. The moderate ranking for this measure reflects these differing conditions |



**Figure 5.4.3-1. In addition to the physical removal of NPS "stuff" from a given view, vegetation or topography may be used to enhance a view through better blending of features with the environment.**

Minimizing the impact of non-contributing NPS features from the viewshed

The Bent's Old Fort NHS Foundation Document (National Park Service 2013) identifies the viewshed as a fundamental resource and value contributing to the historic setting of the fort. This document also identified modern visual intrusions as one of the threats to maintaining the viewshed and removal of NPS "stuff" from within viewshed as one of the management actions and opportunities. Removal of some "stuff" such as equipment may be simply physically removed and/or stored in strategic locations. However, other non-contributing features (e.g., buildings, signs, etc.) may not be physically removed so easily. Thus another management consideration might be using vegetation screening to help some features blend into the environment; thus visually reducing any negative influence they might have on a perceived view (Figure 5.4.3-1).

Development of this concept might be facilitated through a PMIS funded Project as follows:

PRELIMINARY PMIS PROJECT CONCEPT PIECES

*Project Overview*

One of the fundamental values of Bent's Old Fort NHS is maintaining the historic setting. The viewshed surrounding the fort certainly contributes greatly to a visitor's perception "sense of place" of that historic setting, and non-contributing visual intrusions can detract from that perception. This project would use vegetative screening to help minimize the visual impact of non-contributing features that detract from the historic setting.

*Project Justification*

The Bent's Old Fort NHS Foundation Document (National Park Service 2013) identifies the viewshed as a fundamental resource and value contributing to the historic setting of the fort. How observers might perceive a human-made feature in a landscape has been shown to be influenced by how well it seems to fit or blend in with the environment (Kearney et al. 2008, Ryan 2006). Thus, vegetative screening can be used to help features of the landscape such as buildings and signs blend in with the landscape.

*Methods*
Specific methods and approach would best be developed by the park in consultation with NPS planning, but some ideas to consider might be:

1. What features warrant vegetative screening? Buildings? Signs?
2. Can the screening itself be done in such a way so as not to constitute a non-contributing feature itself?
3. Should the screening be done to reflect views from specific vantage points (e.g. the fort bastions)?
4. Can the screening be done using native vegetation?

Consideration of what might be needed to maintain the viewshed and sense of place
In addition to removal of features that might detract from the viewshed, there are also opportunities to enhance the features that contribute to the sense of place. For example, one of the interpretive themes for Bent's Old Fort NHS emphasizes the importance of "its location along the Arkansas River within the shortgrass prairie ecosystem, illustrating the intimate connections between natural setting and human endeavor". The views both from the Fort looking out as well as from the surrounding land looking toward the Fort can reinforce this interpretive theme and could well be expanded in interpretive displays to emphasize this connection (Figure 5.4.3-2).

Coordination with the county's land use planning board to monitor surrounding land management trends that may impact the viewshed
Much of the area within the viewshed of Bent's Old Fort is external to the Historic Site. Johnson et al. (2008) refer to such lands as a "borrowed landscape". Because such lands are not within NPS jurisdiction, the major tool the Historic Site has at its disposal is to work with local governments to ensure that impacts to the Historic Site's viewshed are being considered in local land use planning. The Historic Site is already actively engaged in such efforts and will undoubtedly continue to do so in the future. This natural resource condition assessment can facilitate such an effort by helping to identify areas that may warrant emphasis in such coordination. For example, only a fraction of the area surrounding the Fort is visible to Historic Site visitors such that external development has a high potential to influence the scenic or historic integrity of the viewshed. Areas of rural and agricultural development are visible to the north and west along Highway 194 but such views are limited except for a few gaps by a small ridge that runs parallel to the highway (Figure 5.4.3-3). Similarly views to the south and east from the Fort bastions are largely limited by cottonwood trees along the Arkansas River, except where there is a prominent gap (Figure 5.4.3-4).



**Figure 5.4.3-2. Views both from and of the Fort can reinforce the connection between the Fort and the surrounding landscape.**




**Figure 5.4.3-3. Views to the north and west from the Fort bastions are limited by a ridge running parallel to highway 194.**




**Figure 5.4.3-4. Views to the south and east from the Fort bastions are limited by cottonwood trees except where there is a prominent gap.**

Areas not visible from Historic Site vantage points due to obstruction by topography or vegetation have much less potential to influence the Historic Site's viewshed. Thus, coordination with local planning boards can be more effective by concentrating efforts on those areas most likely to have an influence on the integrity of the Historic Site's viewshed. A Geographic Information System (GIS) viewshed analysis can help to identify areas warranting additional focus by illustrating which areas are and are not visible from a given vantage point taking into account topography and/or vegetation (Figure 5.4.3-5).

Additional GIS tools may be available to help focus attention on areas most likely to influence Bent's Old Fort NHS' viewshed, such as an analysis of where development is most likely to occur. For example, using NPScape (Budde et al. 2009 and Gross et al. 2009) or ESRI Business analyst, it is possible to generate maps of where development, such as housing density, is most likely to occur (Figure 5.4.3-6).

Development of visual impact planning for NPS land north of Highway 194

As the acquisition process for lands north of Highway 194 is finalized, the park might want to consider any visual impacts of non-contributing features, and what, if any, visual restoration might be warranted.

Consideration of cottonwood infilling to buffer visual impacts of Highway 50 and Railway

The BEOL Foundation Document (NPS 2013) reports that: "a 2002 wildfire killed a number of cottonwoods impacting the viewshed, although the removal of tamarisk is promoting a healthier cottonwood stand along the Arkansas River." Although, the number of density of cottonwoods along the Arkansas River is probably less than occurred historically, they have not been deemed to detract from the historic setting of the fort. Cottonwoods along the Arkansas River also buffer the visual impact of Highway 50 and the railway on the south side of the river. They also provide a buffer to the existing intermittent noise impacts from trains, seasonal crop dusters, highway noise, and farm machinery (see soundscape). As such, the park might want to consider the potential for re-establishing cottonwoods that are lost due to fire or other reasons. This re-establishment could be in the form of fire protect for natural regeneration

of cottonwoods, or in the absence of natural regeneration, the park may wish to consider replanting native cottonwoods to promote regeneration.

Data Gaps

There are no major data gaps with respect to the viewshed. However, there are many features on the landscape, such as vegetation and some human structures that our general GIS analysis may not adequately capture. Thus, we would encourage more specific ground-truthing and or a more extensive analysis should it be needed for a specific project application requiring high accuracy.

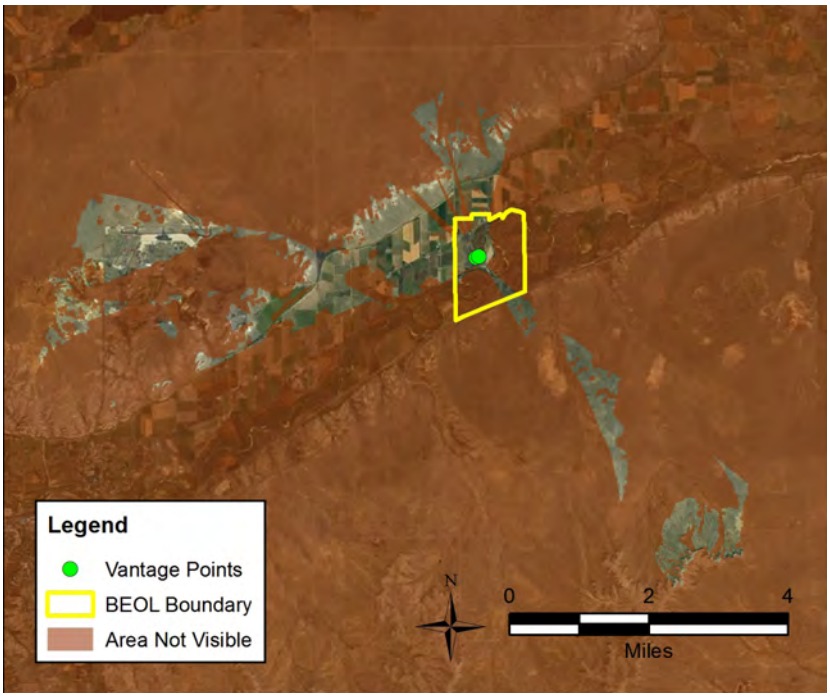



**Figure 5.4.3-5. Only a fraction of the area surrounding Bent's Old Fort NHS is visible from a given vantage point. A GIS viewshed analysis can then help to identify areas that may or may not be visible from that vantage point, which can facilitate a concentrated focus on areas most likely to have an impact on the viewshed.**

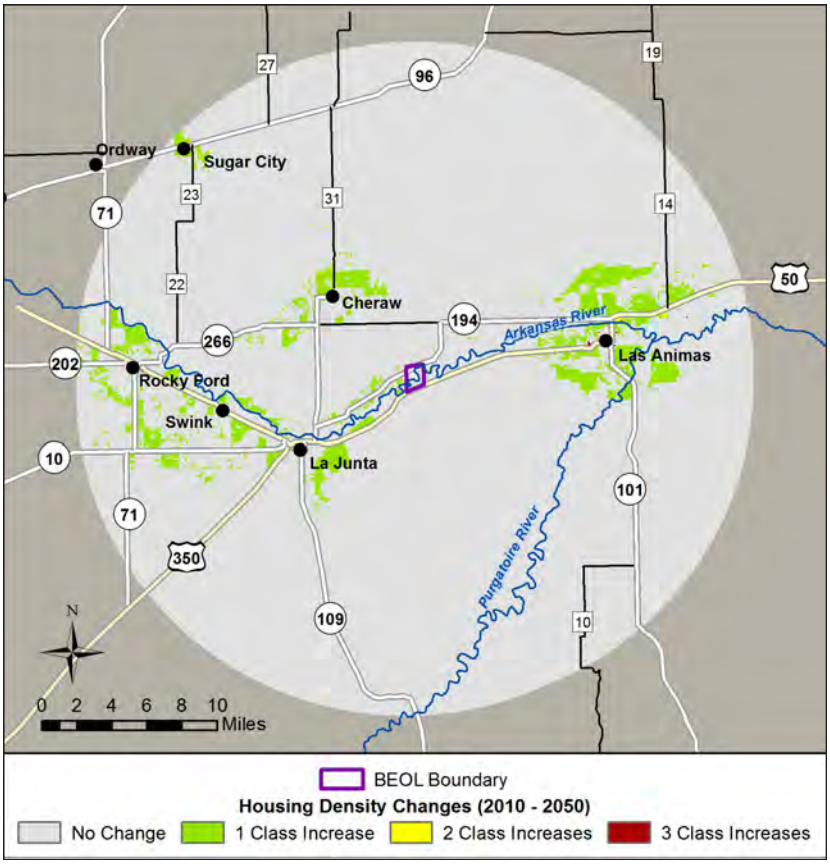



**Figure 5.4.3-6. Map generated using NPScape (citation) data showing areas where relative housing density is predicted to increase.**

## 5.5. Night Sky Resource Brief and Narrative

### *5.5.1. Condition Rationale*

Bent's Old Fort National Historic Site (NHS) is primarily a cultural resource Historic Site, and the cultural significance of dark night skies should be recognized in that context as part of the cultural landscape. Night skies, and the objects that can be seen, have strong cultural connections. For thousands of years, people have watched the night sky and told stories connected to the stars, planets, and constellations that they observe. The night sky played a critical role in the history of Bent's Fort. In November 1833, William Bent met with Cheyenne Chief White Thunder. As they talked, a meteor shower lit up the sky over the plains, and that event changed the course of history, forging strong connections between the two men and spreading peace through the region.

Natural dark skies are a valued resource for many reasons; they are an important factor for maintaining healthy biological systems and have an aesthetic appeal for recreational value. Night skies are also part of the cultural landscape, and night sky interpretive programs at the Historic Site are an important component. Because of the topography and the vegetation that somewhat shields local point sources of light, the sky quality is relatively good with regard to the constellations and night sky features that are visible. The overall quality of the night sky, however, is degraded by light domes from nearby cities (La Junta and Pueblo), and even cities farther away (Colorado Springs and Denver) (Table 5.5.1-1).

### *5.5.2. Management and Project Considerations and Narrative*

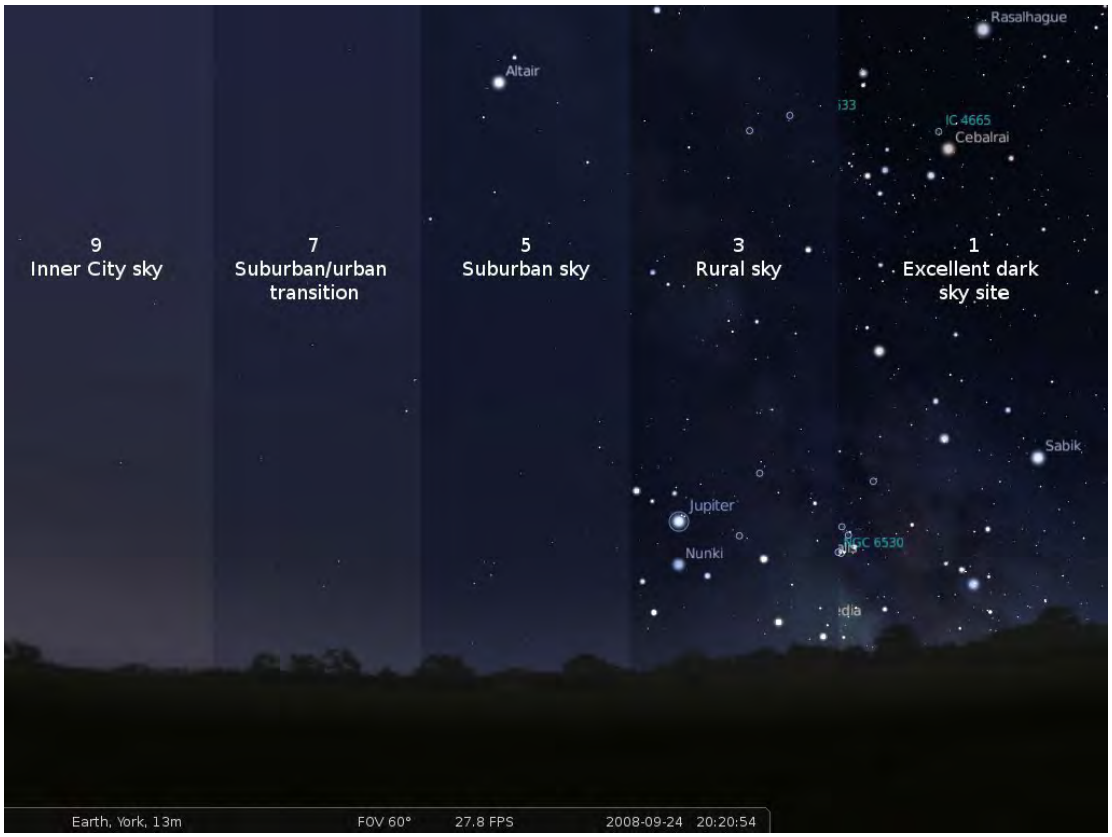
Night skies are an important natural and cultural resource to parks, however, much of the impact to the night sky resource occurs beyond the park's boundaries. In spite of that, there are a few potential considerations relative to night sky management.

Historic Site Lighting

**Table 5.5.1-1. Summary of overall night sky condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site.**

| **Night Sky** | |  | |
|---|---|---|---|
| Indicators of Condition | Specific Measures | Condition Status/ Trend | Rationale |
| Sky Brightness | All-sky Anthropogenic Light Ratio |  | This measure results from modeling data provided by the NPS Night Sky Program. Specific thresholds for condition classes have been set by the NPS. In this case, the moderate condition (0.78) likely resulted from the significant light domes of nearby cities. No ground-based measurement has been collected, therefore, the confidence level in this assessment is medium. |
| Sky Quality | Bortle Dark-Sky Scale |  | Although star gazing at Bent's Old Fort can be quite good as far as seeing constellations, the Milky Way, and other celestial bodies, the light dome from nearby La Junta was quite visible; and point sources for homes, farm buildings and roads were also evident. Inside the Historic Site, the interfering light sources are mostly shielded by the topography and riparian vegetation, which results in this qualitative assessment of good condition (Bortle class 3). Because this measure is qualitative, it has a low confidence level. |

The International Dark Sky Association (http://www.darksky.org/) provides many resources for improving and protecting the quality of night skies. One consideration is to modify outdoor lighting to be consistent with International Dark Sky Association guidance by replacing with Association approved light fixtures. These fixtures help to preserve local night sky condition by directing light down toward the ground and away from the sky, thereby, creating less light glow, which contributes to sky pollution.




**Composite image illustrating the range of night sky conditions based on the Bortle Dark Sky Scale.**

## 5.6. Soundscape Resource Brief and Narrative

### *5.6.1. Noteworthy Highlights*

The image below shows a large school group that was touring at the time of the 1-hour cottonwood-Nature Trail on-site listening session along the Arkansas River. No noises generated from this group were heard at the cottonwood site.

### *5.6.2. Condition Rationale*

Soundscape condition was assessed using audibility and sound levels at three locations throughout Bent's Old Fort NHS. The percent time audibility of noise was greater than 50% at all locations, and reached 100% at the picnic area, thus warranting significant concern.

The decibel levels of noises heard were relatively low, except for the picnic area where vehicles traveling along Highway 194 outside the Historic Site contributed to the loudest noises. Sound levels modeled by Mennitt et al. (2013) suggest a moderate soundscape condition for the Historic Site and area surrounding the site.

When combining all three soundscape condition measures, we consider the Historic Site's soundscape to be of moderate concern (Table 5.6.2-1).

### *5.6.3. Management and Project Considerations and Narrative*

In our soundscape assessment, we distinguish between sounds that are consistent with, and add to, the historic setting and living history at Bent's Old Fort NHS by making the fort "come alive". Noises originating from modern sources, (e.g., trains, aircraft, and vehicles) are inconsistent with the historic setting and may detract from the cultural landscape. Cultural sounds such as the wood fire crackling, the blacksmith shop bellows, and fort animals contribute to the liveliness that is unique to the Historic Site (Figure 5.6.3-1). In the Historic Site's Foundation Document (NPS 2013), specific issues and management considerations relevant to the soundscape were identified as follows:

- Soundscape study for both inside and outside the Fort
- Work with staff to minimize noise impacts from Historic Site operations

<u>Soundscape Study</u>

While a rapid soundscape assessment was conducted for the Historic Site for the purposes of this NRCA, it in no way captured information to the degree that a formal soundscape study conducted by the NPS Natural Sounds and Night Skies Division (NSNSD) would. Given the fact that the cultural and natural sounds are intrinsically connected, we agree with the staff recommendation of requesting a formal assessment and have included



MARK BRUNSON

**This group of 100+ people could not be heard at the cottonwoods-Nature Trail soundscape monitoring location.**

**Table 5.6.2-1. Summary of overall soundscape condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site.**

| **Soundscape** | |  | |
|---|---|---|---|
| Indicators of Condition | Specific Measures | Condition Status/Trend | Rationale |
| Audibility | % Time Audible |  | The percent time audibility of all non-natural sounds ranged from 53% of the time to 100%, indicating that noises could always be heard over more than half of the monitoring time. There were a higher number of natural and cultural sounds compared to noises at all three locations, even though vehicles were commonly heard. Additionally, jets were heard from within the Fort and cottonwoods, whereas, the train was only heard while in the Fort. Due to the considerable presence of noise at all three locations, we consider this measure to be of significant concern. |
| Sound Level | Amplitude of sound Level Impact (park-wide/regional model) |  | The modeled impact sound level for the Historic Site ranged between 4.1-9.2 dBA. This range is within a condition rating for moderate concern when evaluating a park classified between a non-urban and urban park using NSNSD thresholds. |
| | Amplitude (of sounds at on-site monitoring locations) |  | The louder noises were heard at the picnic area due to traffic traveling outside the Historic Site's boundary. Vehicle noises were also commonly heard within the Fort and along the Nature Trail, but at lower levels due to the increased distance from the roads. Even though the train noise heard was not very loud while monitoring, according to one employee, if the wind is blowing from the south or southwest, it can be very loud. Consequently, we considered this measure to be between good and moderate condition. |

a technical assistance request for acoustical monitoring for the Historic Site. (Form is on the next page.)

Consideration of what might be needed to maintain the soundscape

While monitoring for sources of sounds within the Fort, cottonwood gallery, and picnic area, it was apparent that the higher sound levels were due to traffic traveling along Highway 194 and were concentrated to the north side of the Historic Site. Whereas, with the exception of a periodic train passing by, vehicle noises were relatively quiet within the Fort and at the cottonwoods site and could only be heard off in the distance. Maintaining this concentration of noise along the north side of the Historic Site would help to preserve the soundscape to the extent possible. Additionally, the planting of cottonwood trees along the Arkansas River to buffer the visual impact of Highway 50 and the railway on the south side of the river would also likely preserve (and possibly improve) the soundscape condition. An additional road is currently being considered to divert traffic from Highway 50 into the Historic Site. A formal soundscape assessment would help determine if this new road would have a positive or negative impact on the overall soundscape.



NPS

**Figure 5.6.3-1. Sounds from a crackling wood fire enhance the Historic Site's soundscape.**

## FY 2014 Technical Assistance Request Form

| | |
|---|---|
| **Park:** Bent's Old Fort National Historic Site | **Region:** Intermountain |
| **Fiscal Year:** 2015 | **Estimated Time:** 80+ hours |
| **Program Area:** Soundscapes/Acoustical Assistance | |
| **Title:** Conduct Baseline Acoustic Assessment at Bent's Old Fort National Historic Site | |
| **Problem Statement:** (A brief summary of the issue, including information pertaining to park management prescriptions/management objectives tied to the issue, known resources at risk, etc.)<br><br>The architecturally accurate, reconstructed fort and its historic setting preserves the interconnection between the natural and cultural environments and offers a unique living history experience that educates and allows visitors to "step back" in time. The fort is a national living history laboratory and training center that demonstrates many aspects of life at a remote post between 1833 and 1849. Living history programs recreate the sights, sounds, and smells of the past with guided tours, demonstrations, and special events.<br><br>In the BEOL Foundation Document, the cultural sounds within the fort (blacksmith shop bellows, hammer and anvil, peacock screech, etc.) were identified as a fundamental resource. There has never been an acoustical monitoring study conducted at BEOL and a study inside the fort was identified as a data need to help protect and maintain this fundamental resource. Additionally, a soundscape study, including natural sounds outside of the fort, was identified as a request that would originate out of the process of conducting an NRCA.<br><br>The Site's Foundation Document identifies the need for a soundscape study for both inside and outside the Fort. The park has a need to establish baseline existing and natural ambient sound levels in a number of locations around the site. Given the fact that cultural and natural sounds are intrinsically connected, we are requesting acoustic monitoring inside the fort to capture cultural sounds that are consistent with, and add to, the historic setting and living history at Bent's Old Fort NHS by making the fort "come alive". Cultural sounds such as the wood fire crackling, the blacksmith shop bellows, and fort animals contribute to the liveliness that is unique to the Historic Site.<br><br>We are also requesting acoustic monitoring outside the fort in a number of locations to capture both natural sounds and noises originating from modern sources, (e.g., trains, aircraft, and vehicles) that are inconsistent with the historic setting and may detract from the cultural landscape. And a nearby railway has been identified as one of the largest impacts on visitor experience. Suggested locations could include the cottonwood gallery south of the fort, the picnic area at the main gate, the half-way point along the main trail to the fort. Additional locations could be identified at the beginning of the study. | |
| **Target Expertise:** Someone experienced with developing soundscape standards & identifying and implementing methods for assessment of soundscape conditions. | |
| **What are you asking the NRSS to do?** (Tied to already scheduled construction project or GMP? Provide consultation, protocol development, scoping, report writing, position paper, product development, etc.)<br>Provide consultation for development of an ambient model or sound monitoring program to include: 1) identifying and implementing indicators of soundscape quality; 2) identifying and implementing methods for monitoring soundscape conditions to ensure that quality standards are being met; 3) identifying processes to eliminate or mitigate sources of sound that are not appropriate to park purposes and management objectives.<br><br>1. Develop a plan for conducting a baseline acoustic survey at the park. Park staff suggests the best time of year to conduct the baseline acoustic monitoring would be summer and winter.<br>2. Conduct ambient modelling or acoustic survey work.<br>3. Identify management and mitigation measures for noise pollution.<br>4. Compile this information in a technical report, formatted for the Natural Resource Technical Series, and available on IRMA (https://irma.nps.gov). | |
| **What alternatives does the park have to accomplish the work?**<br>Park staff can provide a general framework for a soundscape assessment program by providing park specific information concerning present and potential sources of noise pollution. But expertise relating to soundscape standards, indicators, modeling, and monitoring is lacking to develop a soundscape assessment program. | |
| **Park has Superintendent Approval?** | **Travel Needs:** Travel will be needed for this project. The park does not have park housing and travel support would be minimal. The park will request support through PMIS for this project from Natural Resources Regional Block Funds. |
| **Park has Travel Funding?** | **Requires Private Land Access?** |
| **Expected Date of Completion?** | **Multi-Year Project?** |

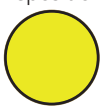
## 5.7. Air Quality Resource Brief and Narrative

### *5.7.1. Condition Rationale*

Air quality doesn't just affect the air we breathe, it also affects many air quality related values such as visibility and cultural and natural resources. There are different facets to air quality monitoring including measuring ozone levels, visibility conditions, and wet deposition levels. Currently, all levels, with the exception of wet deposition for total sulfur, warrant a moderate concern condition at the Historic Site (Table 5.7.1-1). These values are based upon 5-year interpolated averages since no on-site monitoring occurs within or in close proximity to the Historic Site. The Historic Site contains two ozone-sensitive plant species, Indian hemp and Green ash. Levels of nitrate in precipitation decreased significantly from 2000-2009, while there were no significant trends for ammonium and sulfate. As a result, there is considered to be no significant trend in total wet nitrogen or sulfur deposition.

The Historic Site's air quality is largely influenced by activities and operations that occur outside its boundary, and the future of its air quality condition is ultimately dependent on local, regional, and national planning.

**Table 5.7.1-1. Summary of overall air quality condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site.**

| **Air Quality**  | | | |
|---|---|---|---|
| Indicators of Condition | Specific Measures | Condition Status/Trend | Rationale |
| Visibility | Haze Index |  | For 2006–2010, estimated average visibility in the Historic Site was 4.4 deciviews above natural conditions, therefore, the condition status warrants moderate concern based on NPS Air Resource Division benchmarks. No trend information is available because there are not sufficient on-site or nearby visibility monitor stations. |
| Ozone | Annual 4th-highest 8-hour Concentration |  | The estimated ozone level for 2006–2010 at the Historic Site was 74.0 parts per billion, therefore, the condition status warrants moderate concern based on NPS Air Resource Division benchmarks. Ozone-sensitive plants in the Historic Site include *Apocynum cannabinum* (Indianhemp) and *Fraxinus pennsylvanica* (Green ash). No trend information is available because there are not sufficient on-site or nearby ozone monitor stations. |
| Atmospheric Wet Deposition  | Atmospheric Wet Deposition in Total N |  | For 2006–2010, estimated wet nitrogen deposition was 1.9 kilograms per hectare per year, therefore, the condition status warrants moderate concern based on NPS Air Resource Division benchmarks. Levels of nitrate in precipitation decreased significantly from 2000-2009, while there were no significant trends for ammonium. |
| | Atmospheric Wet Deposition in Total S |  | For 2006–2010, estimated wet sulfur deposition was 0.7 kilograms per hectare per year, therefore, the resource is in good condition based on NPS Air Resource Division benchmarks. From 2000-2009, there was no significant trend for sulfate. |



KIM STRUTHERS

**Acid rain deposited in the form of precipitation can adversely affect adobe structures like the historic Fort.**

### *5.7.2. Management and Project Considerations and Narrative*

Effects of Acid Deposition

Effects of air quality measures not only impact plant and streams from acidification or ozone damage, but can also impact historic structures. Bent's Old Fort National Historic Site's reconstructed Fort is integral to its Historic Site purpose, significance, and fundamental resources and values (NPS 2013). The current condition of the Fort's adobe structure is considered to be fair to poor (NPS 2013). It is a feature that requires continual maintenance and a comprehensive condition assessment for the Fort has been identified by Historic Site staff as an immediate data need (NPS 2013). Additionally, an Adobe Preservation Plan is considered to be a medium priority by Historic Site staff (NPS 2013). Adobe walls exposed directly to precipitation erode much faster and may be susceptible to acid deposition based upon the mineralogy of the adobe materials (Petuskey et al. 1995). While the condition for atmospheric wet deposition in total S was good, the overall air quality condition was considered to be moderate. Monitoring for potential acid rain effects may assist in providing an overall maintenance regime for the Fort's future condition.

## 5.8. Geology Resource Brief and Narrative

### *5.8.1. Condition Rationale*

Bent's Old Fort NHS does not have a geologic resource focus, in that the Historic Site does not have significant canyons or volcanoes or other prominent geologic features. No specific indicators or measures have been identified by which to assess geologic condition. In this case, we used professional judgment and qualitative assessment of general geologic integrity to assign a good condition at the Historic Site (Table 5.8.1-1).

### *5.8.2. Management and Project Considerations and Narrative*

Geologic resources serve as the foundation of ecosystems and yield important information needed for science-based decision making in National Park System units. Geology is a major determinant of topography, water and soil chemistry, fertility of soils, stability of hill slopes, and flow styles of surface water and groundwater. These factors, in turn, influence biology, including the distribution of habitats and the locations of threatened and endangered species. Geology also influences human settlement patterns and how people use natural resources—for farming, ranching, industry, construction, hunting, fishing, and recreation. Landforms such as the river also figured prominently in the location of the Fort.

Bent's Old Fort National Historic Site (NHS) is located in the Great Plains of southeast Colorado. The Great Plains is a land of contrasts and variety including water-carved rock canyons, dramatic rock uplifts, fluvial sediments containing fossils, and rolling hills of eolian deposits. Bent's Old Fort NHS is located in the Colorado Piedmont section of the Great Plains province. The area around the Fort is generally flat with some gently rolling surfaces and the Arkansas River running through it. The Colorado Piedmont is situated at the foot of the Rockies, largely between the South Platte and the Arkansas Rivers. After leaving the mountains, the South Platte to the north, and the Arkansas to the south, have excavated the Tertiary (65.5- to 1.81-million years old) sedimentary rock layers removing great volumes of sediment. These Tertiary rock units were originally deposited by shifting stream channels, floodplains, swamps, and occasional volcanic ash.

Along the western margin of the Colorado Piedmont, the layers of older sedimentary rock have been sharply upturned by the rise of the mountains. The edges of these upturned layers have been eroded differentially, so that the hard sandstone and limestone layers form conspicuous and continuous hogback ridges.

Much of the terrain in the valleys of the South Platte and Arkansas Rivers has been smoothed by windblown sand and silt. Northwesterly winds have whipped fine material from the floodplains

**Table 5.8.1-1. Summary of overall geology condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site.**

| **Geology** | |  | |
|---|---|---|---|
| Indicators of Condition | Specific Measures | Condition Status/Trend | Rationale |
| Geologic Resource Integrity | None |  | A geologic resource evaluation report was completed in 2005. There are no geologic concerns, and the geologic resources and processes are in a generally natural state and function. |

of the streams and spread it eastward and southeastward over much of the Colorado Piedmont. Blowout dunes are the most common dune type in the vicinity of Bent's Old Fort NHS.

In the Colorado Piedmont the erosional effects of streams are the most conspicuous features of the landscape. These fluvial features are enhanced by the steep tilting of layered rocks along the western margin of the Colorado Piedmont and modified by wind action, which has softened the landscape with a widespread cover of windblown sand and silt (KellerLynn 2005).



NINA CHAMBERS

**Bent's Old Fort National Historic Site has mostly flat to gently rolling surfaces surrounded at a distance by hogback ridges.**

## 5.9. Surface Water Resource Brief and Narrative

### *5.9.1. Condition Rationale*

A long-term surface water monitoring program of the Arkansas River within the Historic Site began in 2012. Consistent with Colorado State water quality monitoring efforts, monitoring results for selenium and specific conductance measures greatly exceeded state water standards. Even though the condition of the remaining water quality measures are variable, ranging from good condition for alkalinity, biological oxygen demand, and emerging contaminants, the persistently high selenium concentrations have resulted in section 303(d) listing for several years. Because of this and the high specific conductance levels, we consider the Arkansas River water quality to be of significant concern (Table 5.9.1-1).

**Table 5.9.1-1. Summary of overall surface water quality condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site.**

| **Surface Water** | |  | |
|---|---|---|---|
| Indicators of Condition | Specific Measures | Condition Status/Trend | Rationale |
| Core Water Quality Parameters | pH, dissolved oxygen, temperature, specific conductance, turbidity, and *E. coli* |  | The core water quality parameters along this stretch of the Arkansas River is typical, however, the most recent specific conductance level was 2,250 micro Siemens/cm. While no standard exists related to water quality, damage to agricultural crops can occur when specific conductance is between 950-1200 micro Siemens/cm within the Arkansas River (USGS 1998). Because of the very high specific conductance results, we consider this measure to be of significant concern. |
| Alkalinity | $CO_3^{2-}$, $HCO_3^-$, and $OH^-$ |  | The alkalinity results were within the range of previously observed seasonal results and is considered to be in good condition. |
| Metals | 15 metals (total and dissolved) |  | Dissolved selenium in all sampling periods exceeded the chronic aquatic life-class 2 standard, Additionally, in May 2013, both total and dissolved selenium exceeded the state agricultural standards for selenium. This river segment is already on the 303(d) list for selenium, and these results indicate that dissolved Selenium is still a concern. Additionally the Lower Arkansas River is considered to be the most saline stream of its size in the U.S. (TetraTech 2007). We consider the metals to be of significant concern. |
| Primary Nutrients | 11 measures |  | All analytes met state standards except for sulfate, which exceeded the state standard during all four sampling periods. As a result we consider the condition of this measure to be of moderate concern. |
| Biological Conditions | Biological oxygen demand |  | No state standard exists for biological oxygen demand, but when levels are high, dissolved oxygen levels are lower. This was not the case for dissolved oxygen results therefore this measure is good. |
| Emerging Contaminants | Presence/Absence |  | Emerging contaminants were sampled for in 2012 and seven were detected, but all were below the established benchmarks. We consider the water quality relative to this measure to be in good condition with an unknown trend. |

### *5.9.2. Management and Project Considerations and Narrative*

The continuation of quarterly water quality monitoring conducted by the SOPN is recommended. In addition correlating water quality results with discharge data from the LaJunta, Colorado monitoring station would provide a more regional and comprehensive perspective (Vana-Miller et al. 2010). Also continuing to partner with the Lower Arkansas Watershed group will maximize coordination of water quality protection efforts for the Arkansas River. Woods and McDonald (2002) collected surface water quality data twice in 2001 at Day pond and Arch wetland. No additional water quality data have been collected since then to assess current condition of these resources. Vana-Miller et al. (2010) recommended monitoring for a suite of water quality parameters similar to those measured by Woods et al. (2002) in the park's wetlands.



NPS

**The Arkansas River is a fundamental resource and value to Bent's Old Fort NHS' historic setting.**

## 5.10. Groundwater Resource Brief and Narrative

### *5.10.1. Condition Rationale*

Various studies have been conducted over the years regarding the alluvial aquifer underlying Bent's Old Fort NHS and the closely associated Arkansas River (Darton 1906; Snipes et al. 1974; Watts and Lindner-Lunsford 1992; Gates et al. 2012). Overall, the perceived trend is that water table elevations have risen locally since the late 1970s, probably from a combination of factors: increased surface-water infiltration from high Arkansas River stages and reduced groundwater withdrawals, increased seepage losses from the canal, decreased groundwater pumpage, and increased percolation of irrigation water to the water table (Woods and MacDonald 2002). Additionally, aggradation of the stream bed has increased river stage in the vicinity of the gage at La Junta (#07123000), but according to Wagner and Martin (2014), it is not known if aggradation has occurred within the Historic Site since no signs of excessive sediment deposition were observed during the 2013 riparian habitat assessment. Water levels in wells near the Fort Lyon Canal and in irrigated areas have had larger changes than those near the river, suggesting a link to irrigation practices (Watts and Lindner-Lunsford 1992).

While high water table conditions may have detrimental effects on agricultural soils, the same conditions may help support plant vigor in riparian and wetland systems. A sustained rise in average water table elevations could trigger a shift in riparian-wetland species composition with more facultative and obligate species colonizing the lower and wetter areas, but overall, a relatively shallow water table is a positive attribute of a healthy riparian system.

High water table elevations, however, have created management problems for Historic Site staff by flooding the Fort basement, leading to the replacement of rotted timbers in 2000. There is tremendous concern that permanent damage may be done to the Fort's wood and adobe structure if water table elevations continue to rise and maintain these high levels over time. Thus, we consider the groundwater resource at Bent's Old Fort NHS to be of moderate condition (Table 5.10.1-1).

### *5.10.2. Management and Project Considerations and Narrative*

Because of the resources associated with the Arkansas River-game, wood, shelter, and water- and the proximity to the Santa Fe Trail, Bent's Old Fort was built and became the largest trading post throughout the Trail's history (NPS 2004). In addition to the surface water of the Arkansas River, groundwater supported the land-use and activities of the Fort. A well dug within the Fort compound supplied drinking water to both residents and travelers. Additionally, an acequia (an

**Table 5.10.1-1. Summary of overall groundwater condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site.**

| **Groundwater** | |  | |
|---|---|---|---|
| Indicators of Condition | Specific Measures | Condition Status/Trend | Rationale for Resource Condition |
| Groundwater | Change in groundwater level |  | The alluvial aquifer and riparian habitat are interconnected and long-term groundwater levels have supported the riparian system within the Historic Site as evidenced by the system's ability to maintain viability through hydrologic variations. However, increased groundwater levels have caused flooding in the historic Fort, which is one of the site's most significant resources, resulting in a moderate concern condition rating. |

irrigation ditch) was built to irrigate agricultural fields to the north of the Fort. While the needs for freshwater and cultivating food remain the same today, the scale of operations surrounding the Historic Site has drastically altered the hydrology and groundwater flows.

Hydrologic Diversions

Currently, over 1,000 miles of Arkansas River water diversions, including the Fort Lyon Canal, which is located to the north of the Historic Site, support an agricultural economy throughout the Arkansas River Valley. As a result of the extensive irrigation and water diversions, the groundwater table has risen, become saline, and waterlogged many of the Valley soils (Gates et al. 2006). Additionally, two major reservoirs have been constructed along the Arkansas River: John Martin Reservoir and Pueblo Reservoir. These reservoirs store water for later season irrigation but have also inadvertently reduced the sediment loads in the river, possibly contributing to the canal seepage that drastically alters groundwater levels since the sediments no longer seal the canal perimeters (Gates et al. 2006). The John Martin Reservoir has dampened the flood flows and created backwater, which have likely contributed to the aggradation of sediments, resulting in a higher river level. The higher river level decreases the gradient that normally would drain water from the land to the river (Gates et al. 2006).

Issues

All of these modifications within the Arkansas River Valley most likely have contributed to a high water table and the periodic flooding of the basement of the Fort. Rotted timbers were replaced in 2000; however, measures such as this are only temporary. There is tremendous concern that permanent damage may be done to the Fort's wood and adobe structure if action isn't taken to mitigate the amount of canal leakage and excess irrigation flowing towards the Fort. NPS (2013) identified flooding as a threat to the reconstructed Fort and identified a data gap relative to the impact of high groundwater levels on the overall site, areas of the Fort, and the septic system.

Current Groundwater Monitoring

The Southern Plains Inventory and Monitoring Network implemented a groundwater monitoring program in 2012. Pressure transducers were placed in four of the groundwater monitoring wells that were installed as part of Woods and MacDonald (2002) groundwater study. Unfortunately, three of the four have filled in enough to make them non-viable monitoring wells. The only viable well from the quartet is the one just to the west of the Fort (Evan Gwilliam, pers. comm. May 31, 2013).

Potential Opportunities and Project Considerations

Michael Martin, NPS Water Resources Division (WRD) Hydrologist, suggests there are management actions that could be taken both locally and regionally that may affect hydrologic trends. Some of the actions previously considered include: (1) deepening the channel of the Arkansas River, (2) lining the Fort Lyon Canal, (3) increasing groundwater withdrawal, (4) installing relief wells, and (5) installing drainage systems. Analyses of these options indicated that effects on the water table could be substantial, but were generally limited in aerial extent and restricted to the location of the treatment (Watts and Lindner-Lunsford 1992). Wagner and Martin (2014) also suggest that improving the understanding of river stage as mechanism for flooding is needed before management action is taken. Even though the groundwater table is elevated by irrigation and canal seepage, Woods and MacDonald (2002) indicated that the Fort basement flooding occurred during one of the highest river stages, which may indicate that regardless of any action to lower the groundwater table, river stage may most often be the controlling factor (obviously depending upon amount of increase). By expanding the Southern Plains Inventory and Monitoring groundwater monitoring program to include wells closest to the Arkansas River to measure the river stage and upland wells, including the area around the

Arch wetland, information could be gathered via dataloggers and further analyzed to assist with developing groundwater management options.

Groundwater Study

Work in conjunction with WRD and SOPN staffs to develop a monitoring/study framework to collect data that addresses the need for understanding Fort flooding sources and/or mechanisms. This study is now underway as of May 2015. Also request assistance with analysis and interpretation of results.

## 5.11. Riparian Habitat Resource Brief and Narrative

### *5.11.1. Condition Rationale*

Wetlands serve many functions including water purification, flood control, buffering riverbank erosion, habitat for numerous wildlife, fish, shellfish, and plant species, and also provide many recreational opportunities. In the arid west, riparian habitat is often in marked contrast with the surrounding terrestrial vegetation and is strongly influenced by the presence or absence of water (NPS-WRD 2011).

An interdisciplinary team of experts from NPS' Water Resources Division conducted a qualitative riparian habitat assessment at the Historic Site along the Arkansas River (Wagner and Martin 2014), using "A User Guide to Assessing the Proper Functioning Condition and the Supporting Science for Lotic Areas" developed by Prichard et al. (1998). This assessment included three main indicators including hydrology, vegetation, and erosion/deposition. A total of 17 common attributes and processes (measures) within each of these three categories was assessed.

The Arkansas River was assessed as one study unit throughout the Historic Site, and based upon nearly all the measures, except for apparent drought stress affecting the willows, the riparian system was considered to be in good condition (Table 5.11.1-1).

**Table 5.11.1-1. Summary of overall riparian habitat condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site.**

| **Riparian Habitat** | |  | |
|---|---|---|---|
| Indicators of Condition | Specific Measures | Condition Status/Trend | Rationale |
| Hydrology | Floodplain |  | River is regulated; flows are controlled by operations of the Pueblo Reservoir. Point bars, high flow channels and low terraces show clear evidence of recent flow (e.g., recent sediment deposition and flood debris), and park staff stated that this occurs in most years. Channel/floodplain form is as expected for this regulated river (no channel incision). Point bars and low terraces exhibit recruitment and maintenance of native riparian vegetation. |
| | Beaver dams |  | n/a |
| | Sinuosity, width/depth ratio, and gradient |  | Overall channel sinuosity and gradient are in balance with the landscape setting. The sinuosity is about 2.18; the channel gradient is about 0.1 percent; and estimates of width-to-depth ratios are primarily above 12. Point bar/cutbank channel forms appear to be in a dynamically stable condition as expected for this regulated river (no excessive lateral erosion). |
| | Riparian wetland area |  | Riparian zone is at or near potential extent as indicated by gradual lateral migration of the channel across the landscape while maintaining a near-constant channel width (cutbank/point bar form is dynamically stable). |
| | Upland watershed |  | No evidence of excessive sediment or water contributions from upland watershed. Higher terraces/riparian areas are well-vegetated. |

***Table 5.11.1-1. Summary of overall riparian habitat condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site. (continued)***

| **Riparian Habitat**  | | | |
|---|---|---|---|
| Indicators of Condition | Specific Measures | Condition Status/Trend | Rationale |
| Vegetation | Age class distribution of riparian wetland vegetation |  | Cottonwood (Populus deltoides) has three age classes including seedlings and young saplings on point bars and side channel bars, approx. 10-20 year olds common on intermediate elevation terraces and upper point bars, and older trees on higher terraces and old meander scars. Sandbar willow (Salix exigua) recruitment is common on point bars and low terraces all the way to the channel banks. Older sandbar willows are common on most intermediate and some higher terraces, but most show significant signs of drought or other stress on these higher landforms. Herbaceous wetland species are expanding in some streambank areas, but their role in bank stabilization is generally minor compared to sandbar willow. |
| | Diverse vegetation composition |  | Sandbar willow is the dominant woody riparian species on most streambanks, point bars, side channel bars and other low/intermediate terraces. Cottonwoods are present in 3 age classes as described above, but recruitment is sparse compared to sandbar willow. Willow baccharis (Baccharis salicina) is well-represented on some point bar and side channel bars, and peach-leaf willow (Salix amygdaloides) is found very occasionally as individual shrubs to small trees. Although sandbar willows on streambanks, point bars and low terrace features are typically vigorous and expanding, drought stress is clearly evident on intermediate and higher terraces. |
| | Soil moisture characteristics |  | Sandbar willow dominates most low streambanks and bars, but hardstem bulrush (Schoenoplectus acutus), common three-square (Schoenoplectus pungens) and common reed (Phragmites australis) protect some streambanks and are found in patches on some lower point bars and low terraces. Saltgrass (Distichlis spicata) dominates the herbaceous community on many intermediate terraces, with wild licorice (Glycyrrhiza lepidota) common/co-dominant at some locations. Showy milkweed (Asclepias speciosa) is present on many intermediate terraces but not dominant. All of the above are native riparian-wetland species. Cattail (Typha sp.) was found on some low terraces (appeared to be either non-native T. angustifolia or a hybrid of T. angustifolia and T. latifolia). Non-native reed-canary grass (Phalaris arundinacea) was present on some low streambanks and terraces, but cover was limited. |
| | Plants have root masses capable of withstanding high streamflow events |  | Sandbar willow and the rhizomatous, herbaceous native wetland plant cover on channel banks, point bars and low terraces have root masses capable of withstanding high flow events (but refer to "vigorous plants" measure below for further discussion). |
| | Vigorous plants |  | Sandbar willows are vigorous on point bars, side channel bars and most low streambanks, but they show major stress (excessive dead stems and branches) on higher streambank and bar locations and on intermediate terraces. We suspect that this 3rd straight year of well below normal precipitation ("exceptional drought" conditions according to the U.S. Drought Monitor) is a major cause, since plant stress appears to correlate with elevation above bankfull stage. |

***Table 5.11.1-1. Summary of overall riparian habitat condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site. (continued)***

| **Riparian Habitat** | |  | |
|---|---|---|---|
| Indicators of Condition | Specific Measures | Condition Status/Trend | Rationale |
| Vegetation (continued) | Vegetation cover |  | Adequate riparian-wetland vegetative cover is present to protect banks and dissipate energy during high flows. |
| | Plant communities are coarse and/or large |  | n/a |
| Erosion/Deposition | Floodplain and channel characteristics |  | Shoot cutoffs, overflow channels, channel sinuosity and point bars contribute to energy dissipation. |
| | Point bars |  | Point bars are revegetating with riparian-wetland vegetation. |
| | Lateral stream movement |  | Lateral stream movement is associated with natural sinuosity |
| | Vertical stability |  | The system is vertically stable, and there are no signs of recent incision. |
| | Balance of water and sediment |  | Stream is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition) |

### *5.11.2. Management and Project Considerations and Narrative*

In 2001, researchers from the University of Montana and Colorado State University installed and monitored staff gages and groundwater wells at the Historic Site to evaluate the cause of basement flooding at the Fort (Woods and MacDonald 2002). They found that groundwater fluctuations in the riparian areas were well-correlated with river stage, whereas wells in the uplands north of the river and in Arch Wetland were controlled primarily by irrigation and leakage from the Fort Lyon Canal and did not correlate well with river stage. These findings suggest that management of river stage could have an effect on riparian water table fluctuations at the Historic Site. The NPS Southern Plains I&M Network recently began monitoring riparian water table elevations at the park (utilizing some of the wells installed by Woods and MacDonald), but data are not available at this time to analyze rates of water table decline during the growing season. We recommend performing such investigations in the near future and, as appropriate, determining if there are ways to manage river stages for the benefit of riparian vegetation, including under severe drought conditions.

A local planning initiative to develop a waterway trail system along the Arkansas River is currently in its infancy stage. At this point, the potential launch and landing locations are unknown, but a potential take out could be at Bent's Old Fort NHS. The implications of visitor access would need to be carefully considered and analyzed to determine the needs and feasibility of implementing those needs as planning advances. Anecdotal evidence from early

descriptions and photos indicate that the Arch Wetland was probably historically a spring-fed wet meadow rather than an open-water wetland as its current state. A limited study using core pollen samples from the wetland area could shed more definitive light on the historic plant communities of this site which would aid in defining a desired future state based on assessing the current hydrology in relation to its historic setting. Thus, A PMIS Project might be considered for such an effort.



NPS-WRD JOEL WAGNER

**Riparian habitat located along the Arkansas River within Bent's Old Fort Historic Site.**

## 5.12. Grasslands Resource Brief and Narrative

### *5.12.1. Noteworthy Highlights*

Grasslands at Bent's Old Fort NHS have experienced a long history of use, from vast herds of ranging bison that were hunted by the plains tribes to farming. Because of proximity to the Fort, the grasslands in the immediate vicinity were used intensively during the active period of the Fort for hunting, gathering, farming, and pasturing of livestock. The grasslands were the setting upon which the western expansion of the U.S. took place, and are an essential part of our history and heritage. However, this long history of use does not come without a cost and in this case, that cost was degradation of the native prairie. Yet, despite this long history of extensive use, remnants of short grass prairie remain, and Historic Site resource staff are actively engaged in bringing these prairies back to life.

### *5.12.2. Condition Rationale*

For nearly all of the measures of grassland condition at Bent's Old Fort NHS, there was substantial variability among sites. Overall grassland condition was generally good at some sites, while being poor in others (Table 5.12.2-1). The condition of moderate concern represents a balance of these extremes (Table 5.12.2-1). It should be also noted that extreme drought conditions have persisted in the area for the past three years adding further stress to an already stressed resource. Historic Site staff have also been actively engaged in exotic plant control and prairie restoration in an attempt to counter a long history of intensive use of grasslands surrounding the Fort. They have already made great strides in reducing species such as Tamarisk, and we are optimizing that continued effort, along with more normal rainfall patterns will result in substantially improved conditions for those sites in poorer condition.

**Table 5.12.2-1. Summary of overall grasslands condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site.**

| **Grasslands** | |  | |
|---|---|---|---|
| Indicators of Condition | Specific Measures | Condition Status/Trend | Rationale |
| Hydrology Soil/Site Stability and Hydrologic Function | Rills |  | Ranges from slight to extreme among sites within Historic Site |
| | Water Flow Patterns |  | Ranges from slight to extreme among sites within Historic Site |
| | Pedestals and/or terracettes |  | Only one site had moderate pedestals |
| | Bare ground |  | Ranges from slight to extreme among sites within Historic Site |
| | Gullies |  | None to slight throughout the Historic Site |

***Table 5.12.2-1. Summary of overall grasslands condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site. (continued)***

| **Grasslands**  | | | |
|---|---|---|---|
| Indicators of Condition | Specific Measures | Condition Status/Trend | Rationale |
| Hydrology Soil/Site Stability and Hydrologic Function (continued) | Wind-scoured, blowout and/or depositional areas |  | Moderate occurrence at only one site |
| | Litter Movement |  | Some concern at three of six sites |
| | Soil surface resistance to erosion |  | Ranges from slight to extreme among sites within Historic Site |
| | Soil surface loss or degradation |  | Ranges from slight to extreme among sites within Historic Site |
| | Compaction layer |  | Some concern at three of six sites |
| Biotic Integrity | Landscape-scale Diversity |  | The spatial patterns of plant community distribution generally coincide with that of the ecological sites and soils |
| | Local Species Composition, |  | Condition of local species diversity ranged from good to poor among sites, |
| | General Life Cycles Relative to Disturbance |  | Grasses were nearly all perennial whereas forbs were more variable among sites. |
| | Relative proportion of functional groups |  | Similar to our other measures, the proportion of functional groups and relative concern regarding this measure was highly variable among both rapid assessment sites and ecological sites |
| | Relative proportion of C3 and C4 species. |  | Some sites had a good mix of C3 and C4 grasses, while other sites were highly dominated by C3 grasses and still others by C4 Grasses. |

### *5.12.3. Management and Project Considerations and Narrative*

Prairie Restoration North of Highway 194

Bent's Old Fort has been actively restoring native prairie habitats that have been degraded as a result of previous land use and prairie dog colonization. The 15 acres north of Highway 194 has had a similar history of agricultural land use that has shifted from the historic prairie condition. This land was in a grazing lease that is no longer in use. Recently, the Historic Site has taken back active management of the area and may wish to consider whether or not efforts to restore these lands to native prairie habitat are warranted. If so, the current restoration efforts can help guide this process.



NPS PHOTO

**Field of western wheatgrass (*Agropyron smithii*) inside the Historic Site.**

## 5.13. Exotic Plants Resource Brief and Narrative

### *5.13.1. Noteworthy Highlights*

One of the most invasive exotic plants, *Tamarix ramosissima*, has been effectively controlled throughout the Historic Site. The removal of this particular species is consistent with the management goal for the Lower Arkansas Watershed Plan, which is to help improve water quality, quantity, and habitat (TetraTech 2007). Additionally in 14.4% of the park-wide plots, no exotic plants were detected..

### *5.13.2. Condition Rationale*

Globalization of commerce, transportation, human migration, and recreation in recent history has introduced invasive exotic species to new areas at an unprecedented rate. Although only 10% of introduced species become established, and only 1% become problematic (Williamson 1993; Williamson and Fitter 1996) or invasive, nonnative species can have profound impacts to native plant communities. Currently, at Bent's Old Fort NHS 32 exotic plant species are found. Many are very difficult to manage once established, and a few notable exotic plants are known for their ability to dramatically alter primary plant communities to the point where they no longer maintain their attributes or processes, including cheatgrass, saltcedar, and Broadleaf pepperweed. While some species like Kochia and field bindweed are widespread, Historic Site staff has been actively managing exotic plants and has been successful in maintaining relatively low plant densities. Overall we consider exotics plants to be of moderate concern with an improving trend at the Historic Site (Table 5.13.2-1).

**Table 5.13.2-1. Summary of overall exotic plants condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site.**

| **Exotic Plants**  | | | |
|---|---|---|---|
| Indicators of Condition | Specific Measures | Condition Status/Trend | Rationale |
| Prevalence of Exotic Plant | Proportion of High Priority and Parkwide Plots Infested |  | Six exotic species were found in greater than 10% of the high priority sampling sites between 2011-2013. Two of these species are considered to be of highest concern, one of high concern, and one of moderate concern. |
| | Density of Exotic |  | For the most part, most of the species warranting high, highest, or moderate concern occur in low densities throughout the Historic Site. Additionally, Historic Site staff proactively manage the exotic plants and have been successful in controlling one of the highest concern species, Saltcedar, so density is considered to be in good condition. |
| Potential to Alter Native Plant Communities | Ecological Impact |  | This measure is based on the premise that species with the largest negative impacts on native plant, animal, and other species populations, and ecosystems generally cause the most severe problems. Several species, particularly, *Bromus tectorum* and *Tamarix chinenesis* are considered to be extremely impactful to native communities, but many of the species with high ecological impact are relatively rare throughout the Historic Site, therefore, we consider this measure to be of moderate condition. |
| | Management Difficulty |  | All eight species (26%) of exotics considered to be the highest or high concern are considered to be very difficult to manage, therefore, we consider this measure to be of significant concern. |

### *5.13.3. Management and Project Considerations and Narrative*

The Vegetation Management Plan and Environmental Assessment for Bent's Old Fort NHS will establish the foundation and general guidelines for vegetation management within the park, including exotic plants. At the present time, Bent's Old Fort staff are working in conjunction with the Southern Plains Network, the Southern Plains Fire Group, and the Southwest Exotic Plant Management Team to develop an implementation strategy for restoration of native plant communities and exotic plant management. This strategy will supplement the Vegetation Management Plan by proposing strategic planning for achieving the goals set forth in the vegetation management plan over the next 5 years. The strategy will consider alternative treatment options and a strategic approach to implementation of those options. Treatment options for controlling exotic plants include chemical, mechanical (e.g., mowing), and biocontrol for selected species such as field bindweed, which is extremely difficult to control. Implications of implementing a management action such as biocontrol would need to be carefully considered to determine trade-offs. The restoration strategy would also include alternative approaches for establishing native plant communities such as fire as part of site preparation, seed collection and seeding. The strategy will also serve to connect management and monitoring to the park's Foundation document as well as the Cultural Landscape Inventory.

## 5.14. Landbirds Resource Brief and Narrative

### *5.14.1. Noteworthy Highlights:*

A total of 103 bird species have been reported to occur at the Historic Site (see Appendix I), with 79 of the species observed during 2009-2012 RMBO surveys. Twenty-three species (excluding one non-native species and including six species observed in 2001-2002 only) are considered species of conservation concern by one or more organization. Five of these 23 species have high conservation potential at the Historic Site, because they are within their normal breeding ranges and breeding habitat exists for them at the Historic Site. Additionally, all five species have been observed in every year of RMBO surveys (2009-2012) at the Historic Site.

### *5.14.2. Condition Rationale*

The condition of breeding landbirds at the Historic Site, assessed using one indicator, species occurrence (presence/absence), is good (Table 5.14.2-1). We evaluated species occurrence using three measures/in three contexts (temporal, spatial, and conservation contexts), all of which were determined to be in good condition. The temporal species occurrence comparison

**Table 5.14.2-1. Summary of overall landbirds condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site.**

| **Breeding Landbirds**  | | | |
|---|---|---|---|
| Indicators of Condition | Specific Measures | Condition Status/Trend | Rationale |
| Species Occurrence | Temporal Context |  | Seventy-four percent of 72 species observed in 2001-2002 bird inventories were observed in 2009-2012 RMBO bird surveys at the Historic Site. Half of the birds not observed during recent surveys are primarily associated with habitat not surveyed in 2009-2012. Additionally, 26 species were observed in the 2009-2012 RMBO surveys that were not observed in 2001-2002. In a temporal context, the condition of breeding landbirds at the Historic Site is good. Data are available for a relatively small number of years, so no trend information is available at this time. |
| | Spatial Context |  | In a comparison of RMBO bird surveys outside of (but in the vicinity of) the Historic Site to RMBO surveys within the Historic Site, there were 15 species that were not observed at the Historic Site from 2009-2012. However, of these 15 species, more than one-half have limited to no breeding habitat at the Historic Site, and all but one of the remaining species were observed only in small numbers in the region. Based on this comparison, the condition of breeding landbirds is good. Because data are available for a relatively small number of years, no trend information is available at this time. |
| | Conservation Context |  | There are 23 species that have been observed during 2009-2012 and/or 2001-2002 surveys that are listed by one or more organization as being of conservation concern. We believe that five of these species have high conservation potential at the Historic Site. These are species that are within their normal breeding range and sufficient habitat exists at the Historic Site to support breeding. All of these species have been observed on recent RMBO surveys (each in all four years). Therefore, we consider the condition of species of conservation concern at the Historic Site to be good. We do not have sufficient data to justify a trend in the condition at this time. |

found that, of 72 bird species detected at the Historic Site in 2001-2002, 53 were detected in recent surveys. Nineteen were not detected in recent surveys. However, half of the birds not observed are associated primarily with habitat not surveyed in 2009-2012. Also, 26 additional species were observed only on recent RMBO surveys. The spatial comparison found that 15 species were observed during regional surveys but not during RMBO surveys at the Historic Site. However, the majority of the species have limited to no breeding habitat at the Historic Site, and nearly all of the remaining species were observed in small numbers in the region. Twenty-three native species that have been reported to occur at the Historic Site are listed by one or more organization as being of conservation concern. Of these, five species are considered as having high conservation potential; these are species that are within their normal breeding range, and sufficient habitat exists at the Historic Site to support their breeding. All of the five species have been observed during all four years of recent RMBO surveys. We consider the condition of species of conservation concern to be good, and the overall landbirds condition is good. Adequate information does not exist at this time to evaluate trends in the condition.

### *5.14.3. Management and Project Considerations and Narrative*

In the recent draft Foundation Document for the Historic Site (NPS 2013), historic setting was listed as one of the Historic Site's fundamental resources and values. Five components of historic setting were identified, including native flora and fauna, which includes breeding landbirds. Landbirds also play a role in two other components of the historic setting—surrounding shortgrass prairie (they are important members of the system) and natural sounds outside the Fort (bird song is a common, natural sound contributing to the setting). Birds are also mentioned as an opportunity with regards to the historic setting, because bird watching provides educational opportunities for visitors. We agree that there are substantial bird watching opportunities at the Historic Site, with at least 103 species of breeding landbirds recorded (see Appendix I). Twenty-three species of birds that are considered by various agencies/organizations as species of conservation concern have been recorded at the Historic Site. Expanding current interpretive programs to include birding opportunities during the migratory seasons could strengthen the connection between the natural setting and significance of the Fort.

The Foundation Document, however, also pointed out at least one type of bird, the swallow, is a threat to the reconstructed Fort (NPS 2013). Swallows are noted in the Foundation Document as pests (along with bats, snakes, and mice), because they may build mud nests on buildings in undesirable locations. Both bird droppings and used mud nests (eventually) fall to the ground, creating both aesthetic and cleanliness issues. Three species of swallow have been observed at the Historic Site during 2009-2012 RMBO surveys, Barn Swallow, Cliff Swallow, and Northern Rough-winged Swallow, and one species, Violet-green Swallow was observed during bird inventories in 2001/2002. The Barn Swallow and Cliff Swallow are the species most likely to build nests on/within the Fort (see Cornell Lab of Ornithology 2013 for specifics on nesting). Numerous pamphlets have been prepared by government agencies, universities, and organizations to address the problem of swallows building unwanted nests on buildings (e.g., Texas Parks and Wildlife 2002; University of California 2005). The Foundation Document calls for a control plan to address the issue. The plan should include alternatives that minimize conflicts with swallows nesting in the visitor use areas and with the preservation of the historic Fort.

There are no major data gaps with respect to breeding landbirds. RMBO has been collecting data on landbirds during the breeding season every year since 2009. Although there are not enough data to determine the trend in the condition at this time, there will be in the future.

## 5.15. Prairie Dog Resource Brief and Narrative

### *5.15.1. Noteworthy Highlights*

Except for a few individuals spotted in the summer of 2013 at the extreme southern boundary of the Historic Site, no black-tailed prairie dogs have been observed at the Historic Site since the population crashed in late 2011/early 2012. It is not known whether those few individuals will inhabit the previous colony or move off-site, or whether their numbers will grow.

### *5.15.2. Condition Rationale*

Prairie dogs are an important component of the ecosystems they inhabit. They directly and indirectly influence grasslands through their grazing and burrowing and as prey (Kotliar et al. 2006). They affect the redistribution of minerals and nutrients, encourage penetration and retention of moisture, and affect plant species composition (Kotliar et al. 2006). Prairie dog burrows and colony-sites provide shelter and nesting habitat for a variety of animals, and many animals prey on prairie dogs. It is from this ecological perspective that we assessed the condition of prairie dogs at the Historic Site, although we also acknowledge that prairie dogs may pose management challenges to national parks. We assessed condition using two measures, area occupied and density of prairie dogs, because both have been used to monitor prairie dogs and we have some data on both (Table 5.15.2-1). In recent years, the area occupied by prairie dogs increased from about 10 acres (4 ha) in 2001 to 68.2 acres (27.6 ha) in 2011. Comparing density estimates from visual surveys, prairie dog densities were below 30 prairie dogs per hectare (12.1 per acre) from 2000-2007, but they increased in 2009 (to 82 per hectare [33 per acre] in July). Densities may have declined somewhat from 2009 to 2011 (based on a crude comparison of estimates from June 2009 to April/May 2011 and July 2009 to July/August 2011), but there was a crash in the population in late 2011/early 2012, when both density and area occupied dropped to 0. The sylvatic plague killed prairie dogs in the Historic Site, with no apparent survivors. To

**Table 5.15.2-1. Summary of overall prairie dog condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site.**

| **Prairie Dog**  | | | |
|---|---|---|---|
| Indicators of Condition | Specific Measures | Condition Status/Trend | Rationale |
| Prairie Dog Occurrence | Area occupied |  | The area occupied by prairie dogs increased from about 10 acres (4 ha) in 2001 to 68.2 acres (27.6 ha) in 2011. However, in late 2011/early 2012, the area occupied dropped to 0 acres. The sylvatic plague is thought to have killed all prairie dogs in and immediately adjacent to the Historic Site. The former colony remains unoccupied to date. Therefore, based on area occupied, the condition of prairie dogs is of significant concern, and the trend is unchanging. It should be noted, however, that in the summer of 2013 a few individual prairie dogs were observed in the vicinity of the southern portion of the previous colony (between the railroad tracks and Highway 50), but it is not known if they will move in to the previous colony or whether their numbers will grow. |
| | Prairie dog density |  | Density (prairie dogs per unit area) was estimated in a number of years from 2000-2011. After several years of roughly similar density estimates from visual surveys, there was an increase from August 2007 to July 2009. Using the density estimates from visual surveys, densities may have declined somewhat from 2009 to 2011 (based on a crude comparison of estimates from June 2009 to April/May 2011 and July 2009 to July/August 2011). Whether or not there was an actual decline over these later years, there was a crash in the density by late 2011/early 2012, when the density reached 0 due to the sylvatic plague. Therefore, based on density, the condition of prairie dogs is of significant concern. Also see last sentence above. |

date, the former colony has not returned. Therefore, based on both area occupied and density, the condition of prairie dogs is of significant concern (Table 5.15.2-1). The trend is unchanging. It should be noted, however, that in the summer of 2013 a few individual prairie dogs were observed in the vicinity of the southern portion of the previous colony (between the railroad tracks and Highway 50); it is not known whether they will move into the previous colony, or whether their numbers will grow.

### *5.15.3. Management and Project Considerations and Narrative*

In the recent draft Foundation Document for the Historic Site (NPS 2013), historic setting was listed as one of the Historic Site's fundamental resources and values. Five components of historic setting were identified, including native flora and fauna, which includes the black-tailed prairie dog. Prairie dogs also play a role in another component of the historic setting—surrounding shortgrass prairie. As described in Chapter 4 of the NRCA, they are important members of the ecosystem.

In addition to playing a significant ecological role in the landscape, the prairie dog may also present management issues for parks in which it occurs. NPS policy is to conserve and recover the black-tailed prairie dog wherever possible. NPS can control prairie dogs within parks to protect human health and safety, for good neighbor relations, and to manage conflicts with other Historic Site objectives, such as the preservation of cultural/archaeological resources. Bent's Old Fort NHS developed a Prairie Dog Management Plan and Environmental Assessment in 2001 (i.e., RWNRC 2001). The plan "provides for continued restoration of the site on the north side of the river to reflect conditions that were present in 1846" and allows for "natural expansion and contraction of the colony south of the Arkansas River. Consistent with the 2001 plan, and given the current absence of prairie dogs in the river bottom habitat, active restoration of this vegetation community would benefit the endemic species that were displaced as a result of the establishment of prairie dog colonies. The river bottom is marginal habitat for prairie dogs, and the previous colonization of this area within the Historic Site is believed to be a result of displacement from the prairie dogs' native grassland habitat. Consideration of control measures may be necessary if the colony expands into adjacent private lands or if they expand onto identified archaeological sites." The management plan discusses potential management options for controlling prairie dogs and describes annual monitoring of the prairie dog population. Although it is possible that, over time, prairie dogs will again inhabit the colony-site south of the river, for the time being the Historic Site does not need to manage prairie dog numbers. Historic Site personnel will continue to watch for returning prairie dogs.



PHOTO: RON SINGER

**Black-tailed Prairie Dog (*Cynomys ludovicianus*), named for its characteristic, black-tipped tail.**

## 5.16. Fish Resource Brief and Narrative

### *5.16.1. Condition Rationale*

Four fish inventories (Nesler et al. 1999; Gionfriddo et al. 2002; Tisdale-Hein 2006; and Foutz et al. (unpub. dataset) 2012) have been conducted at the Historic Site to document the occurrence of species, with a total of 22 fish species identified through these efforts, with one additional species included in the certified species list. Approximately 35% of these represent non-native species. Future monitoring will provide park staff with necessary information to formulate management objectives. The suckermouth minnow (Phenacobius mirabilis) and flathead chub (*Hybopsis gracilis*) are Colorado species of concern. No Arkansas darters were found in the Arkansas River or Arch wetland and habitat is marginally to highly unsuitable, respectively (Tisdale-Hein 2006). No subsequent monitoring has occurred to document the continued presence or absence of these species, therefore, condition status and trend is currently unknown (Table 5.16.1-1).

### *5.16.2. Management and Project Considerations and Narrative*

The fish inventory of the wetlands, specifically the Arch wetland, has not been comprehensive. A new inventory would establish much needed baseline information for potential future efforts.

Preliminary PMIS Project Concept Pieces

*Project Overview*

Two of the fundamental resources and values of Bent's Old Fort NHS include maintaining the historic setting and preserving the archeology and artifacts associated with the fort. Historic accounts and archeological evidence indicate the presence of fish bones and scales throughout the history of the fort's presence. A fish monitoring program is relevant to the interconnectedness of the park's cultural and natural settings and would provide information related to species presence and trends, as well as information relative to metal toxicity within the park's waters, which is one of the indicators monitored to assess water quality condition at the national historic site.

*Project Justification*

The Bent's Old Fort NHS Foundation Document (National Park Service 2013) identifies the historic setting as a significance statement and as a fundamental resource and value contributing to the park's importance as a national park. The setting represents the interconnectedness between the natural and cultural environments, which was necessary to ensure survival of the varied cultures and people that came together at Bent's Old Fort.

**Table 5.16.1-1. Summary of overall fish condition, indicators and measures, and rationale for assigning condition assessment at Bent's Old Fort National Historic Site.**

| **Fish** | | | |
|---|---|---|---|
| Indicators of Condition | Specific Measures | Condition Status/Trend | Rationale |
| Species Occurrence | Presence/absence of fish | | To date, a total of 23 fish species have been detected at the Historic Site, with 8 species (34.8%) representing non-natives. No subsequent monitoring has occurred to document the current presence or absence of these species, therefore, condition status is currently unknown. |

Fish was a food source that provided sustenance to those who visited Bent's as evidenced by archeological remains of fish bones and scales. Bent's Old Fort offers a unique living history experience and not only do fish fit into the historical context but also have relevancy to present day riparian wetland and freshwater community structures. The habitats of the Arkansas River and the park's wetlands are different, therefore, likely support different species of fish. To date, a total of four fish inventories have been conducted, primarily within the Arkansas River, documenting the presence of 23 fish species, 8 of which are non-native. Two species with Colorado state status, Flathead chub (Hybopsis gracilis/Platygobio gracilus) and the Suckermouth minnow (Phenacobius mirabilis) have been observed, and there is potential that habitat for the state-threatened Arkansas darter (Etheostoma cragini) could exist, although this species has yet to be documented at the park. No additional studies have occurred to monitor the trend of these species, as well as the overall health of those species that are present.

*Methods*

Specific methods and approach would best be developed by the park in consultation with Colorado Parks and Wildlife and NPS planning, including Bent's Old Fort and Southern Plains and Sonoran Desert Inventory and Monitoring Network staffs but some ideas to consider might be:

1. How often should monitoring occur?
2. Are there management practices NPS staff can implement to support the fish populations within the park and/or enhance habitat for potential species such as the state-threatened Arkansas darter?
3. How can metal concentrations in fish inform the park's water quality monitoring program?



TODD D. CRAIL 2004

**The Suckermouth Minnow - *Phenacobius mirabilis* is a state endangered species in Colorado.**

## 5.17. Resource Action Item Summary

Below is a summary of the action items outlined above for each resource category.

**Table 5.17.1-1. Summary of action items for each resource**

| Resource | Action Items |
|---|---|
| Viewshed | • Plant tree row to block NPS stuff<br>• Enhanced interpretation<br>• Coordinate with county land use planning processes<br>• Infill spaces in cottonwood gallery along south side<br>• Conduct more extensive viewshed analysis |
| Night Sky | • Modify outdoor lighting |
| Soundscape | • Conduct soundscape assessment |
| Air Quality | • Comprehensive condition assessment of fort and adobe preservation plan |
| Surface Water Quality | • Implement water quality monitoring at Day pond and Arch wetland |
| Groundwater | • Restore ground water monitoring wells to functioning condition<br>• Continue the groundwater study that began in 2015 |
| Riparian Habitat | • Monitor riparian water table elevations<br>• Analyze implications of visitor access for potential boat take-out within park<br>• Conduct a pollen study to determine historic plant communities |
| Grasslands | • Consider if restoration of section north of Highway 194 is warranted |
| Exotic Plants | • Implement strategies for restoration of native plant communities and exotic plant management |
| Vertebrates-Fish | • Conduct new fish inventory of wetlands |
| All Resources: | • Periodically reevaluate current condition status |

## 5.18. Literature Cited

Albright, J. 2010. Standard NRCA report outline – Annotated Version 3.1. Fort Collins, CO. 4p.

Budde, P. J., B. J. Frakes, L. Nelson, and U. Glick. 2009. Technical Guide for NPScape Data and Processing. Inventory & Monitoring Division, National Park Service, Fort Collins, Colorado.

Cornell Lab of Ornithology. 2013. All About Birds. Searchable webpage for information on bird natural history. Available at http://www.allaboutbirds.org/Page.aspx?pid=1189.

Darton, N.H. 1906. Geology and underground waters of the Arkansas Valley in eastern Colorado. Washington Government Printing Office. United States Geological Survey. Professional Paper Number 52. 168pp.

Foutz et al. 2010. Warmwater stream survey, unpublished data.

Gates, T.K., L.A. Garcia, and J.W. Labadie. 2006. Toward optimal water management in Colorado's Lower Arkansas River Valley: monitoring and modeling to enhance agriculture and environment. Colorado Water Resources Research Institute completion report no. 205 and Colorado Agricultural Experiment Station completion report TR06-10. 60 pp.

Gates, T.K., L.A. Garcia, R.A. Hemphill, E.D. Morway, and A. Elhaddad. 2012.

Irrigation practices, water consumption, and return flows in Colorado's Lower Arkansas River Valley. Colorado Water Resources Research Institute completion report no. 221 and Colorado Agricultural Experiment Station completion report TR12-10. 116 pp.

Gionfriddo, J. P., D. R. Culver, and J. Stevens. 2002. Biological Survey of Bent's Old Fort National Historic Site, Otero County, Colorado. Colorado Natural Heritage Program, Fort Collins, CO.

Gross, J. E., L. K. Svancara, and T. Philippi. 2009. A guide to interpreting NPScape data and dnalyses. NPS/IMD/NRTR-2009/IMD/XXX. National Park Service, Fort Collins, Colorado.

Johnson, G. W., J. D. Anderson, and D. Godwin. 2008. A guidebook for the Blue Ridge Parkway Scenery Conservation System. Draft. National Park Service, Asheville, North Carolina.

Kearney, A. R., G. A. Bradley, C. H. Petrich, R. Kaplan, S. Kaplan, and D. Simpson-Colebank. 2008. Public perception as support for scenic quality regulation in a nationally treasured landscape. Landscape and Urban Planning 87:117-128.

KellerLynn, K. 2005. Bent's Old Fort National Historic Site, Geologic Resource Evaluation Report. Natural Resource Report NPS/NRPC/GRD/NRR—2005/005. National Park Service, Denver, Colorado.

Kotliar, N., B. Miller, R. Reading, and T. Clark. 2006. The prairie dog as a keystone species. Pps 53-64, In Hoogland, J. (ed.) Conservation of the black-tailed prairie dog: Saving North America's Western grasslands. Island Press, Washington.

Mennitt, D., K. Fristrup, K. Sherrill, and L. Nelson. 2013. Mapping sound pressure levels on continental scales using a geospatial sound model. Proceedings from Internoise Conference, Innsbruck, Austria, September 15-18, 2013. 11pp.

National Park Service. 2004. Cultural landscapes inventory 2003. National Park Service. Bent's Old Fort National Historic Site. 62pp.

National Park Service. 2012. A Call to Action: Preparing for a Second Century of Stewardship and Engagement. Washington, D.C. 28pp

National Park Service (NPS). 2013. Foundation Document: Bent's Old Fort National Historic Site. National Park Service, Denver, Colorado. 40pp.

National Park Service Water Resources National Division. 2011. Wetlands in the national parks. Online. (http://nature.nps.gov/water/wetlands/aboutwetlands.cfm). Accessed July 19, 2013.

Nesler, T.P., C. Bennett, J. Melby, G. Dowler, and M. Jones. 1999. Inventory and Status of Arkansas River Native Fishes in Colorado. Colorado Division of Wildlife.

Petuskey, W.T., D.A. Richardson, and D.A. Dolske. 1995. Aspects of the deterioration of sandstone masonry in Anasazi dwelling ruins at Mesa Verde National Park, Colorado, USA. The Science of the Total Environment. 167: 145-159.

Prichard, Don, J. Anderson, C. Correll, J. Fogg, K. Gebhardt, R. Krapf, S. Leonard, B. Mitchell, and J. Staats. 1998. A user guide to assessing proper functioning condition and the supporting science for lotic areas. Technical reference 1737-15. Bureau of Land Management, Denver, Colorado.

Ryan, R. L. 2006. Comparing the attitudes of local residents, planners, and developers about preserving rural character in New England. Landscape and Urban Planning 75: 5-22.

Real West Natural Resource Consulting (RWNRC). 2001. Bent's Old Fort National Historic Site prairie dog management

plan and draft environmental assessment. Prepared for Bent's Old Fort NHS, La Junta, Colorado by RWNRC, Laramie, Wyoming.

Snipes, R.J. and others. 1974. Floods of June 1965 in Arkansas River Basin, Colorado, Kansas, and New Mexico. Geological Survey-Water Supply Paper 1850-D. 104pp.

Tetra Tech. 2007. Lower Arkansas watershed plan. Prepared for the Southeast Colorado RC&D, Lamar, Colorado. Tetra Tech Job No. 133-5377.001. 40 pp.

Texas Parks and Wildlife. 2002. Swallow congregations: Dealing with a common problem. Five-page fact sheet. Austin, Texas. University of California. 2005. Cliff Swallows: Integrated pest management around the home. Pest Notes, Publication 7482. Four-page fact sheet.

Tisdale-Hein, Rinda E. 2006. Survey of fish and plant species in Arch Wetland and Arkansas River at Bent's Old National Historic Site. Unpublished Report. Bent's Old Fort National Historic Site, La Junta, CO.

Vana-Miller, D., C. Moore, J. Hughes and K. Noon. 2010. Water resources information and issues overview report: Bent's Old Fort National Historic Site. Natural Resource Report NPS/NRPC/WRD/NRR—2010/258. National Park Service, Fort Collins, Colorado.

University of California. 2005. Cliff Swallows: Integrated pest management around the home. Pest Notes, Publication 7482. Four-page fact sheet.

USGS. 1998. Relations of main-stem reservoir operations and specific conductance in the Lower Arkansas River, Southeastern Colorado. Pueblo, CO. 6pp.

Wagner, J. and M. Martin. 2014. Trip Report detailing Proper Functioning Condition Assessment for the Arkansas River within Bent's Old Fort National Historic Site. 26pp.

Watts, K. and J. Lindner-Lunsford. 1992. Evaluation of proposed water management alternatives to lower the high water table in the Arkansas River Valley near La Junta, Colorado. Water Resources Investigation Report 91-4046. U.S. Geological Survey, Denver, CO.

Williamson, M. 1993. Invaders, weeds and risk from genetically modified organisms. Experientia 49:219–224.

Williamson, M., and A. Fitter. 1996. The varying success of invaders. Ecology 77:1661–1666.

Woods, S.W. and L.H. MacDonald, 2002. The cause of basement flooding at Bents Old Fort National Historic Site. Technical Report for contract: Ca-1200-99-009 CSU-23.

# Appendix A: Team Members and Subject Matter Experts

**Table A.1. Bent's Old Fort National Historic Site NRCA Project Team Members**

| Bent's Old Fort NHS NRCA Project Team |
|---|
| Jeff Albright, NPS Water Resources Division's Coordinator of the NRCA Series |
| Alexa Roberts, NPS High Plains Group (Bent's Old Fort NHS, Sand Creek Massacre NHS, and Capulin Volcano NM) Superintendent |
| Rob Bennetts, NPS Southern Plains Inventory and Monitoring Network Program Manager |
| Nina Chambers, Northern Rockies Conservation Cooperative, Writer/Editor |
| Tomye Folts-Zettner, NPS Southern Plains Inventory and Monitoring Network Biologist |
| Fran Pannebaker, NPS, Bent's Old Fort NHS, Chief Natural Resources |
| Adam Heberlie, NPS, Bent's Old Fort NHS, Biological Science Technician |
| Donna Shorrock, NPS Intermountain Region Natural Resource Condition Assessment Regional Coordinator |
| Heidi Sosinski, NPS Southern Plains Inventory and Monitoring Network Data Manager |
| Kim Struthers, Utah State University, Writer/Editor |
| Patty Valentine-Darby, University of West Florida, Biologist and Writer/Editor |
| Karl Zimmermann, NPS Sand Creek Massacre NHS, Chief Resources and Operations |

**Table A.2. Bent's Old Fort NHS NRCA Subject Matter Experts**

| Subject Matter Expert | Topic | Project Deliverables |
|---|---|---|
| Jeff Albright, National Park Service Water Resources Division, Natural Resource Condition Assessment Series Coordinator | All | Program Level Review |
| Donna Shorrock, National Park Service Intermountain Region Natural Resource Condition Assessment Regional Coordinator | All | Program Level Review |
| Mark Brunson, Professor & Department Head, Environment and Society; Utah State University | Viewshed | Reviewed viewshed and soundscape sections |
| Bent's Old Fort NHS Interpretation Staff | Viewshed | Reviewed viewshed section. |
| Chad Moore, National Park Service Natural Sounds and Night Skies Division Night Sky Program Manager | Night Sky | NPS guidance on night sky monitoring and reviewed of night sky section |
| Emma Lynch National Park Service Natural Sounds and Night Skies Division Acoustical Research Specialist | Soundscape | Reviewed soundscape section |
| Ellen Porter, National Park Service Air Resources Division | Air Quality | Reviewed air quality section |
| Bruce Heise, National Park Service Geologic Resources Division Geologist | Geology | Reviewed geology section |
| Katie KellerLynn, Colorado State University, Research Associate | Geology | Reviewed geology section |
| Evan Gwilliam, National Park Service Sonoran Desert Network Ecologist | Surface Water | Wrote annual water quality reports and reviewed surface water section. |
| Pete Biggam, National Park Service Geologic Resources Division Soil Scientist | Soils | Provided NPS guidance on soils, site visit to conduct soils rapid assessment June 2013 |

***Table A.2. Bent's Old Fort NHS NRCA Subject Matter Experts (cont.)***

| Subject Matter Expert | Topic | Project Deliverables |
|---|---|---|
| Michael Martin, National Park Service Water Resources Division Hydrologist | Groundwater and Riparian Wetlands | Wrote groundwater section and provided expert opinion and report on riparian wetland assessment during June 2013 field visit |
| Joel Wagner, National Park Service Water Resources Division, Wetlands Program Leader | Riparian Wetlands | Provided expert opinion and report on riparian wetlands during June 2013 field visit |
| Tim Seastedt, University of Colorado, Department of Ecology and Evolutionary Biology Professor | Grasslands | Provided grasslands expert opinion during June 2013 field visit |
| Jonathin Horsley, National Park Service Chihuahuan Desert I&M Network and Southern Plains I&M Network Exotic/Invasive Plant Monitoring Crew Leader | Exotic Plants | Provided exotic plants section review |
| Ross Lock Rocky Mountain Bird Observatory Wildlife Biologist | Landbirds | Provided expert opinion on landbird table information |
| **Authors Who Served as Subject Matter Experts** | **Topic** | **Project Deliverables** |
| Tomye Folts-Zettner National Park Service Southern Plains Inventory and Monitoring Network Biologist/ Botanist | All | Provided expert opinion and assistance on grasslands and exotic plants and reviewed all sections |
| Heidi Sosinski, National Park Service Southern Plains Inventory and Monitoring Network Data Manager | All | Viewshed analyses, maps, graphs, and remaining graphics |

# Appendix B: Viewshed Analysis Steps

The process Heidi Sosinski used to complete the Bent's Old Fort NHS's viewshed analyses is listed below.

Downloaded 1/3 arc second national elevation dataset (NED) grid (roughly equivalent to a 30 m digital elevation model [DEM]) from The National Map Seamless Server (http://seamless.usgs.gov/). The x and y values for the NED are in arc seconds while the z data are in meters. Projected NED into NAD83 UTM 13 to get all data in meters.

Adjustments were made to the elevation grid to compensate for areas obcured due to large areas of tree cover. Tree groves were on-screen digitized from basemap aerial imagery provided by ESRI. A height value of 30 meters was assigned to each record of the attribute table. This value represents an average height of trees in the area. A height value of 0 was set to the remaining analysis area. Using the conversion tool in ArcGIS 10.1, the polygon shapfile was converted to raster format with the cell value set to the height attribute. The tree value raster was added to the NED using the Weighted Sum tool in Spatial Analyst Toolbox, with the weighted value of each input set to 1. The resulting raster was used in the following viewshed analysis.

Downloaded Bent's Old Fort National Historic Site boundary, roads, and trails layers from NPS Integrated Resource Management Applications (IRMA) portal (https://irma.nps.gov).

Prepared Observation Point layers for Viewshed Analyses.

Created point layers for bastion towers at the fort.

Used Edit > Create New Feature tool to create 2 observation points (NE Tower and SW Tower). Saved file as obs_point.shp

Added field named "OFFSETA" (type = double) to shapefile and set value to 7.78 for the SW tower and 7.17 for the NE tower in each respective record in the attribute table. The value in the field "OFFSETA" represents an observer height of 1.68m (~5'6") plus the total height of each tower.

Ran Viewshed Analysis using ESRI Spatial Analyst Viewshed Tool.

Using the Viewshed Tool in ESRI's ArcGIS 10, Spatial Analyst Toolbox, ran viewsheds using the following inputs.

- Input raster = 1/3 arc second NED modified to include area tree cover.
- Input point observer feature = obs_point.shp.

# Appendix C: Bortle Dark-Sky Scale

## Key for the Summer Sky— Latitudes 30° to 50° N

**The Milky Way is not visible and sky glow extends above 35 degrees. Little to no dark adaptation is possible. Ground texture is easily seen, and artificial light dominates the landscape. Visible constellations are limited to the very brightest if any. The sky has a uniform washed out appearance.[1]**

If this describes your nighttime environment, continue below

If the nighttime environment appears darker than this description, jump to the next section

Sky appears nearly completely washed out, and is luminous. Dark adaptation is not possible, ground is brightly illuminated and fewer than 200 stars are visible. Only the most major constellations are identifiable. For instance, the entire keystone of Hercules or the five stars of Delphinus are not completely visible.

this is accurate **Bortle Class 9** if darker—proceed below

Constellations are visible but may be missing key stars, sky background has a uniform washed out glow with light domes reaching 60 degrees above the horizon. Stars such as the tip of Sagitta or epsilon Lyrae are not visible. If clouds are present they are brilliantly lit.

this is accurate **Bortle Class 8** if darker—proceed below

Brighter constellations are easily seen in full, yet sky background has greyish or yellow background. Milky Way may be just barely seen near the zenith. The Scutum and Cygnus star clouds are not visible.If clouds are present they are brilliantly lit. Ground texture is still visible.

this is accurate **Bortle Class 7**

**The Milky Way is visible but discontinuous, and lost to light domes near the horizon. Fine details and structure are not easily visible, if at all. Ground texture is still visible, and shadows are cast from light pollution. Light domes are clearly visible along the horizon and appear brighter than any portion of the visible Milky Way.[2]**

If this describes your nighttime environment, continue below

If the nighttime environment appears darker than this description, jump to the next section

The Milky Way is just visible overhead, but is not continuous and is diminished to obvious skyglow. Cygnus ,Scutum, and Sagittarius star fields just visible. If clouds present they are illuminated and reflecting light. Ground texture is seen with difficulty.

this is accurate **Bortle Class 6** if darker—proceed below

Milky Way is faintly present, but may have occasional gaps and is lost to skyglow near the horizon. Great rift in Cygnus is just visible. Any clouds present are brighter than the background sky and reflect light back. Zodiacal light may be glimpsed, but is difficult to see amidst the light pollution. Ground texture is not visible but forms are easily seen.

this is accurate **Bortle Class 5** if darker—proceed below

Milky Way is evident from horizon to horizon, but fine details are lost. Clouds are just brighter than background sky, but appear dark at zenith. Light domes are much brighter than brightest part of Milky Way and extend to up to 15 degrees above the horizon. Zodiacal light is evident in west after sunset or in east before dawn. Deep sky objects such as the M13 globular cluster and Northern Coal Sac are visible.

this is accurate **Bortle Class 4**

**The Milky Way has a defined outline with visible structure and detail. Very few light domes are visible just along the horizon and do not cast shadows. You may see color in the Zodical light when compared to bluish-white color of the Milky Way. Scattered clouds appear dark against the night sky except those clouds just above light domes.**[3]

If this describes your nighttime environment, continue below

Milky Way appears complex with visible outline, however some light pollution is still evident along the horizon. Light domes only slightly brighter than brightest part of the Milky Way. Zodiacal light easily seen, but band and gegenschein difficult or absent. Many summer globular clusters and emission nebulae are visible with the naked eye despite distracting light domes along the horizon. Venus casts an obvious shadow.

this is accurate **Bortle Class 3** if darker—proceed below

Very few light domes are visible; with none extending above 5 degrees and fainter than the Milky Way. Airglow is often visible, and character in its brightness may be seen. Ground is mostly dark. The Zodiacal band (away from the Milky Way and at least 45 degrees above the horizon) and gegenschein are visible. The rift in the Cygnus star cloud is visible. The Prancing Horse in Sagittarius and Fingers of Ophiuchus dark nebulae are visible, extending to Antares. Jupiter and Milky Way cast barely visible shadows.

this is accurate **Bortle Class 2** if darker—proceed below

The Milky Way is intricate, marbled, and veined with Sagittarius region of the Milky Way casting obvious shadows. Milky Way appears 40 degrees wide in some parts with a convoluted outline. The horizon completely free of light domes, though some distant light domes may be visible from mountain tops. Transparency and seeing are excellent (among the best of the year) with very low airglow. Many objects such as M81 or the Helix nebula are visible with the naked eye. Zodical light is striking as a complete band. Any clouds are very difficult to see.

this is accurate **Bortle Class 1**

---

The Bortle Dark-Sky Scale is a qualitative scale developed by John Bortle and published in Sky & Telescope Magaine in 2001. It provides a useful complement to quantitative measures. The National Park Service is testing this dichotomous key for use by professional and citizen scientists. Some knowledge of the night sky and visual observational techniques are required to properly implement this assessment.

**note 1) At least 5 minutes of dark adaptation is required to properly differentiate Class 7,8 & 9 skies.**

**note 2) At least 10 minutes of dark adaptation is required to properly differentiate Class 4, 5 & 6 skies.**

**note 3) 20 to 120 minutes of dark adaptation is required to properly differentiate Class 1, 2 & 3 skies.**

Developed by Jeremy White, Dan Duriscoe, and Chad Moore of the NPS Natural Sounds & Night Skies Division, www.nature.nps.gov/night

August 2, 2012

# Appendix D: Listening Session Reports

## D.1. Inside Fort June 3, 2013

### Soundscape Audibility Report

*No description entered.*

**Sessions:** Duration as seconds: 3,613 Duration as minutes: 60.22 AudRpt ID: 74

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Session ID: | 9097600 | Date: | 6/3/2013 | Name: | Struthers, Kimberly | | |
| Site: | 001 | Start Time: | 10:30 AM | Address: | | | |
| SubSite ID: | FORT | Endt Time: | 11:30 AM | Phone: | | Wind: | 10-15 |
| Park: | BEOL | Time Group: | 0 | Palm ID: | PN70UCM7V2 | Weather: | Sunny |
| Comments: | AVAL/SLIDE IS MAINT OPS WITHIN THE FORT REMAINING GROUNDS NOISES ARE CULTURAL | | | | | | |

Sound Source Audibility (PA: Percentage of period audible, Events reported as seconds)

| Sound ID | Sound Source Description | PA | Max Event | Mean Event | Min Event | SD Event | Count |
|---|---|---|---|---|---|---|---|
| 1.1 | Jet | 11.0 | 94 | 36 | 3 | 32 | 11 |
| 1.2 | Aircraft, Propeller | 1.0 | 15 | 12 | 9 | 4 | 2 |
| 2 | Vehicle | 28.0 | 181 | 40 | 1 | 44 | 25 |
| 5 | Train | 3.0 | 42 | 30 | 23 | 10 | 3 |
| 7 | Grounds Care | 14.0 | 146 | 16 | 0 | 27 | 32 |
| 8.1 | People, Voices | 13.0 | 100 | 34 | 0 | 34 | 14 |
| 11 | Maintenance Ops | 1.0 | 32 | 32 | 32 | | 1 |
| 21 | Wind | 62.0 | 269 | 32 | 1 | 46 | 69 |
| 22.21 | Flowing Water, Rapids | 0.0 | 1 | 1 | 1 | | 1 |
| 22.3 | Interpretive Talk | 44.0 | 813 | 76 | 1 | 184 | 21 |
| 23 | Thunder | 0.0 | 1 | 1 | 1 | | 1 |
| 24.4 | People Walking | 44.0 | 143 | 31 | 0 | 34 | 51 |
| 24.5 | Domestic Animal | 1.0 | 4 | 2 | 0 | 1 | 12 |
| 25 | Bird | 46.0 | 290 | 33 | 0 | 67 | 51 |
| 25.4 | People | 64.0 | 288 | 45 | 0 | 56 | 51 |
| 28 | Insect | 0.0 | 1 | 0 | 0 | 1 | 2 |
| 40 | Natural Unknown | 3.0 | 42 | 15 | 1 | 17 | 7 |
| G0100 | All Aircraft | 11.6 | | | | | |
| G0200 | All Road Vehicles | 27.8 | | | | | |
| G2000 | All Non-natural Sources | 52.9 | | | | | |
| G4000 | All Natural Sources | 98.2 | | | | | |
| NFI | Noise Free Interval | 47.1 | 194 | 35 | 1 | 44 | 48 |

## D.2. Inside Fort - June 4, 2013

### Soundscape Audibility Report

*No description entered.*

**Sessions:** Duration as seconds: 3,600 Duration as minutes: 60.00 AudRpt ID: 79

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Session ID: | 9097603 | Date: | 6/4/2013 | Name: | Struthers, Kimberly | | |
| Site: | 0011 | Start Time: | 9:30 AM | Address: | | | |
| SubSite ID: | fort | Endt Time: | 10:30 AM | Phone: | | Wind: | 5-10 |
| Park: | BEOL | Time Group: | 0 | Palm ID: | PN70UCM7V2 | Weather: | Partly Cloudy |
| Comments: | | | | | | | |

Sound Source Audibility (PA: Percentage of period audible, Events reported as seconds)

| Sound ID | Sound Source Description | PA | Max Event | Mean Event | Min Event | SD Event | Count |
|---|---|---|---|---|---|---|---|
| 1.1 | Jet | 1.0 | 39 | 23 | 7 | 23 | 2 |
| 1.3 | Helicopter | 2.0 | 65 | 65 | 65 | | 1 |
| 2 | Vehicle | 18.0 | 126 | 32 | 1 | 39 | 20 |
| 5 | Train | 14.0 | 178 | 32 | 1 | 44 | 15 |
| 8.1 | People, Voices | 68.0 | 450 | 87 | 1 | 118 | 28 |
| 20 | Non-natural Unknown | 1.0 | 11 | 5 | 2 | 3 | 9 |
| 21 | Wind | 43.0 | 183 | 40 | 3 | 37 | 39 |
| 25 | Bird | 94.0 | 487 | 121 | 0 | 138 | 28 |
| 26 | Cultural Sounds | 75.0 | 265 | 22 | 0 | 32 | 124 |
| 28 | Insect | 1.0 | 34 | 12 | 1 | 19 | 3 |
| 39.1 | Natural Other | 0.0 | 2 | 2 | 2 | | 1 |
| 40 | Natural Unknown | 1.0 | 22 | 12 | 2 | 14 | 2 |
| G0100 | All Aircraft | 3.1 | | | | | |
| G0200 | All Road Vehicles | 17.7 | | | | | |
| G2000 | All Non-natural Sources | 77.5 | | | | | |
| G4000 | All Natural Sources | 97.1 | | | | | |
| NFI | Noise Free Interval | 23.4 | 154 | 26 | 1 | 34 | 32 |

# D.3. Picnic Area - June 3, 2013

## Soundscape Audibility Report

*No description entered.*

**Sessions:** Duration as seconds: 1,800 Duration as minutes: 30.00 AudRpt ID: 75

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Session ID: | 9097601 | Date: | 6/3/2013 | Name: | Struthers, Kimberly | | |
| Site: | 002 | Start Time: | 12:20 PM | Address: | | | |
| SubSite ID: | arch-picnic | Endt Time: | 12:50 PM | Phone: | | Wind: | 10 |
| Park: | BEOL | Time Group: | 0 | Palm ID: | PN70UCM7V2 | Weather: | Sunny |

Comments: People, walking, non-natural unknown are all grouped into Developed Zone Activities. Natural other has been changed to be an extrinsic sound source.

Sound Source Audibility (PA: Percentage of period audible, Events reported as seconds)

| Sound ID | Sound Source Description | PA | Max Event | Mean Event | Min Event | SD Event | Count |
|---|---|---|---|---|---|---|---|
| 1.1 | Jet | 0.0 | 6 | 6 | 6 | | 1 |
| 2 | Vehicle | 38.0 | 95 | 17 | 1 | 17 | 39 |
| 11 | Natural Other | 81.0 | 1,018 | 209 | 12 | 360 | 7 |
| 20 | Developed Zone Activity | 112.0 | 767 | 47 | 0 | 122 | 43 |
| 21 | Wind | 61.0 | 639 | 110 | 7 | 190 | 10 |
| 25 | Bird | 9.0 | 30 | 3 | 0 | 4 | 57 |
| 28 | Insect | 0.0 | 1 | 1 | 1 | | 1 |
| G0100 | All Aircraft | 0.3 | | | | | |
| G0200 | All Road Vehicles | 37.0 | | | | | |
| G2000 | All Non-natural Sources | 99.9 | | | | | |
| G4000 | All Natural Sources | 67.9 | | | | | |
| NFI | Noise Free Interval | 8.3 | 69 | 14 | 1 | 19 | 11 |

## D.4. Nature Trail-Cottonwoods - June 4, 2013

### Soundscape Audibility Report

*No description entered.*

**Sessions:** Duration as seconds: 3,600 Duration as minutes: 60.00 AudRpt ID: 70

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Session ID: | 9097604 | Date: | 6/4/2013 | Name: | Struthers, Kimberly | | |
| Site: | 0033 | Start Time: | 10:45 AM | Address: | | | |
| SubSite ID: | COTTON | Endt Time: | 11:45 AM | Phone: | | Wind: | 5-10 |
| Park: | BEOL | Time Group: | 0 | Palm ID: | PN70UCM7V2 | Weather: | Sunny |
| Comments: | | | | | | | |

Sound Source Audibility (PA: Percentage of period audible, Events reported as seconds)

| Sound ID | Sound Source Description | PA | Max Event | Mean Event | Min Event | SD Event | Count |
|---|---|---|---|---|---|---|---|
| 1.1 | Jet | 39.0 | 185 | 79 | 6 | 59 | 18 |
| 1.2 | Aircraft, Propeller | 2.0 | 62 | 36 | 11 | 36 | 2 |
| 2 | Vehicle | 68.0 | 249 | 66 | 2 | 65 | 37 |
| 5 | Train | 0.0 | 3 | 2 | 2 | 1 | 2 |
| 9 | Domestic Animal | 0.0 | 2 | 2 | 2 | 0 | 2 |
| 20 | Non-natural Unknown | 0.0 | 2 | 1 | 1 | 1 | 3 |
| 21 | Wind | 19.0 | 188 | 40 | 1 | 44 | 17 |
| 25 | Bird | 100.0 | 3,599 | 3,599 | 3,599 | | 1 |
| 28 | Insect | 1.0 | 3 | 1 | 0 | 1 | 22 |
| 39.1 | Natural Other | 87.0 | 995 | 223 | 1 | 285 | 14 |
| 40 | Natural Unknown | 0.0 | 5 | 3 | 1 | 3 | 2 |
| G0100 | All Aircraft | 41.5 | | | | | |
| G0200 | All Road Vehicles | 67.5 | | | | | |
| G2000 | All Non-natural Sources | 87.0 | | | | | |
| G4000 | All Natural Sources | 100.0 | | | | | |
| NFI | Noise Free Interval | 13.0 | 64 | 15 | 1 | 15 | 32 |

## D.5. NSNSD Soundscape Models

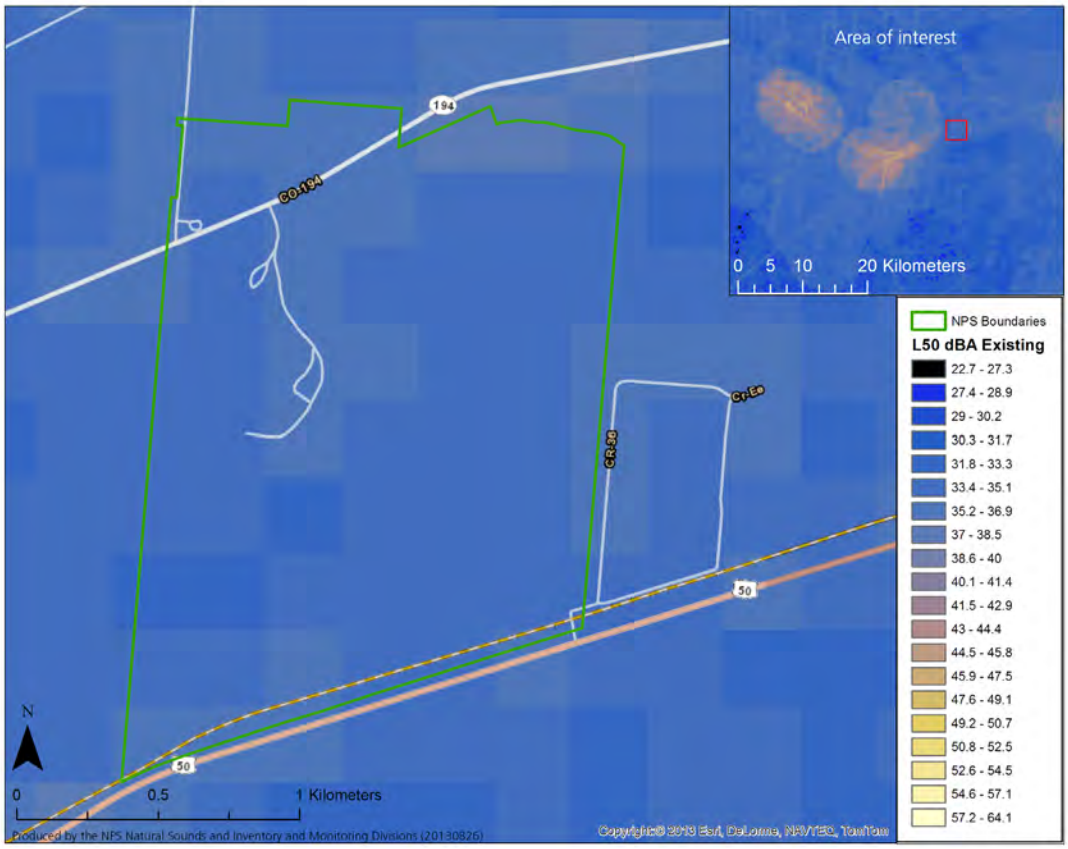



**Figure D-1. Existing CONUS soundscape model zoomed to Bent's Old Fort NHS.**

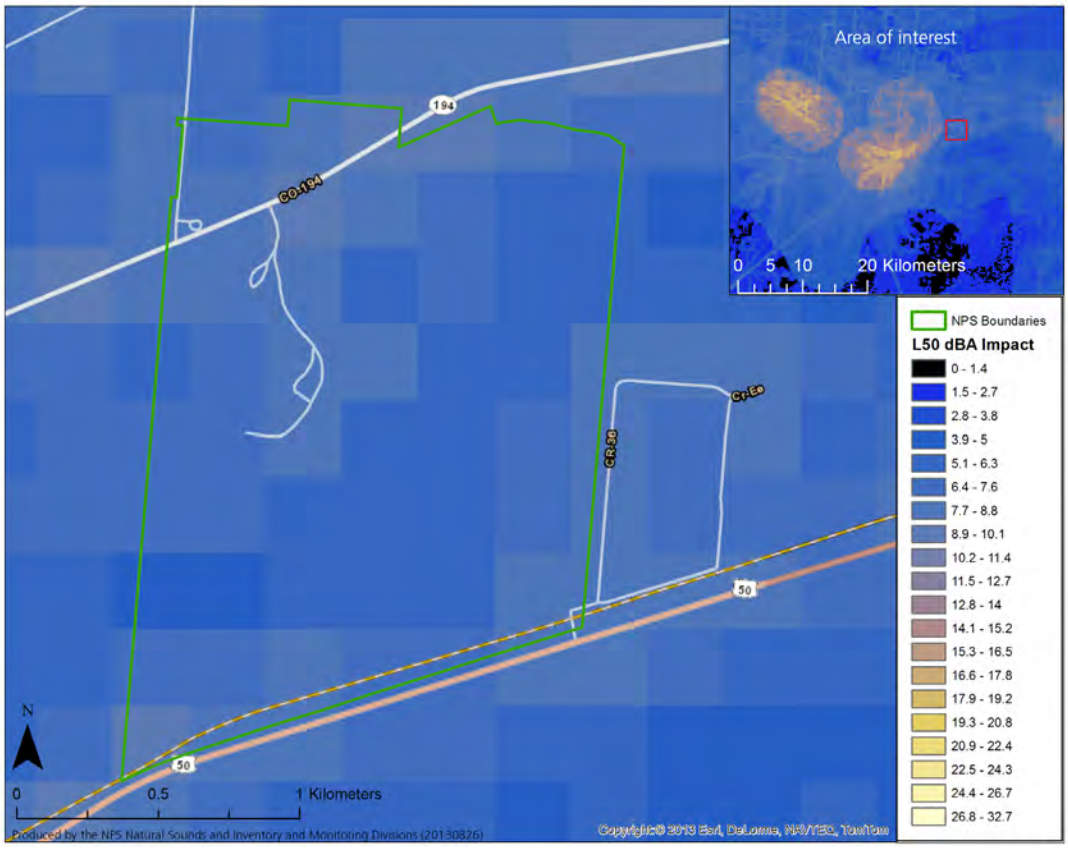



**Figure D-2. Impact between existing and natural CONUS soundscape models zoomed to Bent's Old Fort NHS.**

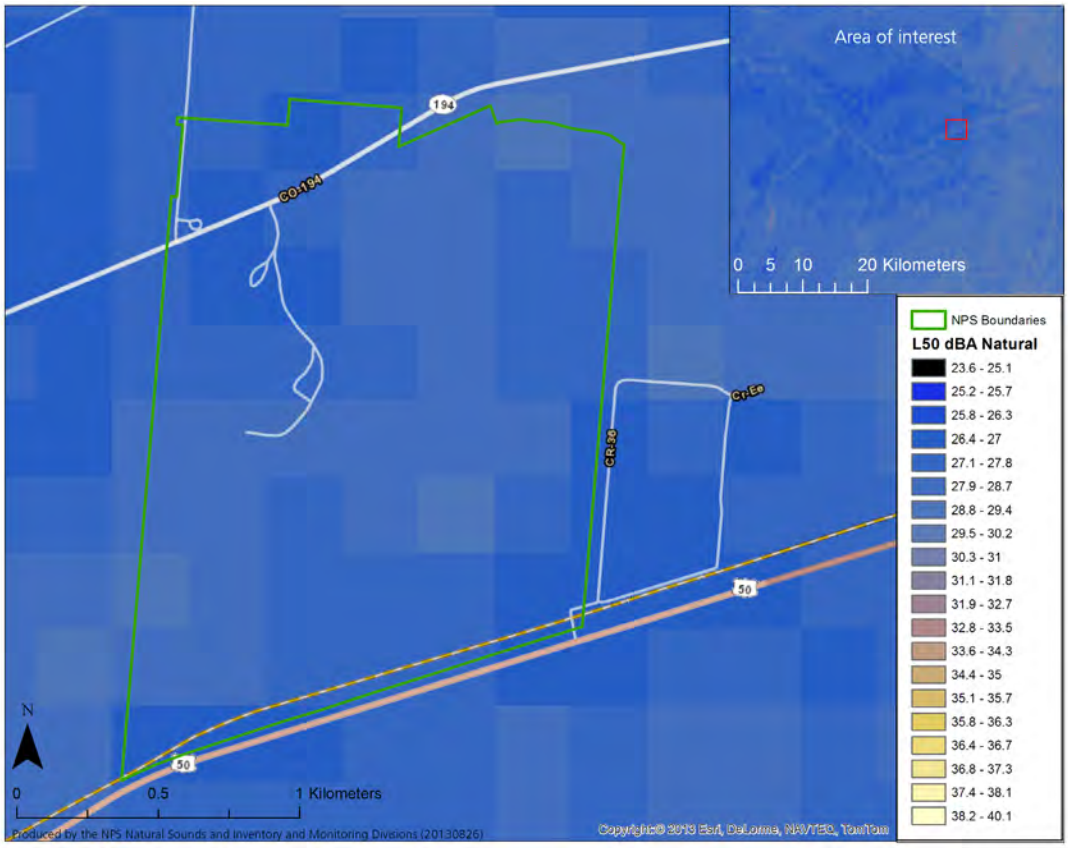



**Figure D-3. Natural CONUS soundscape model zoomed to Bent's Old Fort NHS.**

# Appendix E: Grassland and Soil Assessment - June 3 and 4, 2013

## Overall comments regarding Landscape-scale diversity:

- Sand sage areas relatively kochia-free
- Areas where kochia (*Kochia scoparia*) is a monoculture will require a strategic approach to management; it is a disturbance agricultural weed whose response to CO2 and increased nitrogen deposition is unknown.
- Russian knapweed (*Acroptilon repens*) is a secondary management problem
- What is the rate of nitrogen deposition at the park? Possibly high enough to cause additional impacts to vegetation communities. Ammonia plumes from nearby feedlots are possible
- Given that the north side of the river gets all of the visitor use, what funds are available for proactive vegetation restoration should go to enhancing that area. Such activities would include the removal of individual Russian knapweed, pepper grass plants, and the few surviving or invading tamarisk coming in from adjacent areas. While the south side contains one of the few prairie dog sites (and live prairie dogs were seen just off-site), prairie dogs are not locally rare.

## Site #1 – Restoration area between Admin and Fort.

*Waypoint #001*

Seastadt: Homogeneous topography (lack of microhabitats) contributes to lack of diversity. The extreme drought is of concern and has impacted this community. The amount of grazing taking place in the area adds to the concern – it may now be too much in relation to the dryness and should be rested. Exotics are at low levels and what bindweed (*Convolvulus arvensis*) exists should not get established if other vegetation fills the spaces. The dust storms that occurred within the region during the time of the review caution managers to maintain vegetation cover. Removal of non-natives that provide soil protection during dry periods should be limited to early detection and eradication efforts.

Species Composition – Local Scale: Good for the current drought; absolute cover of concern in regards to current grazing pressure.

Response of Annual Species: Good. Majority of community in native perennials. Annuals are definitely drought-affected.

Relative Proportion of Functional Groups: Good to Moderate. Certainty is difficult given drought condition. Forbs are missing now but have been present in the past. Graminoid dominated. One shrub but consistent with past and current land use.

C3 vs C4: C4 dominated. Few C3s.

Biggam: Loamy range-site. Past land use has affected soil; it was hammered during the fort period and plowed after that.

No rills or water flows; there are some areas of pedestaling due primarily to wind. Bare ground would be moderate under normal conditions but are moderate-extreme due to drought. No gullys. There is wind scour but no sign of deposition. No litter movement (because of very little litter). Soil surface resistance is moderate.

## Site #2 – Cottonwood/Salt grass – north side

*Waypoint #002*

Seastadt: There are signs of a dropped water table.

Landscape-scale Diversity: Good. Higher native component than seen on south side of river in similar habitat (Site #5 & 6). This may be due to a higher rate of exotic control – check with park.

Local-scale Diversity: Good. Young, even-aged cottonwoods with fire scars. Some kochia but little compared to south side. Some knapweed also. More arid community than on south side. No crises issues.

Response of Annual Species: Good. Kochia and salsola (*Salsola tragus*) found primarily near two-track road.

Relative Proportion of Functional Groups: Fairly good. No shrubs in understory. Could this area have suffered from historic horse use?

C3 vs C4: Good balance.

Biggam: The soil is protected by cover. #1-6: normal; #7 none to slight; #8 no crises; no soil surface loss; community is good; no compaction.

## Site #3 – Prairie Dog Town – South side

*Waypoint #003*

Seastadt: Old alfalfa field. If prairie dogs return to this site it will further degrade. At least without winter herbivory, the bindweed is helping to hold the soil. Continued drought and return of prairie dogs will undoubtedly result in surface soil movements and removal. This is a 'natural' (i.e., occurred post Pliestocene in a number of areas of eastern Colorado) but presumed to be highly undesirable.

Landscape-scale diversity: This is a failed agricultural restoration/prairie dog town.

Locale-scale diversity: Poor. Primarily exotic bindweed and salsola. Native milkvetch (*Astragalus* species) and Iva (*Iva axillaris*).

Response of Annual Species: High level of annual forbs; some native perennial forbs.

Relative Proportion of Functional Groups: Poor. No grasses or shrubs.

C3 vs. C4: n/a

Biggam: Salt meadow; verdic soils; heavy clay; difficult soils to revegetate without irrigation; will compact; chances are this will never recover to anything but go-back land. This site is heavily manipulated by seeding. Rills are manmade furrows and moderate to severe. These rills contribute to water flow at moderate to extreme. Pedastals are none. Bare ground is extreme to total. No wind scouring now but potential exists at moderate. Litter movement is moderate. Soil surface resistance is manmade at moderate to extreme. Soil loss has occurred in the past and could occur again at moderate to extreme. Community composition at extreme to total. Compaction is good. Overall score of Severe to Extreme.

## Site #4 – Sand Sage Community

### *Waypoint #004*

Landscape-scale diversity: Moderate concern. This community is a nice addition to the park and is good for plant and wildlife diversity. There is moderate to low heterogeneity and low microsite variability.

Local-scale diversity: Moderate concern (?). Low with current drought but has shown better diversity in the past.

Response of Annual Species: Good. There is low disturbance and very few annuals (occasional salsola).

Relative Proportion of Functional Groups: Moderate concern (?: historical vegetation composition of these communities should be checked to inform this evaluation). Currently no forbs or C3 grasses; probably drought related response?

C3 vs. C4: C4 grasses only. Not sure how to rank this right now.

Biggam: This community is probably a result of continuous grazing. Wildlife potential would be increased if sagebrush were mowed to remove decadent material. Water flow is moderate to extreme. Pedastals are moderate. Bare ground is extreme. No gullies. Wind scour is currently slight to moderate, but the potential is high. Litter movement from none/slight to slight/moderate, although very little litter exists to be more certain. Soils resistance is moderate. Plant community is moderate. Compaction plating is occurring because of the drought and bare ground but ranks at slight to moderate.

## Site #5 – Inland saltgrass – Tamarisk treatment – western site

### *Waypoint #005*

This site has been heavily disturbed because of tamarisk removal activities. The terrain is very uneven due to tamarisk roots catching/holding soil, causing ridges to form and resulting in a concave/convex surface. Post-removal mowing (gyrotrack) of kochia "bones" has caused additional soil disturbance on the sandy soil. Flooding will go a long way to heal this area by redistributing both soil and remaining tamarisk "mulch".

Landscape-scale diversity: While not currently existing, there is a good potential for future diversity

Local-scale diversity: Similar to landscape-scale situation. It should be noted that western wheatgrass (*Pascopyrum smithii*) and inland saltgrass (*Distichlis spicata*), both of which are rhizomatous, are present and spreading, especially in the concave depressions. Rainfall would help them to spread more rapidly.

Response of Annual Species: Kochia (*Kochia scoparia*) is quite common throughout the area, particularly and most thickly in areas where gyrotrack action has disturbed the soil (turning too sharply). In areas that have not been recently disturbed, kochia sprouting has been minimal, possibly due to the extreme drought.

Relative Proportion of Functional Groups: No shrubs, limited forbs (few of which were native). What grasses were present were desirable perennial natives, but this site is still highly disturbed with a short time since major disturbance.

C3 vs. C4: C3s only, no C4s. This is a C3 dominated ecosite.

Biggam: Site is a story of disturbance. Rodents are bringing up sand to surface. Concave depressions are accumulating litter and are establishing a good vegetation cover. Convex ridges show both soil and litter movement due to wind erosion. A big mosaic of vegetation should occur following the next big flood. Plant community is moderate to extreme due to mechanical treatment. No compaction. Overall score of slight to moderate.

Additional comments Seastadt: Biggam's observation that the tamarisk invasion generated 'invasive soils' and microhabitat patterning that formerly didn't exist at the site. This might explain the persistence of kochia in an area that should be eventally colonized by saltgrass. The gyrotrack activity may have been a mixed bag activity given soil disturbance to the former tamarisk mounds, but natives are present and flooding may be able to erase the 'invasive soil' effect.

## Site #6 – Inland saltgrass – Tamarisk treatment – central site

*Waypoint #006*

This site also underwent tamarisk removal in the mid-90s. The ridging is not as prominent and the grass cover is much thicker. This site was gyrotracked in fall 2012.

Seastadt This site 'looked good'. In conjunction with the sagebrush area (which was, as noted by Biggam, perhaps 'overmature') these were the 'best' of the south of river sites.

Landscape-scale diversity:

Local-scale diversity: The mowing has helped the C3 grasses establish and outcompete kochia.

Response of Annual Species: The thick grass cover and extended drought has limited the kochia regeneration. However, again in places where the gyrotrack disturbed the soil, kochia sprouts have taken root. There are beginning to be a few native annual forbs.

Relative Proportion of Functional Groups: This is a cottonwood savanna with very few shrubs, although sand sage may eventually establish on the higher soil ridges. Not many forbs and most are annuals.

C3 vs, C4: There is a good mix of both grasses.

Biggam: This site is in good shape from a soils perspective.

# Appendix F: Maps of the Known Distribution of Exotic Plant Species At Bent's Old Fort NHS

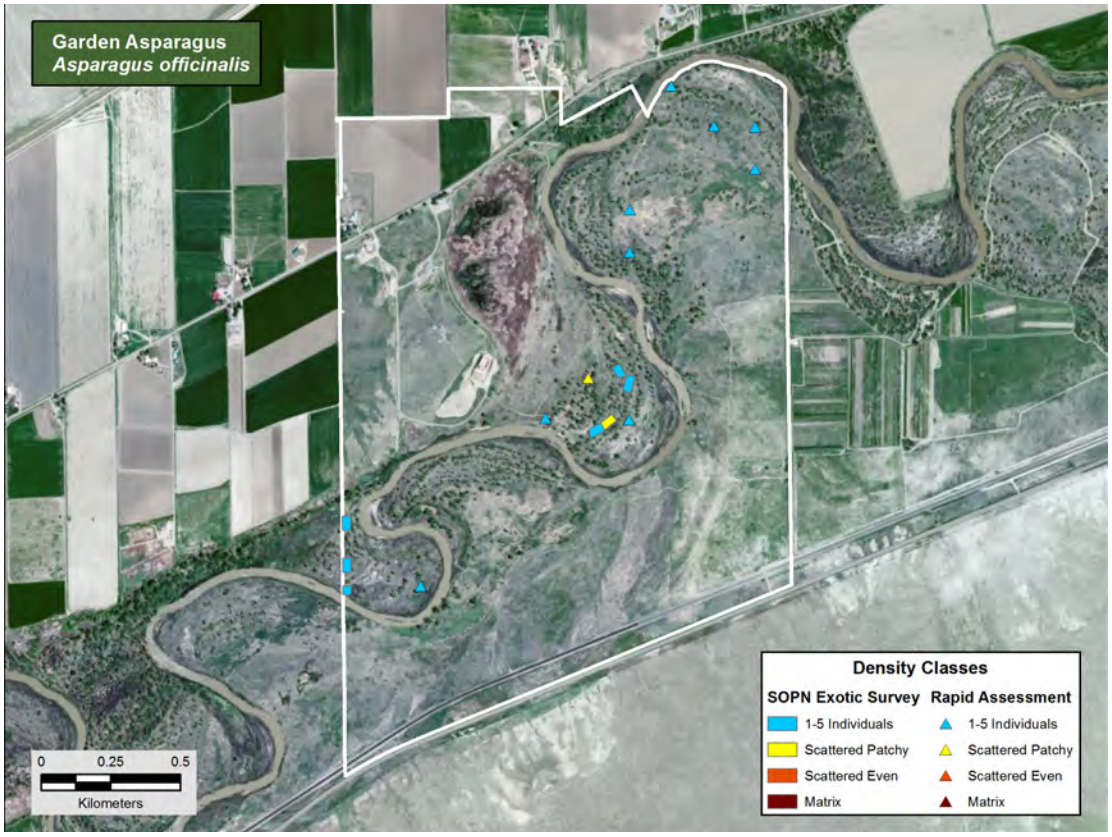



**Figure F-1. Garden Asparagus (*Asparagus officinalis*)**

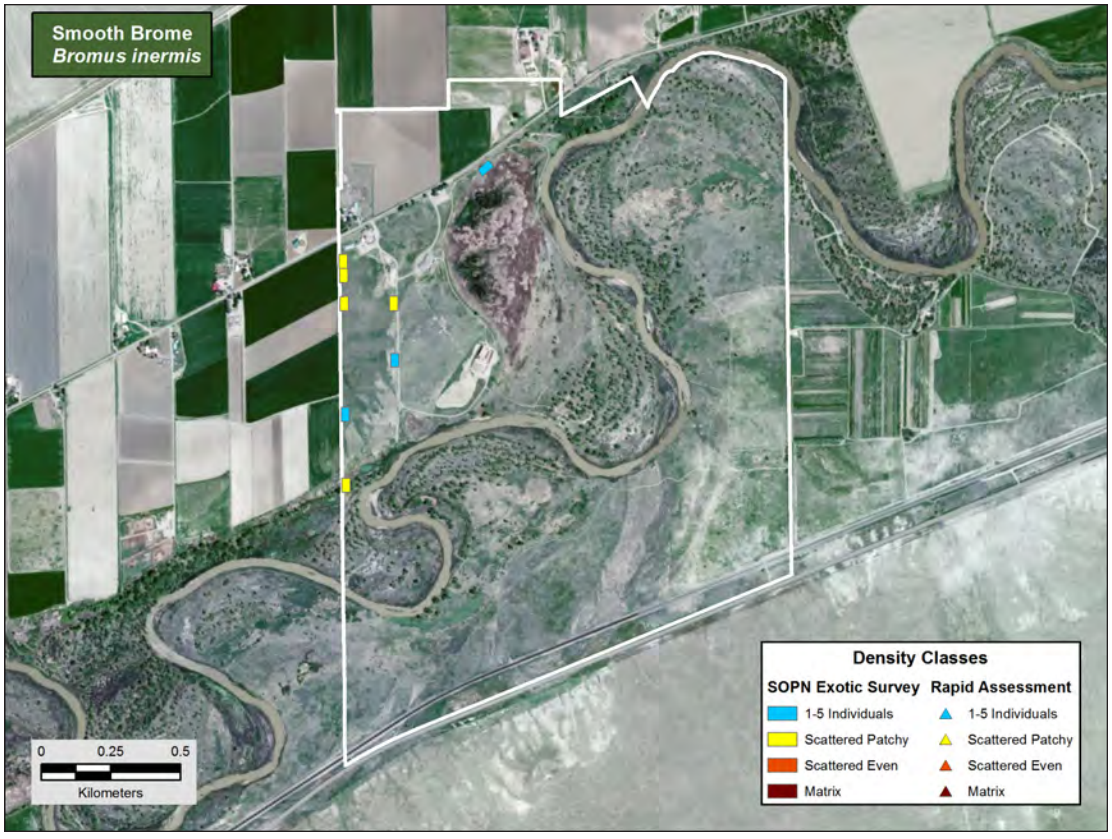



**Figure F-2. Smooth brome (*Bromus inermis*)**

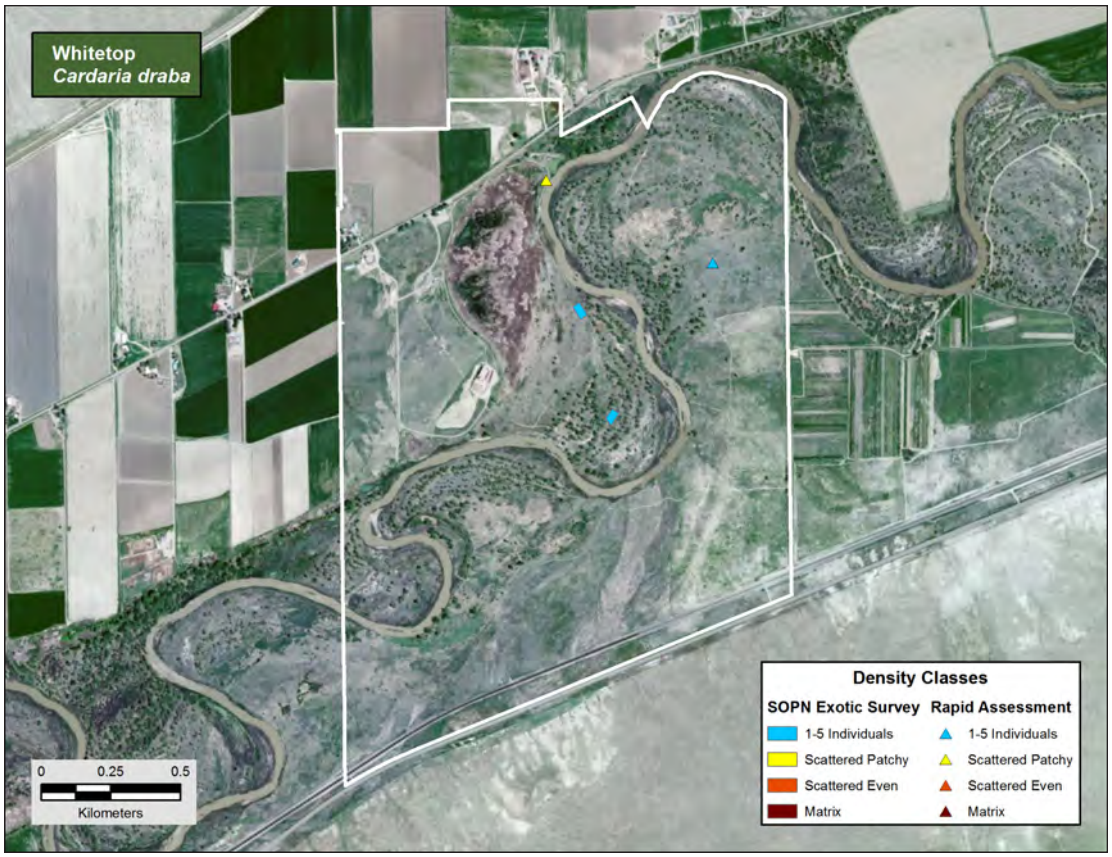



**Figure F-3. Whitetop (*Cardaria draba)***

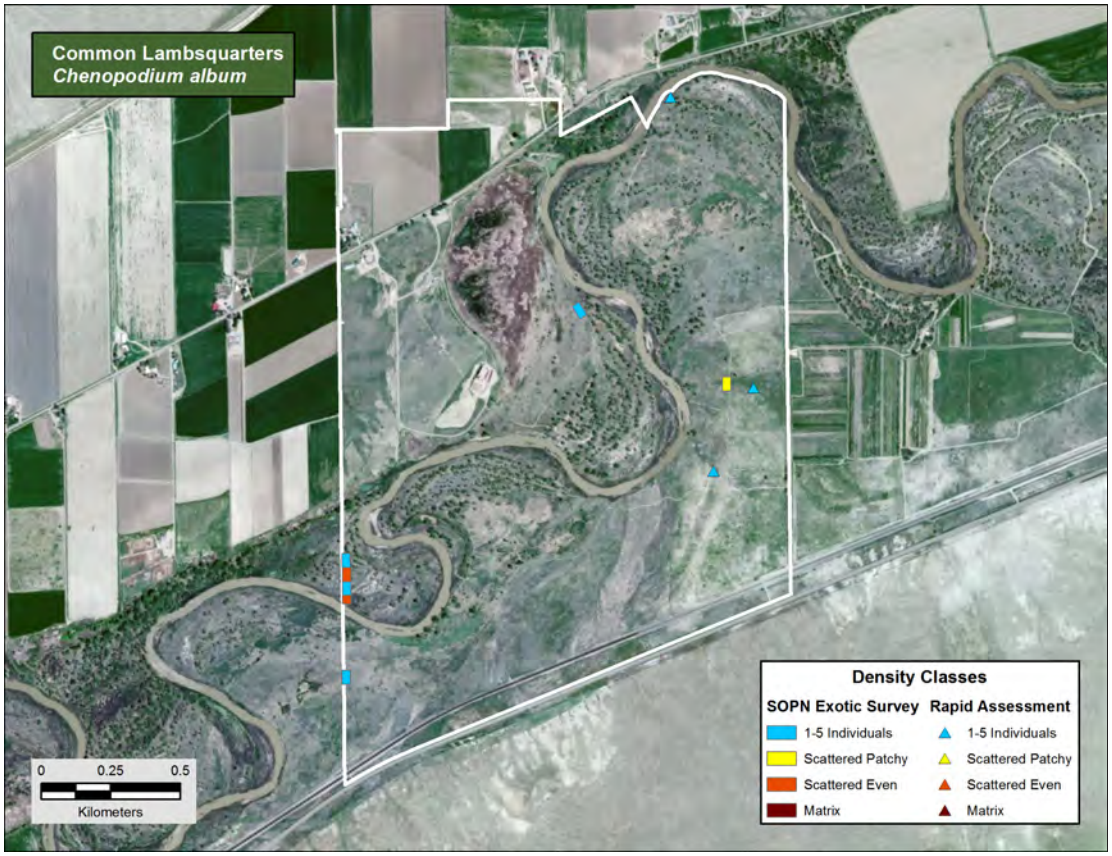



**Figure F-4. Common lambsquarters (*Chenopodium album)***

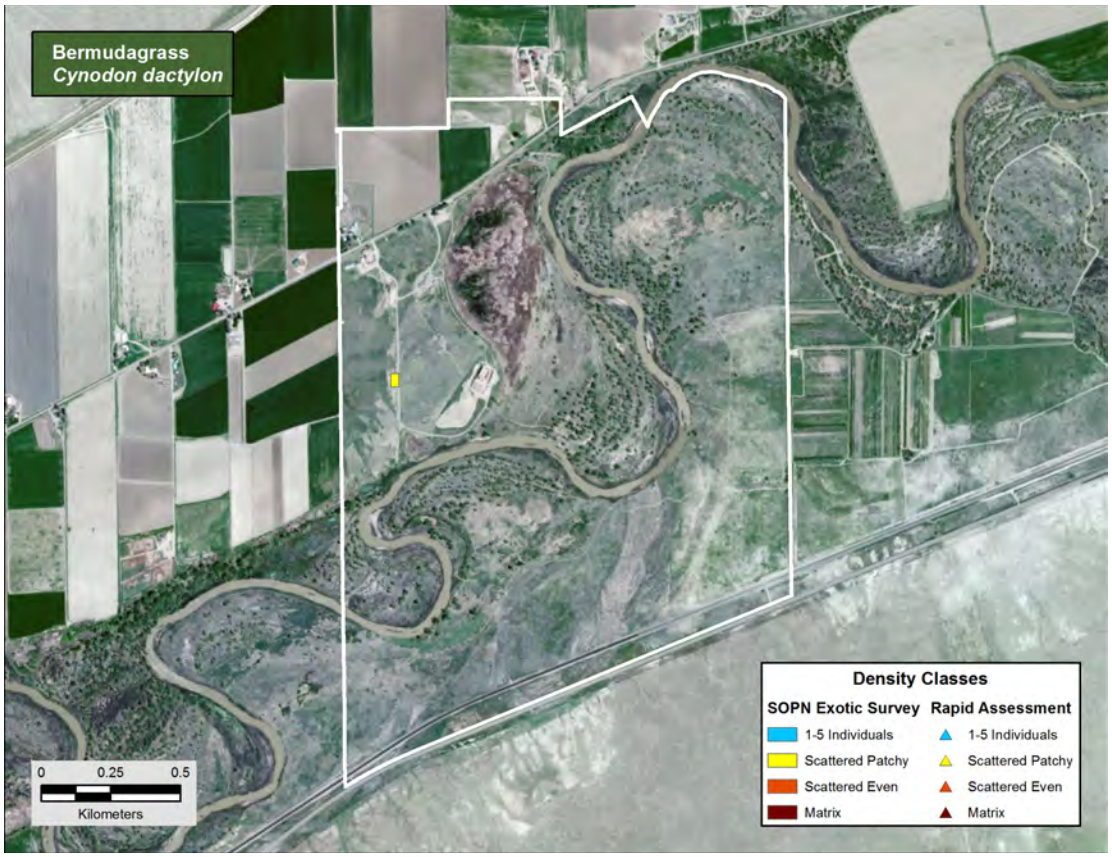



**Figure F-5. Bermudagrass (*Cynodon dactylon)***

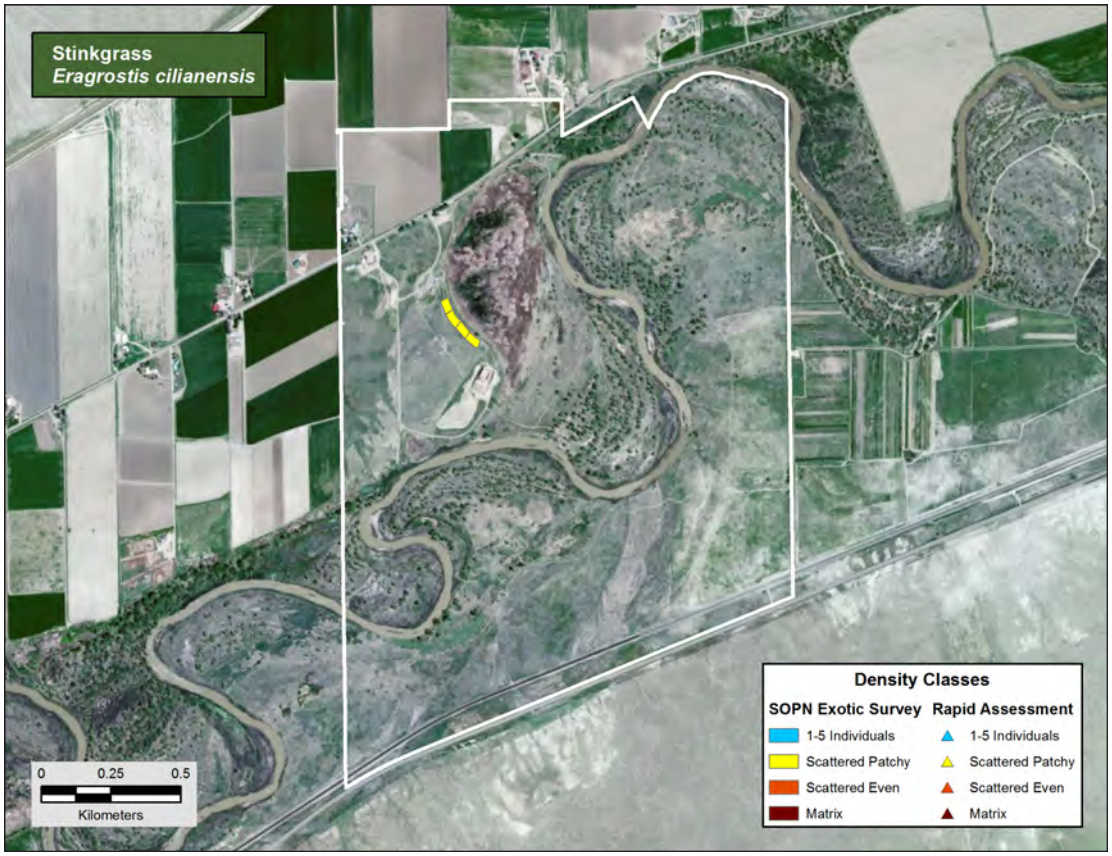



**Figure F-6. Stinkgrass (*Eragrostis cilianensis)***

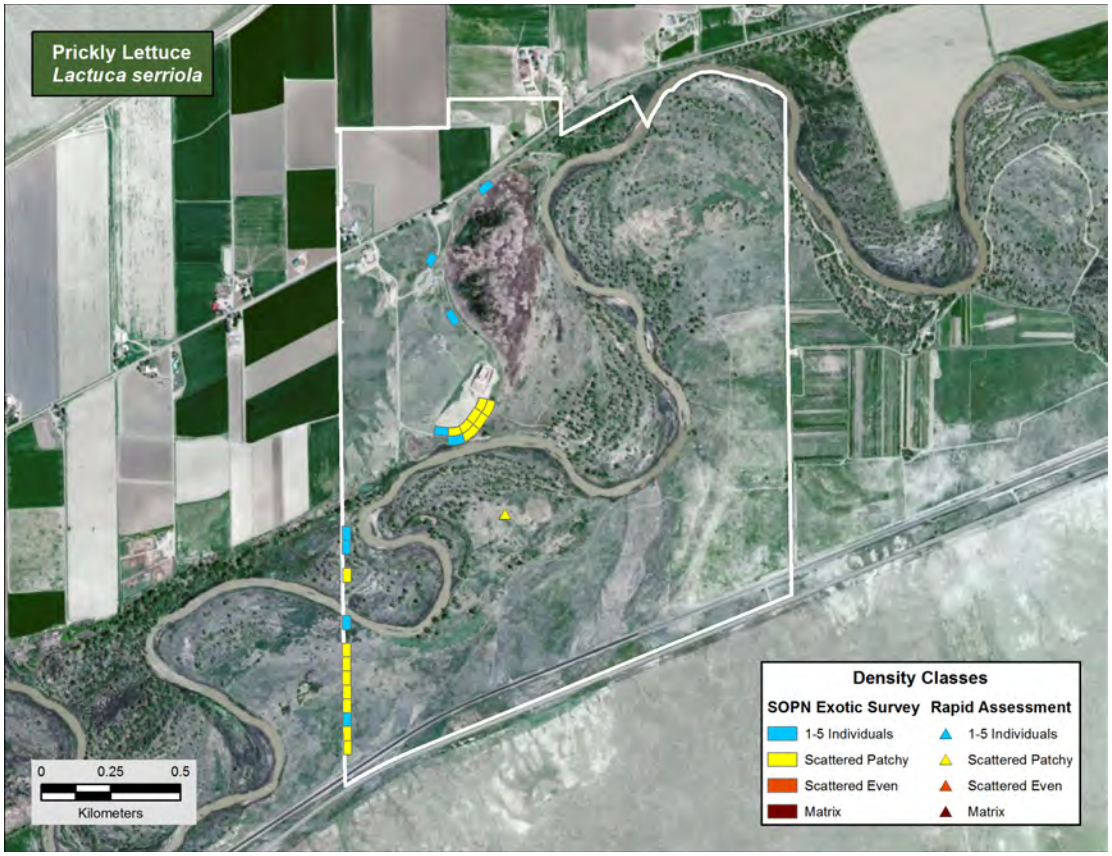



**Figure F-7. Prickly lettuce (*Lactuca serriola)***

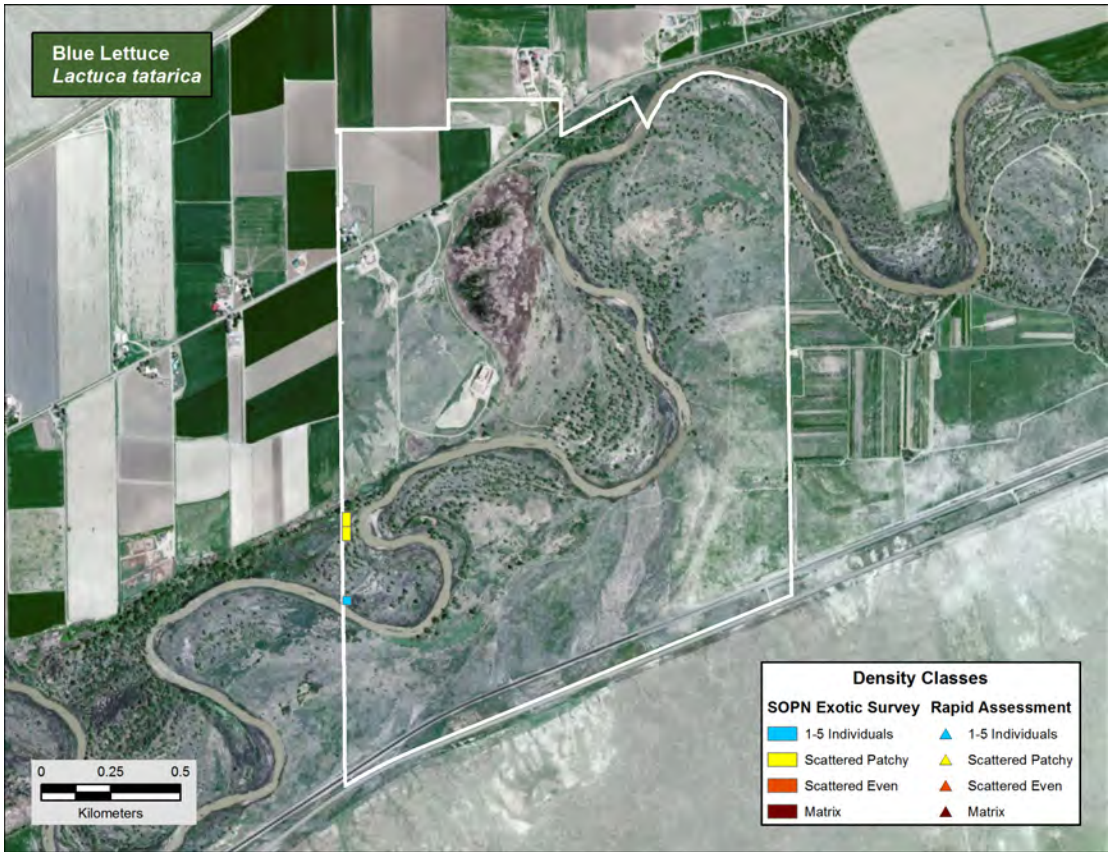



**Figure F-8. Blue Lettuce (*Lactuca tatarica)***

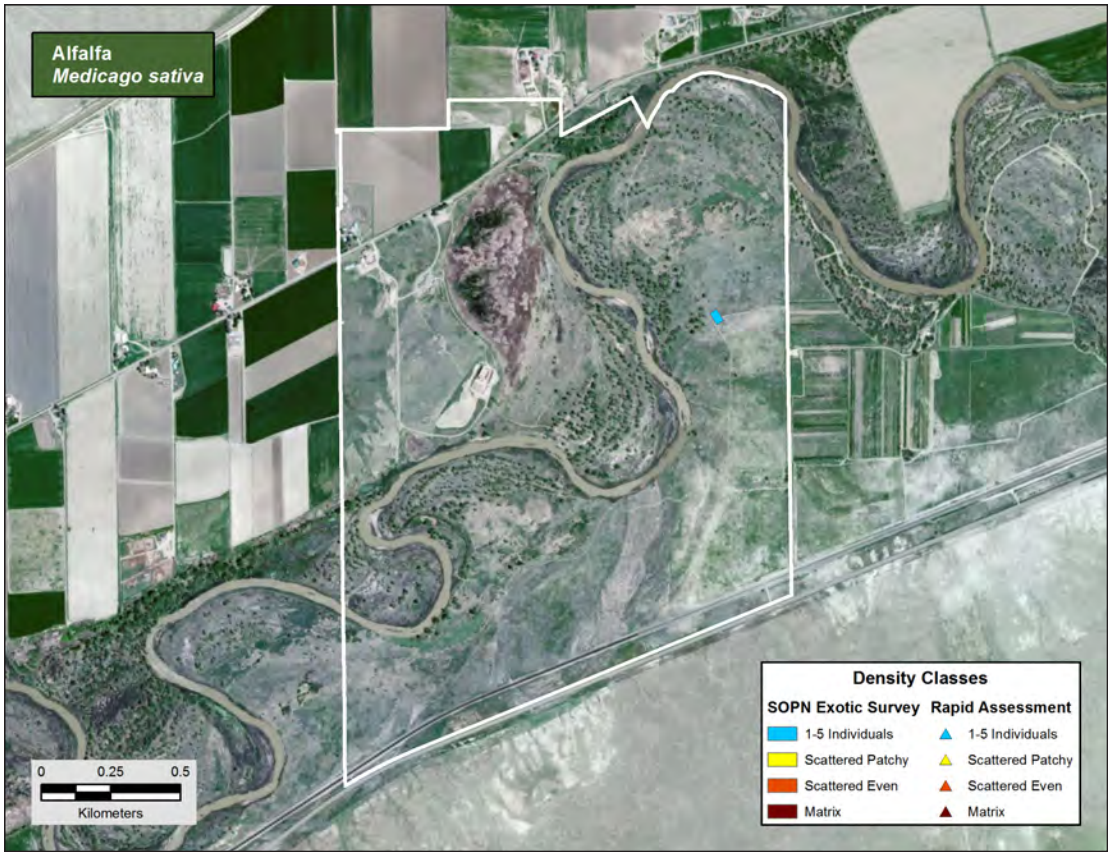



**Figure F-9.**
**Alfalfa (*Medicago sativa)***

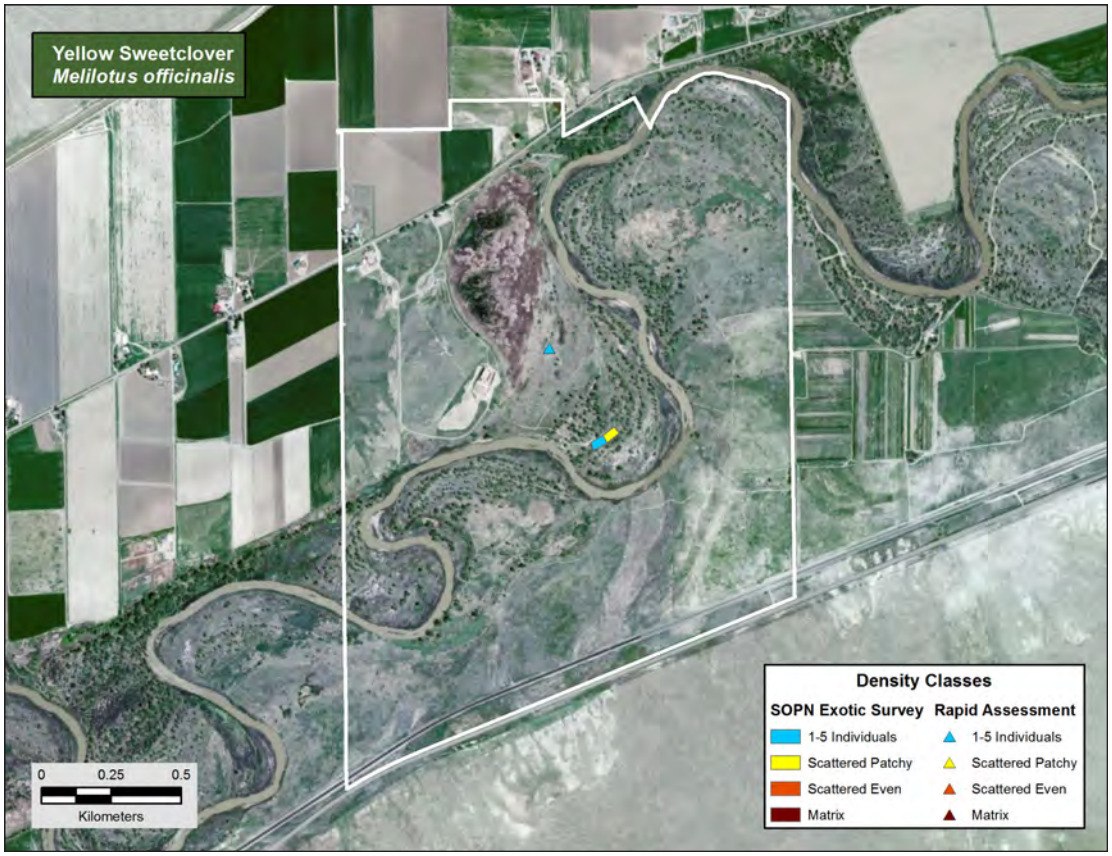



**Figure F-10.**
**Yellow Sweetclover (*Melilotus officinalis)***

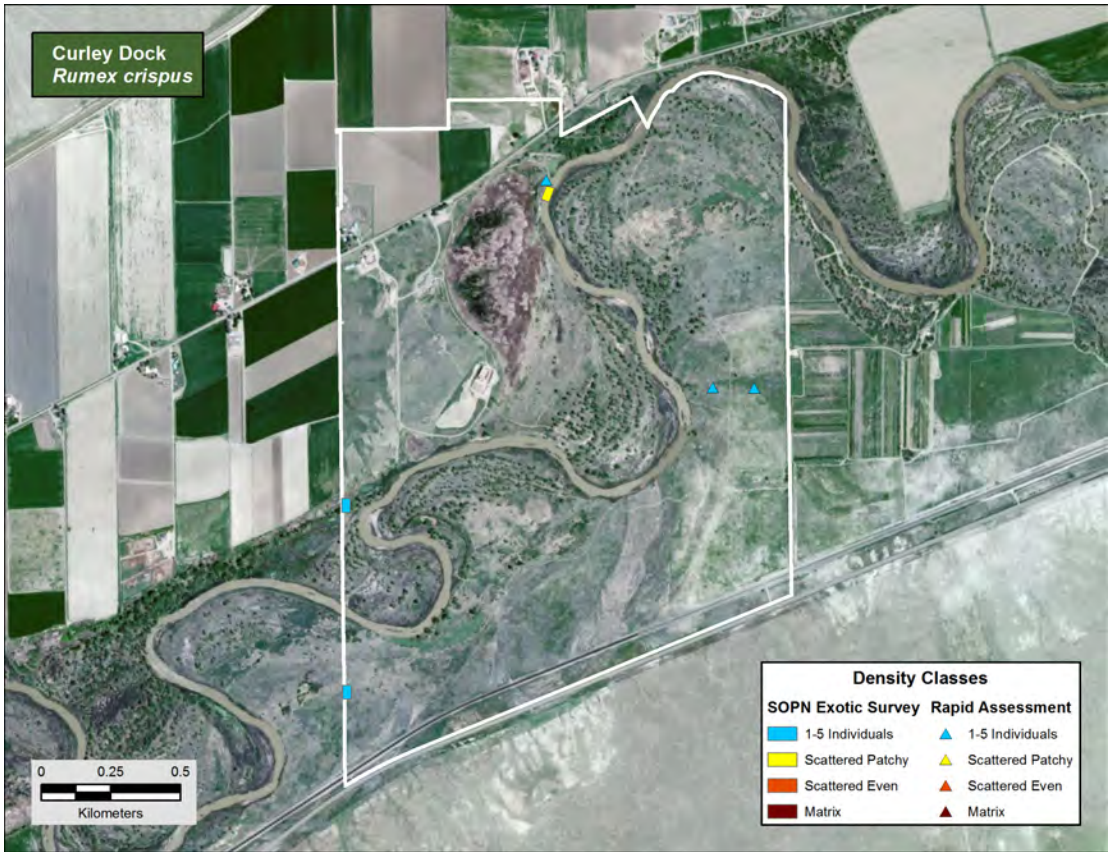



**Figure F-11. Curly dock (*Rumex crispus*)**

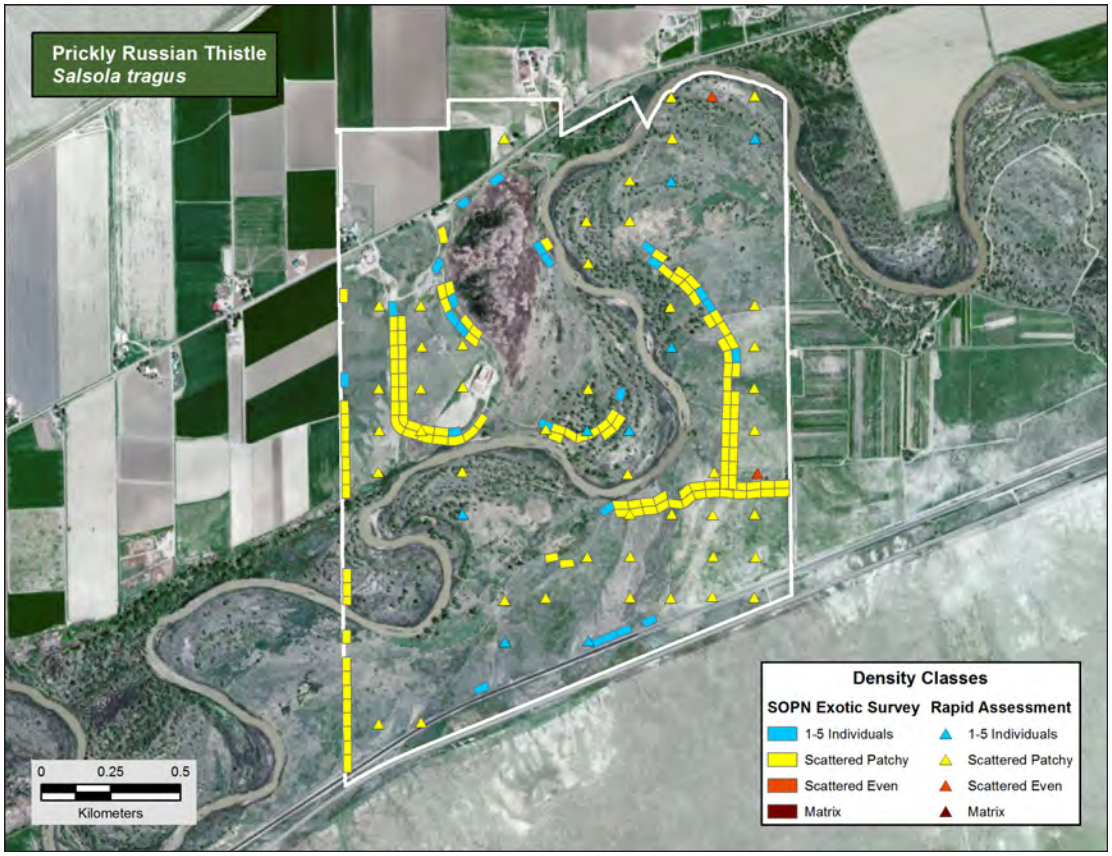



**Figure F-12. Prickly Russian thistle (*Salsola tragus*)**

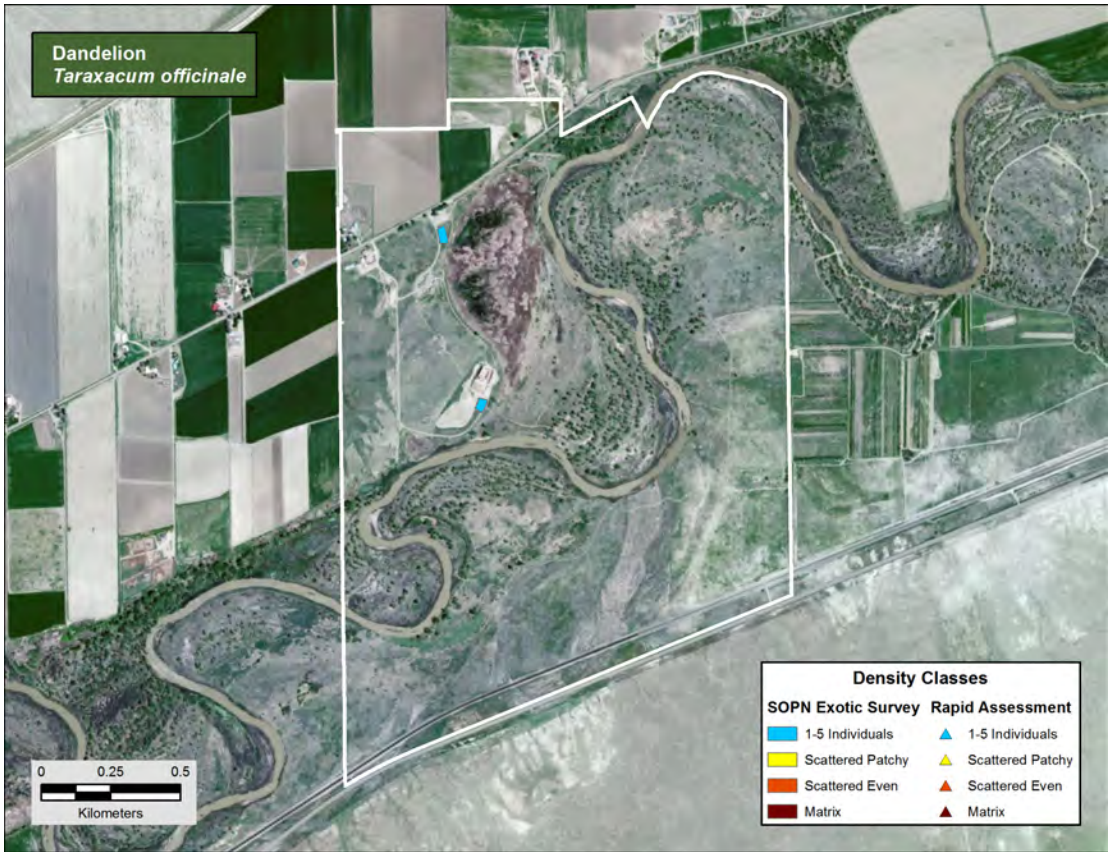



**Figure F-13. Dandelion (*Taraxacum officinale)***

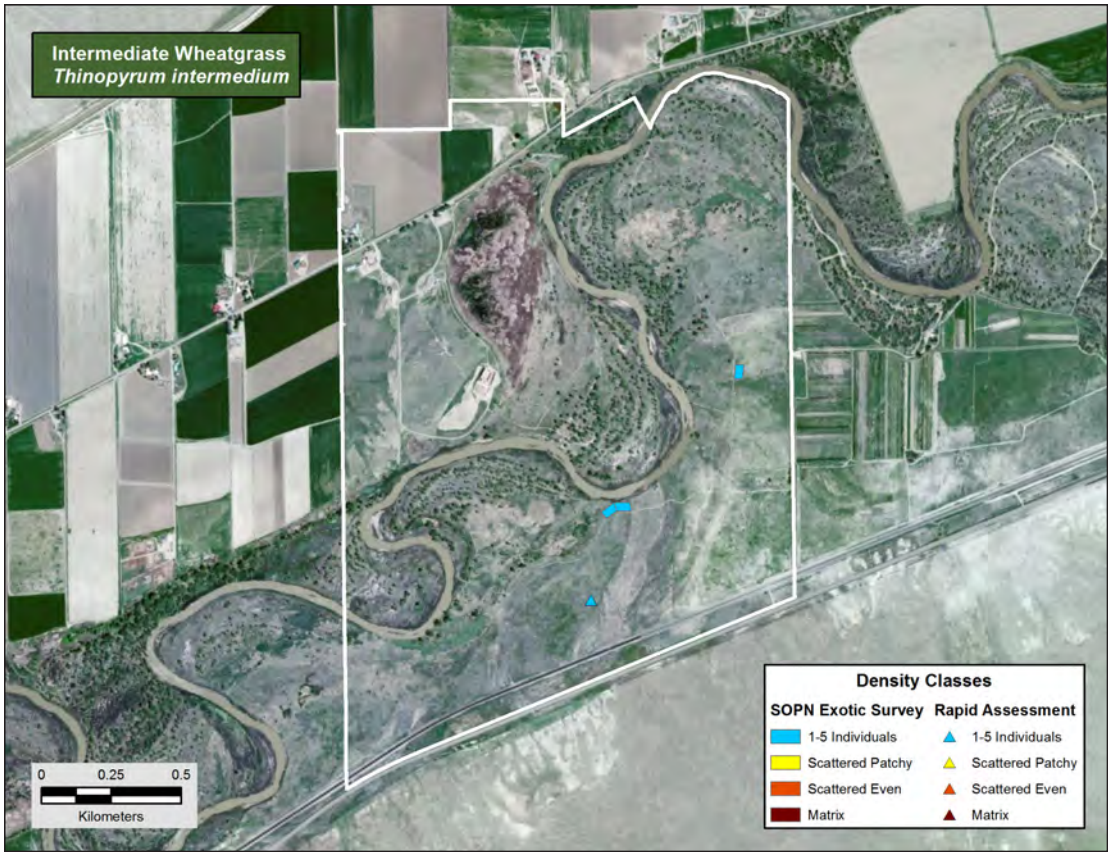



**Figure F-14. Intermediate Wheatgrass (*Thinopyrum intermedium)***

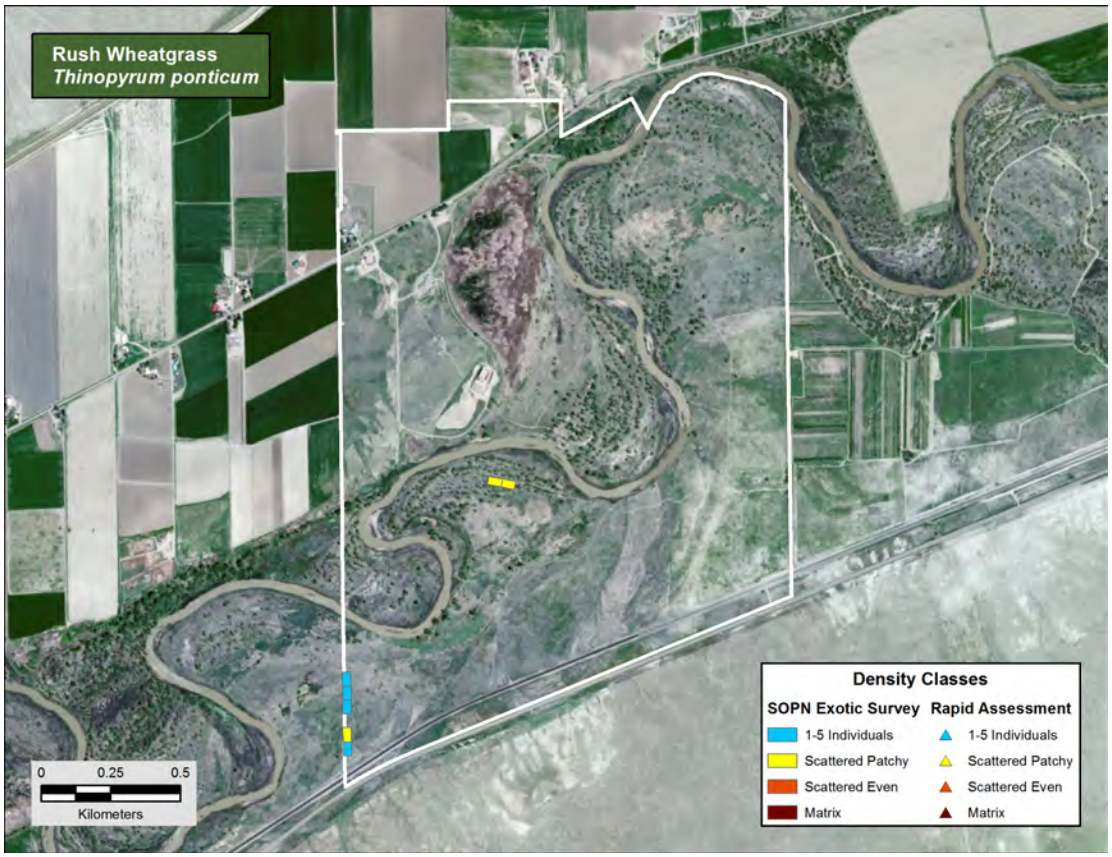



**Figure F-15. Rush Wheatgrass (*Thinopyrum ponticum*)**

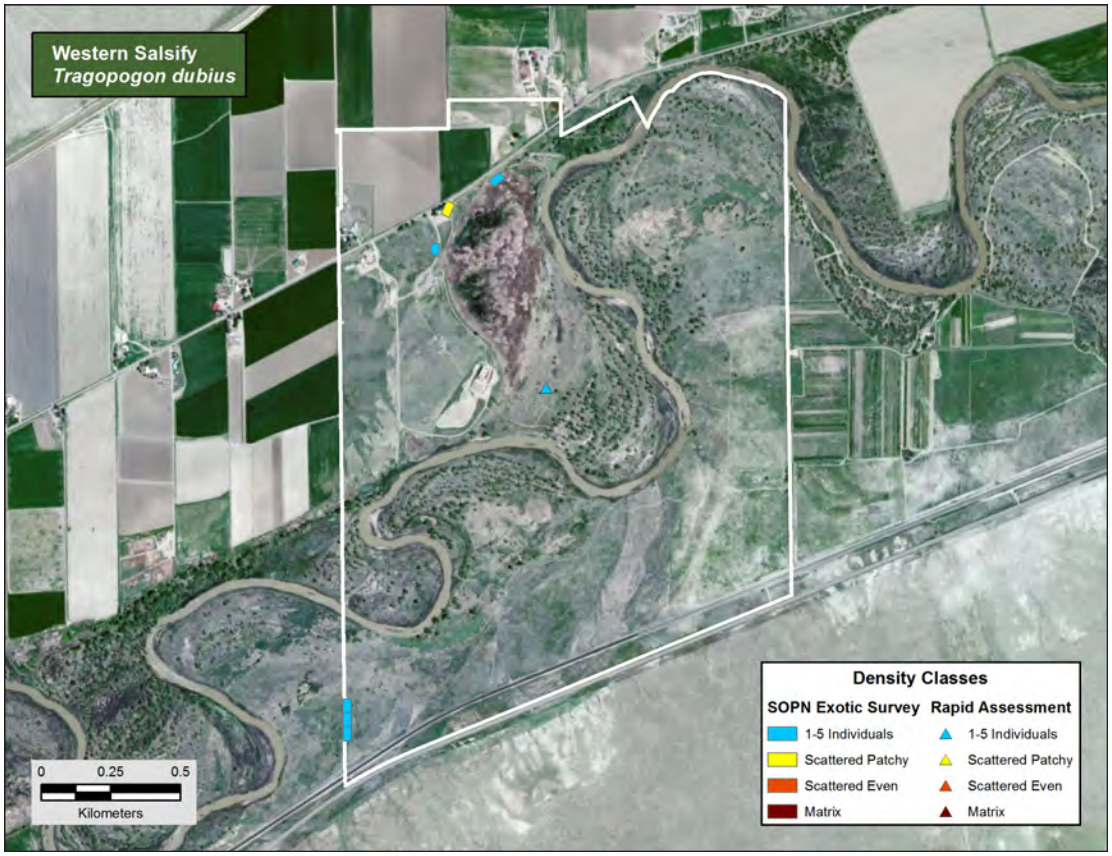



**Figure F-16. Western Salsify (*Tragopogon dubius*)**

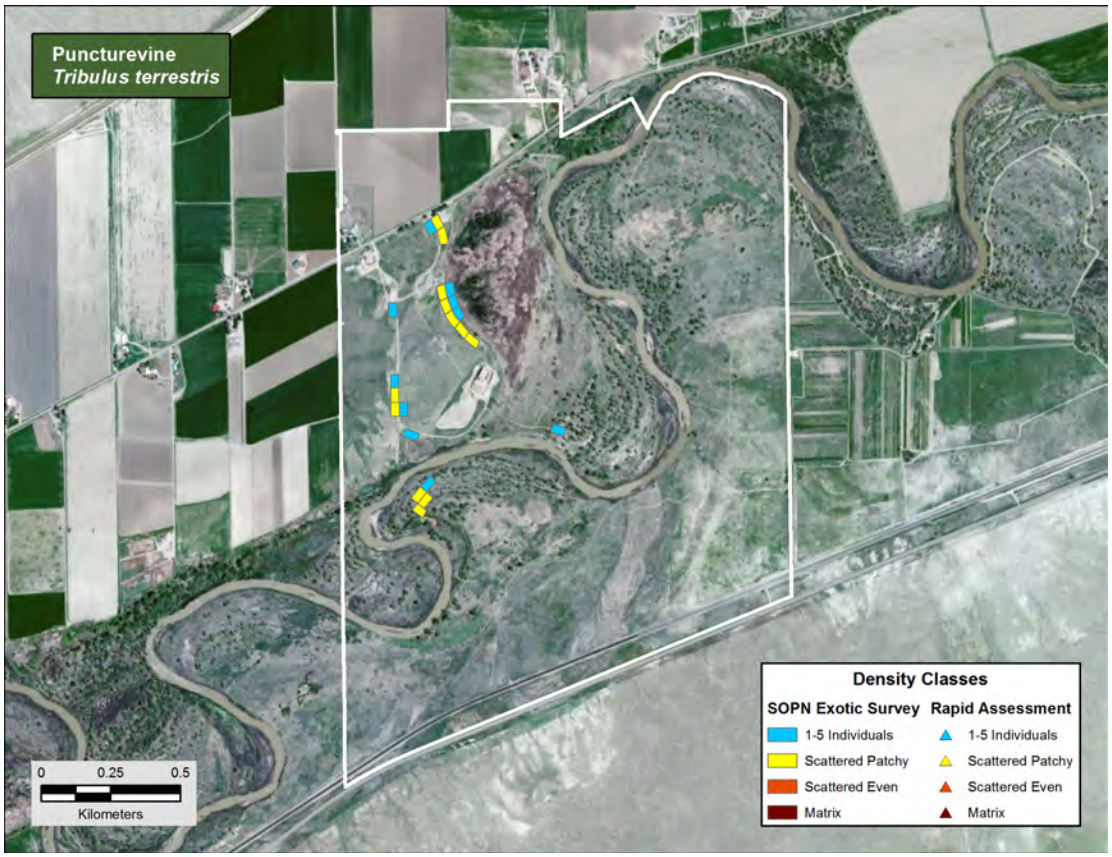



**Figure F-17. Puncturevine (*Tribulus terrestris)***

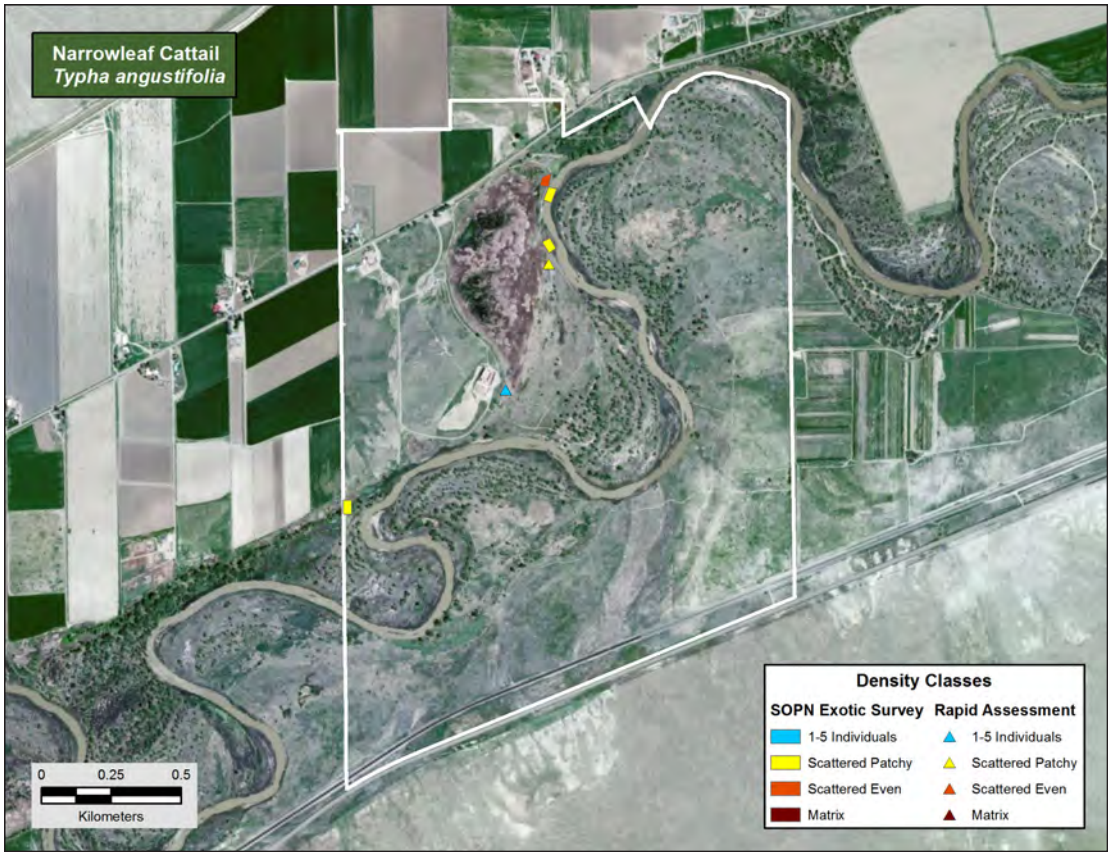



**Figure F-18. Narrowleaf Cattail (*Typha angustifolia)***

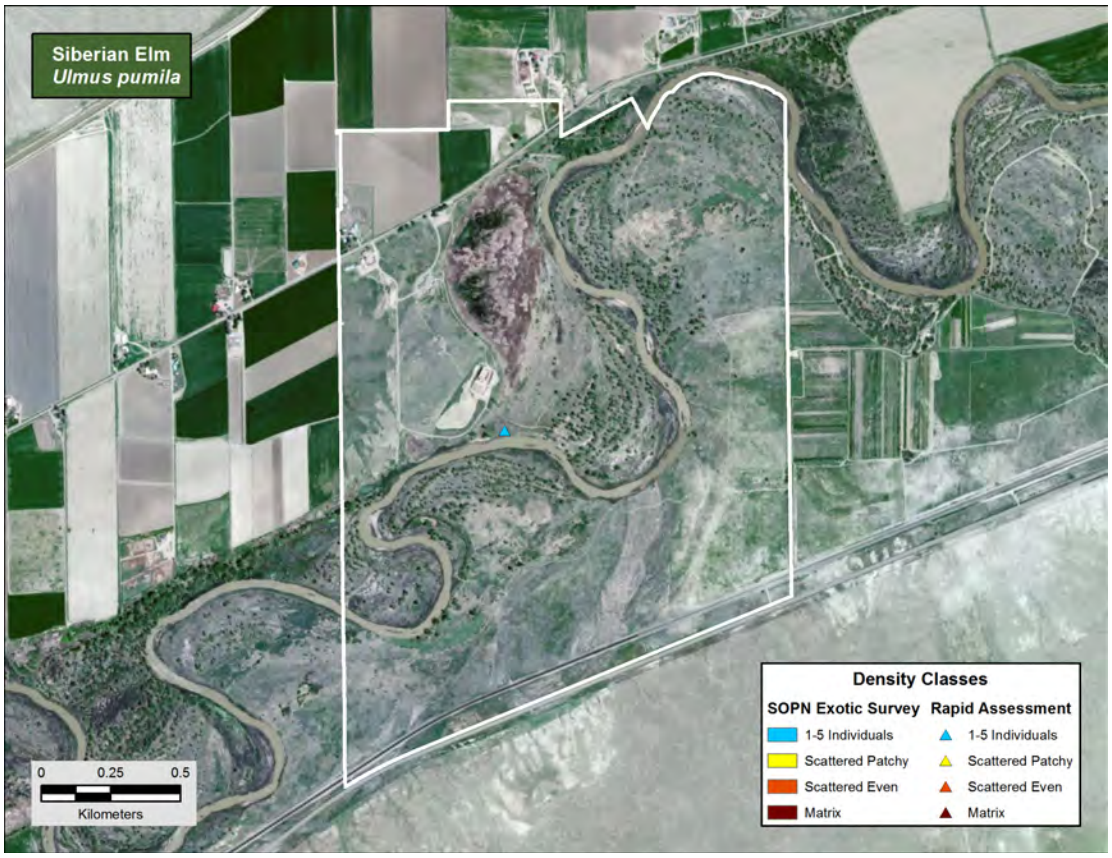



**Figure F-19. Siberian Elm (*Ulmus pumila)***

# Appendix G: Additional Exotic Plant Species at Bent's Old Fort NHS

The following table lists exotic species that are and have been found within Bent's Old Fort NHS.

| Scientific Name | Common name | Noxious* | Ecological Impact | Management Difficulty |
|---|---|---|---|---|
| *Abutilon theophrasti* | Velvetleaf | CW | LOW/INSIG | HIGH/LOW |
| *Aegilops cylindrica* | Jointed goat grass | CW | MED/INSIG | HIGH/LOW |
| *Amaranthus retroflexus* | Redroot pigweed | | | |
| *Asparagus officinalis* | Garden asparagus | | | |
| *Bromus arvensis* | Field brome | | | |
| *Bromus commutatus* | Meadow brome | | MED/INSIG | UNKNOWN |
| *Bromus inermis* | Smooth brome | | | |
| *Chenopodium album* | Common lambsquarters | | | |
| *Chorispora tenella* | Blue mustard | | INSIG | LOW/INSIG |
| *Cynodon dactylon* | Bermudagrass | | MED/LOW | HIGH/MED |
| *Dactylis glomerata* | Orchardgrass | | MED/LOW | MED/LOW |
| *Descurainia sophia* | Herb sofia | | MED/LOW | MED/LOW |
| *Dipsacus fullonum* | Teasel | BW | LOW | MED/LOW |
| *Echinchloa crus-galli* | Barnyardgrass | | LOW/INSIG | UNKNOWN |
| *Elaeagnus angustifolia* | Russian olive | | | |
| *Eragrostis cilianensis* | Stinkgrass | | | |
| *Euphorbia dentata* | Toothed spurge | | | |
| *Hibiscus trionum* | Venice mallow | BW | MED/INSIG | MED/INSIG |
| *Lactuca tatarica* | Blue lettuce | | | |
| *Leonurus cardiaca* | Motherwort | | | |
| *Medicago sativa* | Alfalfa | | | |
| *Phalaris arundinacea* | Carolina canarygrass | | HIGH | HIGH/MED |
| *Polypogon monspeliensis* | Annual rabbits-foot grass | | HIGH/LOW | HIGH/MED |
| *Populus alba* | White poplar | | MED/LOW | HIGH/LOW |
| *Rumex crispus* | Curley dock | | LOW/INSIG | MED/LOW |
| *Rumex obtusifolius* | Bluntleaf dock | | | |
| *Setaria viridis* | Green bristlegrass | | | |
| *Taraxacum laevigatum* | Rock dandelion | | | |
| *Thlaspi arvense* | Field pennycress | | LOW/INSIG | MED/LOW |
| *Typha angustifolia* | Narrowleaf cattail | | HIGH/MED | MED |
| *Ulmus pumila* | Siberian elm | | | |
| *Verbascum thapsus* | Common mullein | | MED/LOW | LOW |

*Noxious = Colorado state noxious status (A list, B list, or C list) (USDA NRCS 2013).

USDA-NRCS. 2013. Colorado state listed noxious weeds. Available at http://plants.usda.gov/java/noxious?rptType=State&statefips=08 (accessed June 13, 2013).

# Appendix H: Background on Bird Species of Conservation Concern Lists

This appendix provides background information on the organizations and efforts to determine species of birds that are in need of conservation. The information presented here supports Section 4.11.2, Data and Methods, of the breeding landbirds chapter. This appendix contains some of the same, but additional, information as that section of the report.

One component of the landbird condition assessment was to assess species occurrence in a conservation context. We compared the list of species that occur at Bent's Old Fort National Historic Site (NHS) (i.e., those detected during Rocky Mountain Bird Observatory [RMBO] surveys at the Historic Site during 2009-2012) to lists of species of conservation concern developed by several organizations. There have been a number of such organizations that focus on the conservation of bird species. Such organizations may differ, however, in the criteria they use to identify and/or prioritize species of concern based on the mission and goals of their organization. They also range in geographic scale from global organizations such as the International Union for Conservation of Nature (IUCN), who maintains a "Red List of Threatened Species," to local organizations or chapters of larger organizations. This has been, and continues to be, a source of confusion and perhaps frustration for managers that need to make sense of and apply the applicable information. In recognition of this, the U.S. North American Bird Conservation Initiative (NABCI) was started in 1999; it represents a coalition of government agencies, private organizations, and bird initiatives in the United States working to ensure the conservation of North America's native bird populations. Although there remain a number of sources at multiple geographic and administrative scales for information on species of concern, the NABCI has made great progress in developing a common biological framework for conservation planning and design.

One of the developments from the NABCI was the delineation of Bird Conservation Regions (BCRs) (U.S. North American Bird Conservation Initiative 2013). Bird Conservation Regions (BCRs) are ecologically distinct regions in North America with similar bird communities, habitats, and resource management issues.

The purpose of delineating these BCRs was to:

- facilitate communication among the bird conservation initiatives;
- systematically and scientifically apportion the U.S. into conservation units;
- facilitate a regional approach to bird conservation;
- promote new, expanded, or restructured partnerships; and
- identify overlapping or conflicting conservation priorities.

## H.1. Conservation Organizations Listing Species of Conservation Concern

Below we present a snapshot of some of the organizations that list species of conservation concern and briefly discuss the different purposes or goals of each organization.

### *U.S. Fish & Wildlife Service*

The Endangered Species Act, passed in 1973, is intended to protect and recover imperiled species and the ecosystems upon which they depend. It is administered by the U.S. Fish and Wildlife Service (USFWS) and the Commerce Department's National Marine Fisheries Service (NMFS). USFWS has primary responsibility for terrestrial and freshwater organisms, while the responsibilities of NMFS are mainly marine wildlife, such as whales, and anadromous fish.

### *State of Colorado*

Under the authority of the Nongame, Endangered, or Threatened Species

Conservation Act, the State of Colorado, through the Division of Wildlife (CDOW) (now Colorado Parks and Wildlife), maintains listings of species considered as threatened or endangered within the State (Colorado Parks and Wildlife 2012). The lists include State special concern species, although this designation is not a statutory category.

### *USFWS Birds of Conservation Concern*

The USFWS has responsibilities for wildlife, including birds, in addition to endangered and threatened species. The Fish and Wildlife Conservation Act, as amended in 1988, further mandates that the USFWS "identify species, subspecies, and populations of all migratory nongame birds (i.e., Birds of Conservation Concern) that, without additional conservation actions, are likely to become candidates for listing under the Endangered Species Act" (USFWS 2008). The agency's 2008 effort, *Birds of Conservation Concern*, is one effort to fulfill the Act's requirements. The report includes both migratory and non-migratory bird species (beyond those federally-listed as threatened or endangered) that USFWS considers the highest conservation priorities. Three geographic scales are included--National, USFWS Regional, and the NABCI BCRs. The information used to compile the lists came primarily from the following three bird conservation plans: the Partners in Flight North American Landbird Conservation Plan, the U.S. Shorebird Conservation Plan, and the North American Waterbird Conservation Plan. The scores used to assess the species are based on factors such as population trends, distribution, threats, and abundance.

### *National Audubon Society/American Bird Conservancy*

The National Audubon Society and American Bird Conservancy each formerly published their own lists of bird species of concern, but have recently combined efforts into a single "Watch List". This collaborative effort was based on a concern by these organizations that there were too many lists with similar purposes (Butcher et al. 2007). Their 2007 WatchList is based on, but not identical to, the Partners in Flight (PIF) approach to species assessment (see below).

The 2007 WatchList has two primary levels of concern: a "Red Watchlist" and a "Yellow WatchList", although the latter is subdivided into two categories. The Red WatchList identifies what these organizations consider as species of highest national concern. This list overlaps considerably with the IUCNs "Red List" (not presented here), thus, can essentially be considered as a list of globally threatened birds that occur in the United States (Butcher et al. 2007). The Yellow WatchList is made up of species that are somewhat less critical, but serves as an early warning list of birds that have the potential of being elevated to the Red WatchList. Species on this list can be there either because their populations are declining or because they are considered rare.

### *Partners in Flight*

*Partners in Flight* is a cooperative effort among federal, state, and local government agencies, as well as private organizations. One of its primary goals, relative to listing species of conservation concern, is to develop a scientifically based process for identifying and finding solutions to risks and threats to landbird populations. Their approach to identifying and assessing species of conservation concern is based on biological criteria to evaluate different components of vulnerability (Panjabi et al. 2005). Each species is evaluated for six components of vulnerability: population size, breeding distribution, non-breeding distribution, threats to breeding, threats to non-breeding, and population trend. The specific process is presented in detail in the species assessment handbook (Panjabi et al. 2005).

Their assessments are conducted at multiple scales. At the broadest scale, the North American Landbird Conservation Plan (Rich et al. 2004) identifies what PIF considers "Continental Watch List Species" and "Continental Stewardship Species." Continental Watch List Species are those that are most vulnerable at the continental scale, due to a combination of small and declining populations, limited distributions, and high

threats throughout their ranges (Panjabi et al. 2005). Continental Stewardship Species are defined as those species that have a disproportionately high percentage of their world population within a single Avifaunal Biome during either the breeding season or the non-migratory portion of the non-breeding season.

More recently, PIF has adopted BCRs, the common planning unit under the NABCI, as the geographic scale for updated regional bird conservation assessments. These assessments are available via an online database (http://www.rmbo.org/pif/pifdb.html) maintained by RMBO. At the scale of the individual BCRs, these same principles of concern (sensu Continental Watch List Species) or stewardship (sensu Continental Stewardship Species) are applied at the BCR scale. The intention of this approach is to emphasize conservation of species where it is most relevant, as well as the recognition that some species may be experiencing dramatic declines locally even if they are not of high concern nationally, etc. There are two categories (concern and stewardship) each for Continental and Regional levels. The details of the criteria for inclusion in each can be found in Panjabi et al. (2005), and a general summary is as follows:

### *Criteria for Species of Continental Importance*

A. Continental Concern (CC)
- Species is listed on the Continental Watch List (Rich et al. 2004).
- Species occurs in significant numbers in the BCR.
- Future conditions are not enhanced by human activities.

B. Continental Stewardship (CS)
- Species is listed as Continental Stewardship Species (Rich et al. 2004).
- Relatively high density (compared to highest density regions) and/or a high proportion of the species occurs in the BCR.
- Future conditions are not enhanced by human activities.

### *Criteria for Species of Regional Importance*

Regional scores are calculated for each species according to which season(s) they are present in the BCR. The formulae include a mix of global and regional scores pertinent to each season (see Panjabi et al. 2005 for details). The criteria for each category are:

A. Regional Concern (RC)
- Regional Combined Score > 13 (see Panjabi et al. 2005 for details).
- High regional threats or moderate regional threat combined with significant population decline.
- Occurs regularly in significant numbers in the BCR.

B. Regional Stewardship (RS)
- Regional Combined Score > 13 (see Panjabi et al. 2005 for details).
- High importance of the BCR to the species.
- Future conditions are not enhanced by human activities.

### *Colorado Species of Greatest Conservation Need*

In addition to listing threatened and endangered species, the State of Colorado developed a Comprehensive Wildlife Conservation Strategy, also known as a Wildlife Action Plan (CDOW 2006). The plan identifies species and conservation needs for what they consider the Species of Greatest Conservation Need (SGCN). The strategy reflects a basic goal of securing wildlife populations so that they do not require protection through federal or state listing regulations (CDOW 2006).

## H.2. Literature Cited

Butcher, G.S., D.K. Niven, A.O. Panjabi, D.N. Pashley, and K.V. Rosenberg. 2007. WatchList: the 2007 WatchList for United States birds. American Birds 61:18-25.

Colorado Division of Wildlife (CDOW). 2006. Colorado's Comprehensive Wildlife Conservation Strategy and Wildlife Action Plans. Available online (http://wildlife.state.co.us/WildlifeSpecies/

ColoradoWildlifeActionPlanPages/ColoradoWildlifeActionPlan.aspx).

Colorado Parks and Wildlife. 2012. Colorado Endangered, Threatened and Species of Special Concern. Accessed July 1, 2013. Available online (http://wildlife.state.co.us/WildlifeSpecies/SpeciesOfConcern/Birds/Pages/BirdsOfConcern.

Panjabi, A. O., E. H. Dunn, P. J. Blancher, W. C. Hunter, B. Altman, J. Bart, C. J. Beardmore, H. Berlanga, G. S. Butcher, S. K. Davis, D. W. Demarest, R. Dettmers, W. Easton, H. Gomez de Silva Garza, E. E. Iñigo-Elias, D. N. Pashley, C. J. Ralph, T. D. Rich, K. V. Rosenberg, C. M. Rustay, J. M. Ruth, J. S. Wendt, and T. C. Will. 2005. The Partners in Flight handbook on species assessment. Version 2005. Partners in Flight Technical Series No. 3. Rocky Mountain Bird Observatory website: http://www.rmbo.org/pubs/downloads/Handbook2005.pdf.

Rich, T. D., C. J. Beardmore, H. Berlanga, P. J. Blancher, M. S. W. Bradstreet, G. S. Butcher, D. W. Demarest, E. H. Dunn, W. C. Hunter, E. E. Iñigo-Elias, J. A. Kennedy, A. M. Martell, A. O. Panjabi, D. N. Pashley, K. V. Rosenberg, C. M. Rustay, J. S. Wendt, T. C. Will. 2004. Partners in Flight North American Landbird Conservation Plan. Cornell Lab of Ornithology. Ithaca, NY. Partners in Flight website. http://www.partnersinflight.org/cont_plan/ (VERSION: March 2005).

U.S. North American Bird Conservation Initiative. 2013. Main page. Online. (http://www.nabci-us.org). Accessed January 8, 2013.

U.S. Fish and Wildlife Service. 2008. Birds of Conservation Concern 2008. United States Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, Virginia. 85 pp. [Online version available at <http://www.fws.gov/migratorybirds/>].

# Appendix I: Bent's Old Fort NHS Bird Lists

Listed below is the full list of species reported to occur or that have occurred at Bent's Old Fort NHS according to the sources noted. Note that the 2005 Certified List from NPSpecies (the most recent available) is identical to the Gionfriddo et al. lists combined (shown in the second column).

| Common Name | 2009-2012 Surveys (RMBO) | Gionfriddo et al. (2002) [1] & Gionfriddo and Stevens (2003) [2] | SOPN-RMBO List [3] |
|---|---|---|---|
| American Avocet | | X [2] | X |
| American Bittern | | X [2] | X |
| American Coot | | X [2] | X |
| American Crow | X | X [1, 2] | X |
| American Goldfinch | X | X [1] | X |
| American Kestrel | X | X [1, 2] | X |
| American Robin | X | X [1, 2] | X |
| Ash-throated Flycatcher | X | X [1, 2] | X |
| Barn Swallow | X | X [1, 2] | X |
| Bell's Vireo | X | | X |
| Belted Kingfisher | X | X [2] | X |
| Black Rail | X | | X |
| Black Tern | | X [2] | X |
| Black-billed Magpie | | X [1, 2] | |
| Black-crowned Night-Heron | | X [2] | X |
| Black-headed Grosbeak | X | X [2] | X |
| Blue Grosbeak | X | X [1, 2] | X |
| Blue Jay | X | X [1, 2] | X |
| Blue-winged Teal | | X [2] | X |
| Brewer's Blackbird | X | | X |
| Brown Thrasher | X | X [1, 2] | X |
| Brown-headed Cowbird | X | X [1, 2] | X |
| Bullock's Oriole | X | X [1, 2] | X |
| Burrowing Owl | X | | X |
| Canada Goose | X | | X |
| Cassin's Kingbird | X | X [1, 2] | X |
| Cassin's Sparrow | X | X [1] | X |
| Chihuahuan Raven | X | | X |
| Chimney Swift | X | | X |
| Chipping Sparrow | X | X [1] | X |
| Cinnamon Teal | | X [2] | X |
| Cliff Swallow | X | | X |
| Common Grackle | X | X [1, 2] | X |
| Common Nighthawk | X | X [1, 2] | X |

1= Gionfriddo et al. (2002). 2= Gionfriddo and Stevens (2003). Note that this column/list is identical to the list certified on September 29, 2005 (obtained from NPSpecies May 2013). 3=List is based on RMBO sampling in 2009-2012, the two CNHP inventories, and birds detected incidentally to surveys.

| Common Name | 2009-2012 Surveys (RMBO) | Gionfriddo et al. (2002) [1] & Gionfriddo and Stevens (2003) [2] | SOPN-RMBO List [3] |
|---|---|---|---|
| Common Poorwill | | | X |
| Common Yellowthroat | X | X [2] | X |
| Dickcissel | X | X [1] | X |
| Downy Woodpecker | X | X [1, 2] | X |
| Eastern Bluebird | X | X [1] | X |
| Eastern Kingbird | X | X [1, 2] | X |
| Eurasian Collared-Dove | X | | X |
| European Starling | X | X [1, 2] | X |
| Ferruginous Hawk | | X [1, 2] | X |
| Forster's Tern | | X [2] | X |
| Grasshopper Sparrow | | X [1, 2] | X |
| Great Blue Heron | X | X [1, 2] | X |
| Great Crested Flycatcher | X | | X |
| Great Horned Owl | X | X [1, 2] | X |
| Greater Roadrunner | | | X |
| Great-tailed Grackle | X | | X |
| Green Heron | X | X [1, 2] | X |
| Horned Lark | X | | X |
| House Sparrow | X | X [1, 2] | X |
| House Wren | X | X [1] | X |
| Indigo Bunting | X | | X |
| Killdeer | X | X [1, 2] | X |
| Ladder-backed Woodpecker | X | | X |
| Lark Bunting | | X [1] | X |
| Lark Sparrow | X | X [1, 2] | X |
| Lazuli Bunting | X | | X |
| Lesser Goldfinch | X | | X |
| Lesser Yellowlegs | | | X |
| Lewis's Woodpecker | X | X [2] | X |
| Loggerhead Shrike | | X [1] | X |
| Long-billed Dowitcher | | | X |
| Mallard | X | X [1, 2] | X |
| Mississippi Kite | X | | X |
| Mourning Dove | X | X [1, 2] | X |
| Northern Bobwhite | X | X [1, 2] | X |
| Northern Flicker | X | X [1, 2] | X |
| Northern Harrier | X | X [1] | X |
| Northern Mockingbird | X | X [2] | X |
| Northern Rough-winged Swallow | X | | X |
| Northern Shoveler | | X [2] | X |
| Orchard Oriole | X | X [2] | X |
| Prairie Falcon | | | X |

1= Gionfriddo et al. (2002). 2= Gionfriddo and Stevens (2003). Note that this column/list is identical to the list certified on September 29, 2005 (obtained from NPSpecies May 2013). 3=List is based on RMBO sampling in 2009-2012, the two CNHP inventories, and birds detected incidentally to surveys.

| Common Name | 2009-2012 Surveys (RMBO) | Gionfriddo et al. (2002) [1] & Gionfriddo and Stevens (2003) [2] | SOPN-RMBO List [3] |
|---|---|---|---|
| Red-eyed Vireo | X | | X |
| Red-headed Woodpecker | X | X [1, 2] | X |
| Red-tailed Hawk | X | X [1, 2] | X |
| Red-winged Blackbird | X | X [1, 2] | X |
| Ring-necked Pheasant | X | X [1, 2] | X |
| Rock Pigeon | X | X [1, 2] | X |
| Rock Wren | | X [2] | X |
| Say's Phoebe | X | | X |
| Short-billed Dowitcher | | | X |
| Sora | | X [2] | X |
| Spotted Sandpiper | | X [1, 2] | X |
| Swainson's Hawk | X | X [1] | X |
| Turkey Vulture | X | X [1, 2] | X |
| Violet-green Swallow | | X [2] | X |
| Virginia Rail | X | | X |
| Warbling Vireo | X | | X |
| Western Kingbird | X | X [1, 2] | X |
| Western Meadowlark | X | X [1, 2] | X |
| Western Tanager | X | X [2] | X |
| Western Wood-Pewee | X | X [1, 2] | X |
| White-breasted Nuthatch | X | | X |
| White-eyed Vireo | X | | X |
| White-faced Ibis | | X [2] | X |
| Wild Turkey | X | X [1, 2] | X |
| Willow Flycatcher | X | | X |
| Yellow Warbler | X | | X |
| Yellow-billed Cuckoo | X | X [1] | X |
| Yellow-breasted Chat | X | | X |
| Yellow-headed Blackbird | | X [1, 2] | X |

1= Gionfriddo et al. (2002). 2= Gionfriddo and Stevens (2003). Note that this column/list is identical to the list certified on September 29, 2005 (obtained from NPSpecies May 2013). 3=List is based on RMBO sampling in 2009-2012, the two CNHP inventories, and birds detected incidentally to surveys.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 417/129324, July 2015

**National Park Service**
**U.S. Department of the Interior**

**Natural Resource Stewardship and Science**
1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA™