



Chaco Culture National Historical Park International Dark Sky Park Application

July 2013



"Milky Way, Fajada Butte"

Photo: Stan Honda



Table of Contents

Executive Summary		v
International Dark Sky Park Support Letters		vii
Letter from acting Chaco Culture NHP Superintendent, Larry Turk	vii	
Nomination Letter from TAAS President, Dee Friesen	ix	
I. Park Location and General Description		1
II. Park Resources and Significance		2
Natural Resources	2	
Cultural Resources	3	
III. Night Sky Preservation Guidance		5
National Park Service Organic Act	5	
State of New Mexico Night Sky Protection Act	5	
NPS Management Policies 2006	6	
CCNHP Resource Management Plan	6	
CCNHP Foundation for Planning and Management	7	
CCNHP Comprehensive Interpretive Plan	7	
NPS <i>A Call to Action</i>	8	
IV. Sky Quality at Chaco Culture NHP		9
Existing Night Sky Conditions	9	
International Dark Sky Park <i>Gold Tier</i> Eligibility	10	
NPS-NSNSD Night Sky Quality Monitoring Report	11	
<i>Light Pollution Map from ClearDarkSky.com</i>	14	
Light Pollution Threats	15	
Sky Quality Monitoring	15	
V. Chaco Astronomy		17
Ancient Practices and Traditions	17	
Contemporary Astronomy at Chaco Culture NHP	18	
The Chaco Canyon Observatory	18	
Astrophotography	19	
Chaco Astronomy in Publications and Popular Media	20	
VI. Interpretive and Educational Programs		21
Established Programming	21	
Archaeoastronomy of Chaco	21	
Pueblo Bonito Full Moon Walks	21	
Public Telescope Viewing	21	
Campfire Astronomy	21	
Special Astronomy Events	22	

VII. Partnerships and Community Outreach		23
⇒ <i>New Dark Skies Outreach and Education for 2013</i>		24
<i>The Dark Night Sky</i> interpretive program	24	
Night skies traveling trunk	24	
International Dark Sky Park portable exhibit	24	
Annual community star party	24	
Future outreach goal	25	
VIII. CCNHP Outdoor Lighting Guidelines		27
Purposes and Goals	27	
National Park Service Guidance	28	
Outdoor Lighting Principles	28	
Lighting Management Zones	29	
Mitigation Strategies	30	
Lighting Prescriptions	31	
Employee and Visitor Education	33	
IX. CCNHP Outdoor Lighting Inventory & Mitigations		34
Facilities Overview	35	
Lighting Inventory Maps	38	
⇒ <i>Special Demonstration Project: Visitor Center Lighting Retrofit</i>	42	
Lighting Inventory Charts	44	
References		67
Contributors		71
Acknowledgements		72



Bats prefer natural darkness.

NPS photo

Executive Summary

This International Dark Sky Park application for Chaco Culture National Historical Park signifies the latest chapter in the park's long-standing commitment to preserve the night sky over Chaco Canyon and to share the wonders of a clear, dark sky with countless thousands of park visitors. We are confident that this document demonstrates the remarkable night sky quality at Chaco, as well as the park's continuing commitment to the preservation and interpretation of natural nighttime darkness. We believe this application meets or exceeds all of the requirements of the IDA's International Dark Sky Park Program Criteria and Designation Guidelines, Version 1.3.1, and we urge the IDA Dark Sky Places Committee to support the nomination of Chaco Culture National Historical Park to become the next International Dark Sky Park.

Part IV of this application provides a detailed description of Chaco's excellent sky quality, as well as a summary of factors supporting the park's designation at the gold tier level. Chaco is fortunate to have some of the darkest skies measured in the U.S. National Park System, though it remains vigilant to emerging threats to those conditions from light pollution, including impacts associated with regional urbanization and energy development. Ancient traditions of astronomy going back at least 1000 years, as well as contemporary studies of astronomy and archaeoastronomy at Chaco, are highlighted in Part V. The monumental constructions of the ancient Chacoan people, many of which reflect an acute understanding of astronomical phenomena, are the very reason that Chaco Canyon was declared a national monument in 1907; this highly-designed built landscape was also a central purpose both for Chaco's elevation to national park status in 1980 and its designation as a UNESCO World Heritage Site in 1987.

A sense of connection with the ancient Chacoan people permeates the park's *Night Sky* interpretive programs which include archaeoastronomy talks, full moon walks, and telescope viewing; these are highlighted in Part VI of this application. Part VII includes a discussion of some of the key partnerships that enable the park to provide a quality night sky experience to its visitors. Also featured are the park's new interpretive and educational programs, and its enhanced community outreach focus. In concert with its International Dark Sky Park nomination, Chaco has added a new weekly interpretive program, *The Dark Night Sky*, featuring the science, psychology, and resource values of natural darkness. Outreach to schools and nearby communities through site visits, traveling trunks and exhibits, and an annual community star party are also part of Chaco's efforts to use innovative techniques to reach new and diverse audiences; it is hoped that many of those engaged also become champions for dark sky preservation.

Though the park continues its decades-long embrace of the night sky, the lighting inventory documented in Part IX of this application revealed shortcomings in Chaco's own lighting management since the time when corrective actions were first undertaken in the 1990s. This time, fortunately, most problems required only a simple light bulb replacement. The inventory clearly showed, however, that exterior lighting on the park's new visitor center was substantially inconsistent with outdoor lighting best practices. With a generous grant from its friends group, the park has undertaken a retrofit of all exterior lighting that is scheduled to be completed by September 30, 2013. This restoration project will be incorporated into the park's night sky programs and media, and will include a poster for display in the visitor center lobby. New, night sky friendly lighting will be in place for the October 4-5, 2013 *Chaco Canyon Star Party*, during which Chaco hopes also to publicly celebrate its IDA International Dark Sky Park designation.



United States Department of the Interior

NATIONAL PARK SERVICE
Chaco Culture National Historical Park
P.O. Box 220
Nageezi, New Mexico 87037-0220



Date: 07/16/2013

IDA Board of Directors
International Dark-Sky Association
3225 North First Avenue
Tucson, Arizona 85719

Dear IDA Board of Directors:

As the superintendent of Chaco Culture National Historical Park, I strongly support this nomination for International Dark Sky Park designation. Our park possesses one of the most amazing astronomical displays in northern New Mexico. Due to its isolated location far from towns and other sources of light pollution, the park's night skies have remained near pristine.

The Organic Act of 1916 directs the NPS to protect three primary resources—historic and cultural objects, plant and animal life, and scenery. While scenery has been traditionally thought of as being distant vistas and habitable landscapes, it also includes the night sky. Standing at one of the park's approximately 4,000 known archeological sites, one can easily imagine humans across the centuries gazing into the same dark sky that we can see today, surrounded by ecosystems that have adapted to the natural rhythms of the moon and stars.

As over-lit skies become more common, the public is increasingly seeking star-filled skies at places like Chaco Culture NHP. Visitors are often pleasantly surprised to experience the beauty of the night at Chaco, perhaps having never before witnessed an unfettered view of a starry sky. Here visitors can enjoy stargazing through telescopes, experience an ancient great house by moonlight, or camp beneath the stars. Park staff and volunteers not only connect visitors to the cultural and natural resources of a park, but also to the night sky and ancient astronomy.

Unspoiled night lightscapes have natural, cultural, and scenic importance, and the NPS is charged with their protection. It is my personal commitment to ensure that the park will be brought into conformance with the outdoor lighting guidelines included in this nomination package. The entire park staff is committed to maintaining a dark sky lightscape as an important element of the park environment.

Chaco Culture National Historical Park is a prime candidate for your International Dark Sky Park designation. Please give this nomination your utmost consideration.

Sincerely,

Lawrence T. Turk
Acting Superintendent, Chaco Culture National Historical Park



To the IDA Board of Directors:

17 May 2013

It is with great enthusiasm that I nominate Chaco Culture National Historical Park for an International Dark Sky Park designation by the International Dark-Sky Association. For thousands of years the Chaco location has served as a dark sky place for many different societies. Remotely located in northwest New Mexico, the human-created structures that still exist at Chaco were designed and constructed centuries ago by the ancient societies who had a deep and appreciative understanding of both the day and the night sky. Designating Chaco as an IDA Dark Sky Park will honor the memory of these early occupants, and will result in extending this Chaco dark sky experience to future generations.

Chaco should have no problem in meeting the basic IDA requirements for a Dark Sky Place. It is very remotely located in a site that is absent of any nearby gateway city and the usual lighting issues with an adjacent community. The Chaco park personnel are well aware of the park lighting conditions needed to meet IDA requirements. The current park superintendent, Larry Turk, was stationed at the Natural Bridges National Monument when they became the first national park to receive the IDA designation as a Dark Sky Park. The rest of the staff enthusiastically supports the dark sky designation effort.

In the matter of public outreach, Chaco has had a well-developed night sky program since 1991. It is actively involved with The Albuquerque Astronomical Society (TAAS) in public outreach. Twice a year in the spring and in the fall, TAAS joins Chaco in a weekend public star party for the many park visitors. The event includes day- and nighttime observing, astronomy lectures and information about light pollution and proper night sky lighting methodology. In addition, fifteen years ago TAAS assisted Chaco in the establishment of an observatory that is used in the Chaco Night Sky Program. The 25-inch Obsession telescope that resides in the Chaco Observatory was a gift from TAAS member John Sefick.

Chaco Culture National Historical Park truly is a phenomenal place to visit, learn about the nature of the dark sky and how to best preserve the dark sky experience not only at Chaco, but also at the home location of the visitors to the park.

On behalf of The Albuquerque Astronomical Society (TAAS), I heartily endorse the award of IDA International Dark Sky Park status to Chaco Culture National Historical Park.

Best regards,

Dee W. Friesen
President, TAAS
www.TAAS.org
IDA Member
505-856-1593



Figure 1: Location Map

Chaco Culture National Historical Park and surrounding areas, including *Kin Bineola*, *Kin Ya'a*, and *Pueblo Pintado* units.

I. Park Location and General Description*

Chaco Culture National Historical Park (CCNHP, Chaco, or the park) is in northwestern New Mexico, about 150 miles northwest of Albuquerque, New Mexico. The park was first established as a national monument by Presidential Proclamation in 1907. It was later expanded and designated Chaco Culture National Historical Park in 1980 to recognize the interconnections between the park and its 40,000-square-mile area of influence.

From the 9th to 13th centuries, Chaco Canyon was the center of a civilization of social, political and architectural sophistication. An engineered system of roads and evidence of a vast trading network are indicators of its former inhabitants' relationship with a broader area of influence. The characteristic building of the Chacoan civilization is the "great house," a multistoried, multi-roomed structure found throughout the Four Corners region of the American Southwest.

The park extends over 33,000 acres and contains some 4,000 recorded archeological sites. The Chacoan people combined many elements: pre-planned architectural designs, astronomical alignments, geometry, landscaping, and engineering to create an ancient urban center of spectacular public architecture—one that still awes and inspires us a thousand years later. In recognition of its superb resources, Chaco Culture National Historical Park was named a United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Site in 1987.

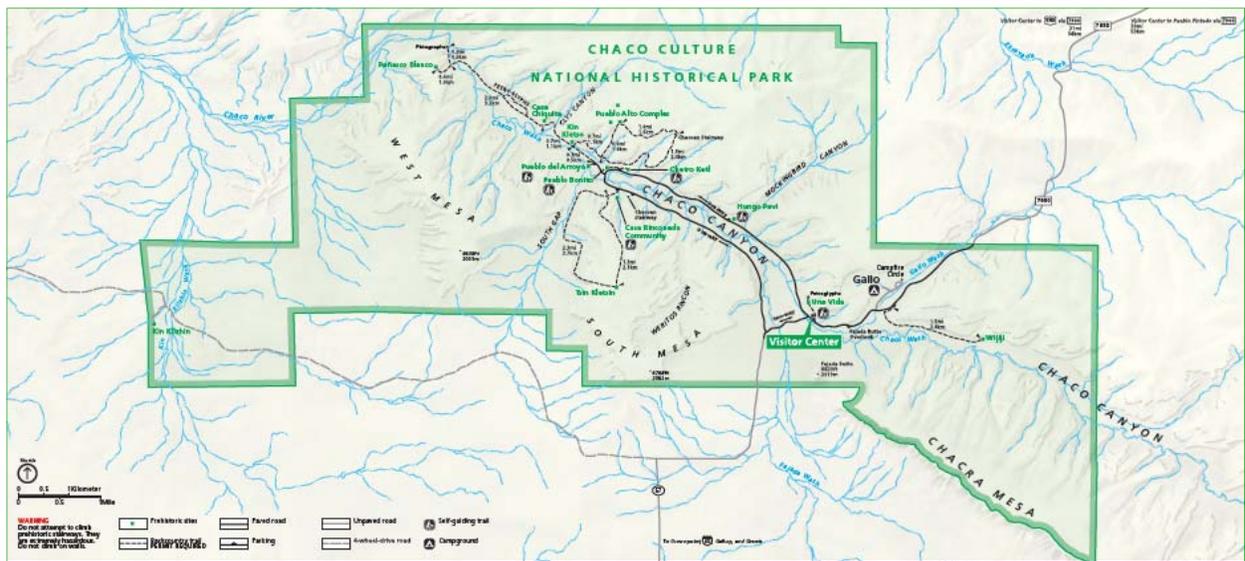


Figure 2: Map of Chaco Culture National Historical Park (Main Unit)

NPS-Harpers Ferry Center

The park is bounded primarily by Navajo Nation tribal lands with some nearby lands owned by the Bureau of Land Management (BLM), state of New Mexico, and private owners. The main access to the park is from the northeast via CR 7950 that starts at New Mexico 44/U.S. 550, the main northwesterly highway from the Four Corners region to Albuquerque. The distance from this highway to the park entrance is 21 miles; 13 of these miles are on an unpaved road. A second road approaches the park from the south from US 40 via Crownpoint; the last 19 miles of this road are also unpaved. A third unpaved road that provided access to the site from the northwest was closed in 1994.

II. Park Resources and Significance*

Natural Resources

Chaco Culture National Historical Park is near the geographic center of the San Juan Basin. The San Juan Basin is located primarily in the northwestern corner of New Mexico, stretching into southwestern Colorado and abutting the Four Corners area. Geographic features within the San Juan Basin vary from plains and valleys to buttes, canyons, and plateaus. The park is a semi-arid desert steppe in the southeast corner of the Colorado Plateau. The park's elevation ranges from 6,000 to 6,800 feet, and it encompasses three prominent land forms: (1) the alluvium-filled valley floor of Chaco Canyon, with its prominent drainage features; (2) expansive cretaceous sandstone mesas, topped by slickrock outcrops and gently rolling hills; and, (3) a number of small side canyons (locally known as "rincons") eroded into the sandstone faces adjacent to the main canyon floor.



Fajada Butte with Chaco Wash in foreground

NPS photo

The park's vegetation is predominantly Great Basin grassland and desert scrub. Riparian vegetation, including cottonwood and willow groves, is locally abundant along the canyon floor arroyo and around seeps and springs. Diverse scrub and wildflower communities occur on the sandstone bluffs throughout the canyon. Pinyon-juniper woodland is also well developed at the park's highest elevations on Chacra Mesa, and along the margins of several other mesas.

Although established primarily for its archeological resources and historic structures, the park's natural area is regionally significant. The park is one of only two protected areas in the San Juan Basin, and serves as an island of biodiversity harboring plants and wildlife that have otherwise been significantly affected by grazing, mineral extraction, and other adjacent land-use activities. Diverse microclimates associated with soil types, water availability, elevation, and solar aspect angle combine to create a rich variety of ecological zones within the park. This diversity may account for a long history of human occupation—at least 7,000 years in Chaco Canyon.

Cultural Resources

For all the wild beauty of Chaco Canyon's high desert landscape, its long winters, short growing seasons, and marginal rainfall create an unlikely place for a major center of the Chacoan civilization to take root and flourish. Yet this valley was the center of a thriving culture a thousand years ago. The monumental scale of its architecture, the complexity of its community life, the high level of its social organization, and its far reaching commerce created a cultural vision unlike any other seen in ancient North America.



Pueblo Bonito great house

Photo: NASA, from *Traditions of the Sun*

The complex system began at least by the mid 800s and lasted more than 300 years. It is seen most clearly in the grand scale of the architecture. Using masonry techniques unique for their time, they designed and constructed massive stone buildings (great houses) of multiple stories containing hundreds of rooms much larger than any they had previously built. The buildings were planned from the start, and required a vast amount of quarried stone, hundreds of thousands of logs brought in from distant forests, and the engineering skills to erect four and five

storied structures. Construction on some of these great house buildings spanned centuries. Although each is unique, all great houses share a suite of architectural features that make them recognizable as Chacoan.

In the mid 800s, construction began on the great houses of Pueblo Bonito, Una Vida, and Peñasco Blanco, continued into the mid 900s and early 1000s. Construction of Hungo Pavi, Chetro Ketl, Pueblo Alto, and others began in the 1000s. These structures were positioned and oriented to reflect solar and possibly lunar events. A network of signaling stations interconnecting most of the great houses allowed communication. Sophisticated astronomical markers, communication features, water control devices, and formal earthen mounds surrounded them. The buildings were placed within a landscape that incorporated sacred mountains, mesas, and shrines that still have deep spiritual meaning for their descendants.

Chaco became the ceremonial, administrative, and economic center of a far flung system that centered on the San Juan Basin. Its sphere of influence was extensive. Dozens of great houses in Chaco Canyon were connected by roads, as well as trade, political, and economic networks, to more than 150 great houses throughout the region. The great houses themselves may have served as “public architecture” that were used periodically during times of ceremony, commerce, and trading.

In the mid 1100s and 1200s, new construction slowed and Chaco’s role as a regional center shifted. Chaco’s influence continued at Aztec, Mesa Verde, the Chuska Mountains, and other centers to the north, south, and west. In time, the people shifted away from Chacoan ways, migrated to new areas, reorganized their world, and eventually interacted with foreign cultures. Their descendants are the modern Southwest Indians. Southwest Indian people look upon Chaco as an important episode in their clans’ sacred migration paths—a spiritual place to be honored and respected.

**Parts I and II excerpted from CCNHP General Management Plan Amendment (2012)*

III. Night Sky Preservation Guidance

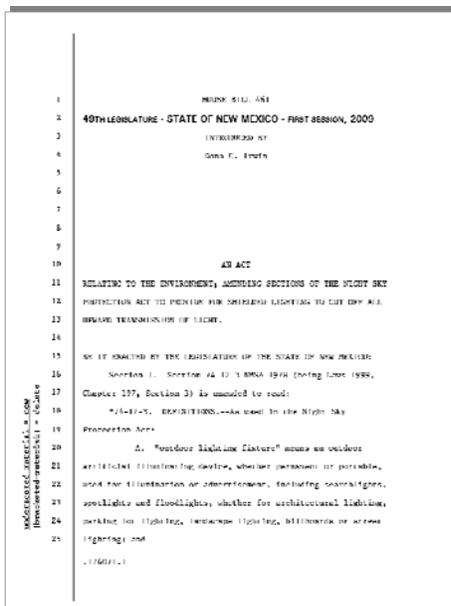
At the federal, state, and park level, a variety of laws, policies, plans and initiatives serve to guide Chaco Culture National Historical Park in the protection of its dark night skies. These begin with the NPS Organic Act that established the U.S. National Park Service in 1916, to *A Call to Action*, the initiative to prepare the NPS for its centennial in 2016 and to provide leadership for the national parks into the next century. Goal #27 of that initiative, “Starry, Starry Night,” served as the impetus for Chaco’s International Dark Sky Park application, as a way of fostering a dark sky cooperative on the Colorado Plateau. Preserving dark night skies has been an important resource goal at the park since at least the early 1990s and is reflected in the parks management plans and other guiding documents.

National Park Service Organic Act

The 1916 NPS Organic Act created the U.S. National Park Service and still serves as the agency’s foundation for conservation. Among its purposes is scenic preservation, which includes dark sky resources and the mandate to keep them unimpaired for future generations.



“The service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.”



State of New Mexico Night Sky Protection Act [74-12-1 to 74-12-10 NMSA 1978]

In 1999, New Mexico passed the Night Sky Protection Act, one of the earliest state laws of its kind.

74-12-2. Purpose.

“The purpose of the Night Sky Protection Act [74-12-1 to 74-12-10 NMSA 1978] is to regulate outdoor night lighting fixtures to preserve and enhance the state's dark sky while promoting safety, conserving energy and preserving the environment for astronomy.”

An amendment to the Act, “The Night Sky Protection Enforcement Act,” was passed in 2009 to introduce penalties and mandatory enforcement of the Night Sky Protection Act provisions.

NPS Management Policies 2006

This volume of NPS Management Policies is the basic Service-wide policy document of the U.S. National Park Service. It is designed to provide NPS management and staff with required and/or recommended actions to help manage parks and programs effectively.

4.1.4 Partnerships

“The Service will seek the cooperation of others in minimizing the impacts of influences originating outside parks by controlling noise and artificial lighting. . .”

4.10 Lightscape Management

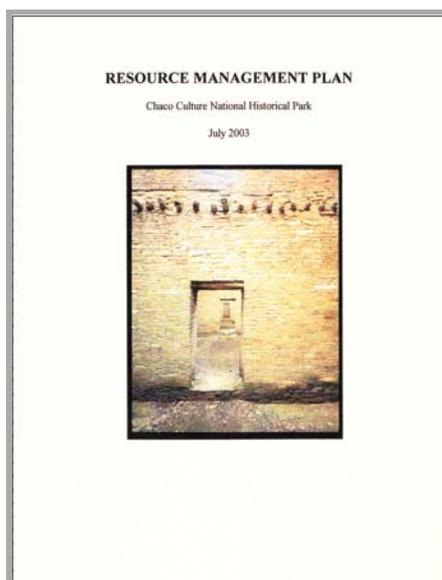
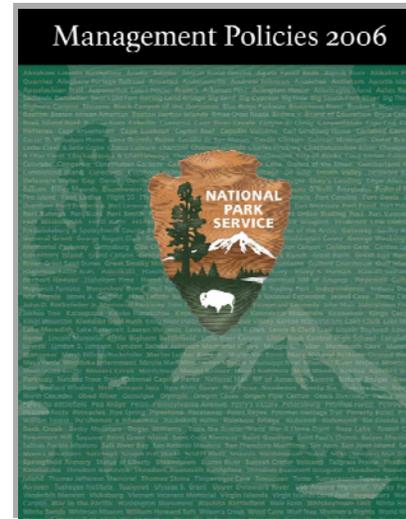
“The Service will preserve, to the greatest extent possible, the natural lightscape of parks, which are natural resources and values that exist in the absence of human caused light. . .” “The stars, planets, and earth’s moon that are visible during clear nights influence humans and many other species of animals, such as birds that navigate by the stars or prey animals that reduce their activities during moonlit nights.”

9.3.1.4 Amphitheaters

“Artificial lighting must be carefully directed and kept to a minimum, with due regard for natural night sky conditions.”

9.3.2.1 Campgrounds

“Lighting will be energy efficient and shielded as much as possible so that visitors have the opportunity to experience the natural darkness and night skies.”



Resource Management Plan (RMP)

Chaco Culture NHP, July 2003

The 2003 RMP outlines the park’s strategy for preserving, protecting, studying, and restoring the park’s cultural and natural resources.

Aesthetic values (Scenery, Light Pollution, Noise)

“In surveys of park visitor values, the solitude, natural quiet, and clear night time sky were rated as significantly contributing to the recreational experience of the canyon. In 2001, in cooperation with The Albuquerque Astronomical Society (TAAS) and the University of New Mexico, the park began monitoring the effects of light pollution from distant communities on night sky darkness. Because of evidence that astronomical indica-

tors may have places an important role in Chacoan Society there appears to be justification for the park to consider the night sky as an aesthetic cultural landscape.”

Foundation for Planning and Management

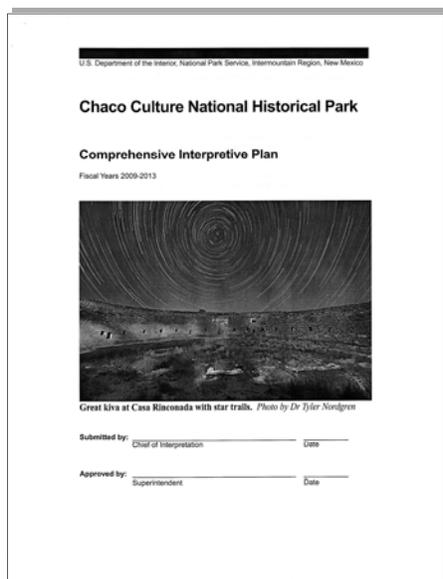
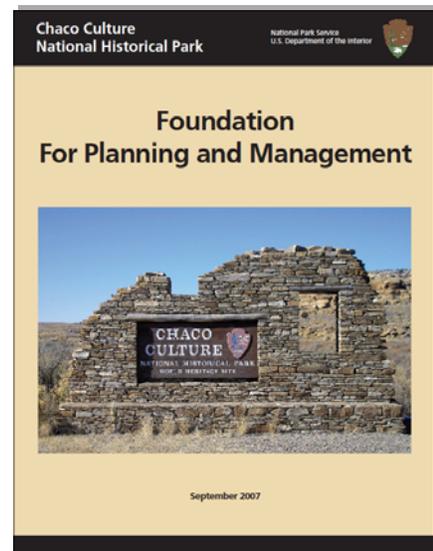
Chaco Culture NHP, September 2007

The *Foundation* document provides a formal statement of core missions, values, and resources significant and fundamental to the park.

Fundamental Resource/Value #7:

Archaeoastronomy and Dark Night Sky

“The dark night sky provides visitors with an opportunity to make astronomical observations and experience the same sky the Chacoans observed and incorporated into their landscape, buildings, and culture. Chaco provides habitat for many wildlife species, such as amphibians, mammals, migrating birds, moths and other insects, and large cats that depend on dark night skies for existence and ecological processes. There is an interpretive opportunity to illustrate the problem of light and air pollution.”



Comprehensive Interpretive Plan (CIP)

Chaco Culture NHP (draft), 2013

The CIP provides the long-term vision and direction for the park’s interpretive programming and media. The CIP shares many of the same resources and values statements as the park’s 2007 *Foundations* document, including those pertaining to archaeoastronomy and dark night skies.

Fundamental Resource/Value #7:

Archaeoastronomy and Dark Night Sky

“The dark night sky provides visitors with an opportunity to make astronomical observations and experience the same sky the Chacoans observed and incorporated into their landscape, buildings, and culture. Chaco provides habitat for many wildlife species, such as am-

phibians, mammals, migrating birds, moths and other insects, and large cats that depend on dark night skies for existence and ecological processes. There is an interpretive opportunity to illustrate the problem of light and air pollution.”

A Call to Action

U.S. National Park Service, 2011 (revised 2012)

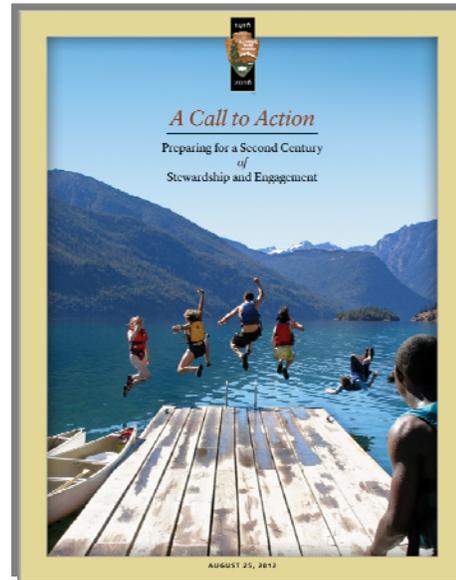
A Call to Action is a strategic plan created to set a new direction for the U.S. National Park Service in its second century of stewardship and engagement. The plan is organized around broad themes and supported by specific goals and measurable actions. Each NPS park unit selects goals that strategically focus its efforts on actions that advance the NPS mission. Chaco Culture NHP is working toward achieving several Call to Action goals, including the following initiatives which advance the park's commitment to preserving natural darkness in the nighttime sky:

Goal #27: "Starry, Starry Night"

"Lead the way in protecting natural darkness as a precious resource and create a model for dark sky protection by establishing America's first Dark Sky Cooperative on the Colorado Plateau in collaboration with other federal agencies, partners, and local communities."

Goal #38: "Enjoy the View"

"Protect clean, clear air and spectacular scenery now and for future generations. To do this we will lead collaborative efforts in 10 parks creating viewshed cooperatives with other federal agencies, tribes, and local partners to assess air pollutants and preserve treasured viewsheds and natural and cultural resources."



IV. Sky Quality at Chaco Culture NHP

Existing Night Sky Conditions

Based on sky quality measurements taken at Chaco by the NPS Night Skies Team, the NPS Natural Sounds and Night Skies Division (NSNSD) provided the following sky quality assessment:

“The park was one of the first [NPS] units to receive an inventory of night sky quality in 2002. Subsequent data collection in 2008 provided higher resolution and accuracy than what was available in 2002. Additional data was collected on June 1, 2013. Preliminary results show that nighttime photic environment has not substantially changed since 2008. The Night Sky Monitoring Report from 2008 gives Chaco a Sky Quality Index measurement of 90.1, indicating an excellent dark sky [figure 4]. The Sky Quality Index number is the result of a combination of sky brightness data measurements and environmental parameters, and provides a single-number representation of night sky quality.

Sky quality in the park is very good. Views from the canyon floor are superb, typically reaching Class 2 on the nine-step Bortle Dark-Sky Scale. The lightscape from the canyon rim, representative of sites such as Pueblo Alto, is slightly altered from natural conditions, described as Bortle Class 3 (almost reaching Class 2). Conditions remain among the best in the NPS system. Zenith brightness measures (22.15 magnitudes per square arc second) indicate that there is very little or no artificial light straight overhead. The brightest artificial light source in the image (19.91 magnitudes per square arc second), is slightly dimmer than the brightest part of the Milky Way. Therefore, the natural features of the night sky predominate—a condition that is rarely found in the lower 48 states today.

Data was collected using the methods described by Duriscoe, Luginbuhl, and Moore 2007. The NPS CCD camera system is able to precisely measure the photic environment in a wavelength mimicking human vision. From these images, quantitative measurements of existing conditions are derived and expressed in absolute terms as well as ratios of the natural sky (the natural sky is comprised of the Milky Way, the Zodiacal light, airglow, and starlight). To isolate artificial light, NSNSD removed natural light sources from the dataset. This analysis resulted in a maximum vertical illuminance of 0.08 milliLux. This indicates that direct glare from point sources and discrete light domes is below the threshold where human dark adaptation can begin to be impacted. The level measured at CCNHP is also below illuminance levels generated by Venus at its brightest (0.10 milliLux); Venus is the brightest natural light in the moonless sky. This data also indicates that natural features predominate over artificial ones.

The 2008 data [figures 5-8] show that the amount of artificial light was 15% of natural amounts; in other words, the Anthropogenic Light Ratio was 0.153. This indicates a very good condition. Though many discrete light sources are visible in the image, they are either distant cities, or small nearby towns. The panoramic image [figures 5 & 6] shows the view from the canyon rim (36.0315 N, 107.9065 W) looking southward. False color provides contrast. Visible in the image is the arch of the Milky Way and several small light sources dotting the horizon. This data from 2008 was taken under atmospheric conditions commonly found in the canyon and is representative of clear air conditions roughly at the 75th percentile of air quality for this region. Under conditions of diminished air quality light sources within 30 km would tend to be amplified,

and light sources at distances greater than 30km would tend to be suppressed.

As seen from the panoramic image, there are five prominent light domes along the horizon. Each is attributed to urban centers in New Mexico. The largest light dome, visible at ~345° is Farmington, about 84 km from Chaco. The next prominent dome is generated from Albuquerque and Rio Rancho, visible as a single light dome at ~130°. Albuquerque is 153 km away from Chaco but still contributes a large portion of the visible light. Other smaller domes consist of Grants, 97 km away at 176°; Crownpoint, 44 km away at 210°; and Gallup, 94 km away at 232°.”

The techniques utilized by the NPS Night Skies Team represent the state of the art in sky quality measurement. Another indication of Chaco’s night sky quality comes from the *World Atlas of Artificial Light Pollution*, as depicted in figure 9 (Cinzano *et al.* 2001). *ClearDarkSky.com* provides additional context by providing descriptions and visual characteristics of the dark sky quality classes represented in the map (figure 10).

International Dark Sky Park *Gold Tier* Eligibility

With respect to the three night sky quality tiers (*gold*, *silver* and *bronze*) utilized by the IDA for International Dark Sky Park designations, CHNHP meets or exceeds all of the requirements for becoming an International Dark Sky Park at the gold tier level which has the highest requirements for night sky quality. Chaco is fortunate to have some of the darkest night sky conditions in the lower 48 United States and readily meets this set of standards (figure 3). The park’s naturally dark conditions exceed all gold-tier numeric standards, and the full range of observable sky phenomena (e.g., Milky Way, Zodiacal light) are regularly seen. In addition, sources of light pollution—though both noticeable and concerning—have not resulted in more than minor degradation of the overall night sky quality at the park.

Sky Quality Measurement	Gold Tier Standards	CCNHP Existing Conditions (<i>meets all standards</i>)
Artificial Light and Skyglow	Typical observer is not distracted by glary light sources. Light domes are dim and close to horizon.	Light domes restricted to horizon; effects of light pollution on viewing conditions in the canyon are minor.
Visual Limiting Magnitude (VLM)	Equal or greater than 6.8 under clear skies and good seeing conditions.	VLM of 7.1 recorded June 1, 2013
Bortle Sky Class	Class 1-3	Class 2 on canyon floor; Class 2-3 on mesa tops.
Observable Sky Phenomena	Full array of visible sky phenomena (e.g. aurora, airglow, Milky Way, zodiacal light, and faint meteors).	Natural sky phenomenon dominate the night sky. The full array of visible sky phenomenon can be viewed regularly.
Unihedron™ Sky Quality Meter	21.75 mags/arc-sec ² or above.	Avg. SQ = 21.83 mags/arc-sec ² . Darkest recorded SQ = 22.27 mags/arc-sec ² .

Figure 3: IDA standards for International Dark Sky Park *Gold Tier* status and CCNHP eligibility



National Park Service Night Sky Program

Night Sky Quality Monitoring Report

Report date: x 10/20/2011

PARK:		EQUIPMENT:	IMG 2, 50mm f/2, 6084
SITE NAME:	Water Tank	OBSERVERS:	K Magargal, D Duriscoe
LONGITUDE:	-107.90854	AIR TEMP (°F):	67
LATITUDE:	36.03153	REL HUMID (%):	15
ELEVATION (m):	1955	WIND SP (mph):	3
DATE (UT):	May 31, 2008	CCD TEMP (°C):	-20
TIME START (UT):	5:17:34	EXP (seconds):	12
DATA QUALITY:		BORTLE CLASS:	ZLM:
NARRATIVE:			

SKY BRIGHTNESS DATA										LIGHT DOME DATA			
Data Set	Time (LMT) Decimal Hours	Extinction coefficient (mag/air-mass)	Std Err Y Extinction Regression (mags)	Zenith (SKIES) mag/sq arc- sec	Whole Sky (mLux / mags)	Sky Above 20° Altitude (mags)	Brightest (mag/sq arc- sec)	Darkest (mag/sq arc- sec)	Synthetic SOM	City	Distance (km)	Azimuth	Illuminance (mLUX)
1st	Start 22.1 End 22.42	0.155	0.035	0.796 22.25	1.649 -7.03	-6.31	19.96	22.27	88.4 21.94				
2nd	Start 23.12 End 23.45	0.152	0.034	0.825 22.21	-7.06	-6.40	19.95	22.14	90.1 21.82				
3rd	Start 0.15 End 0.47	0.162	0.034	0.869 22.15	-7.04	-6.40	20.08	22.20	86.8 21.79				
4th	Start 1.17 End 1.5	0.176	0.052	1.139 21.86	-7.05	-6.40	19.56	22.25	87.3 21.77				
5th													
6th													
7th													93.2
8th													0.97
SKY QUALITY INDEX													90.1

Figure 4: May 2008 Night Sky Monitoring Report with Sky Quality Index of 90.1

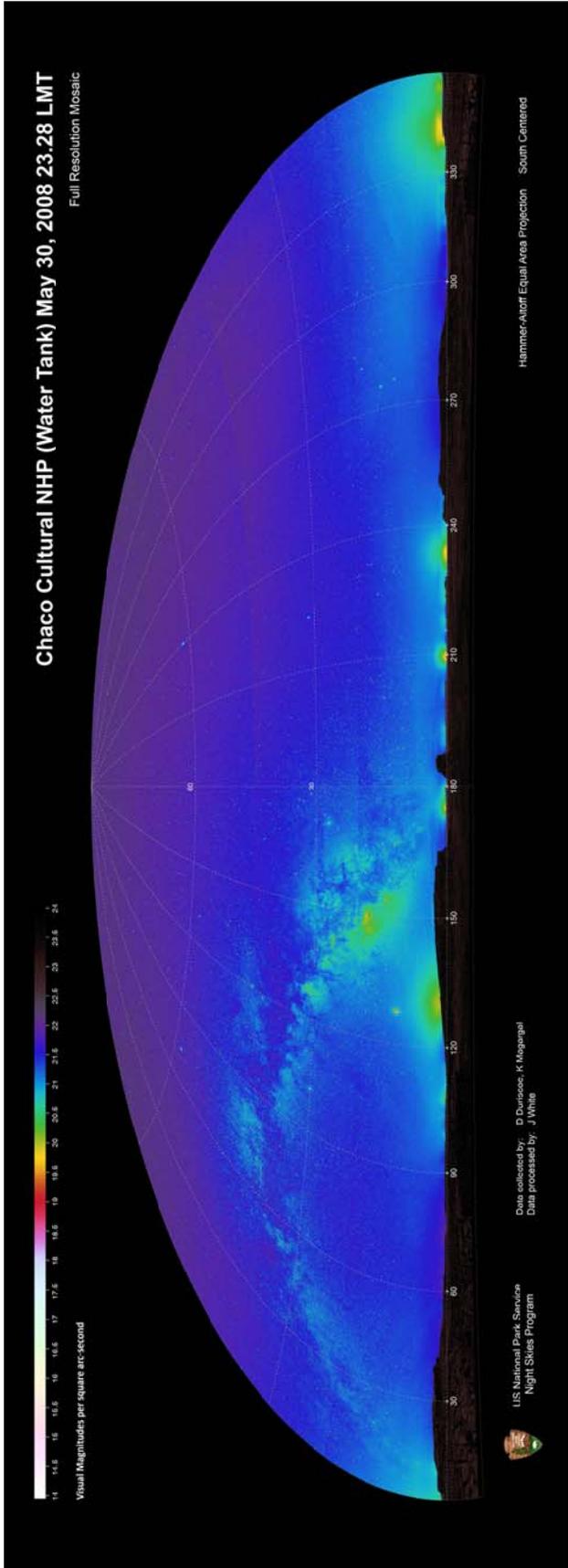


Figure 5: Panoramic map of natural and anthropogenic sky luminance.

NPS-NSNSD

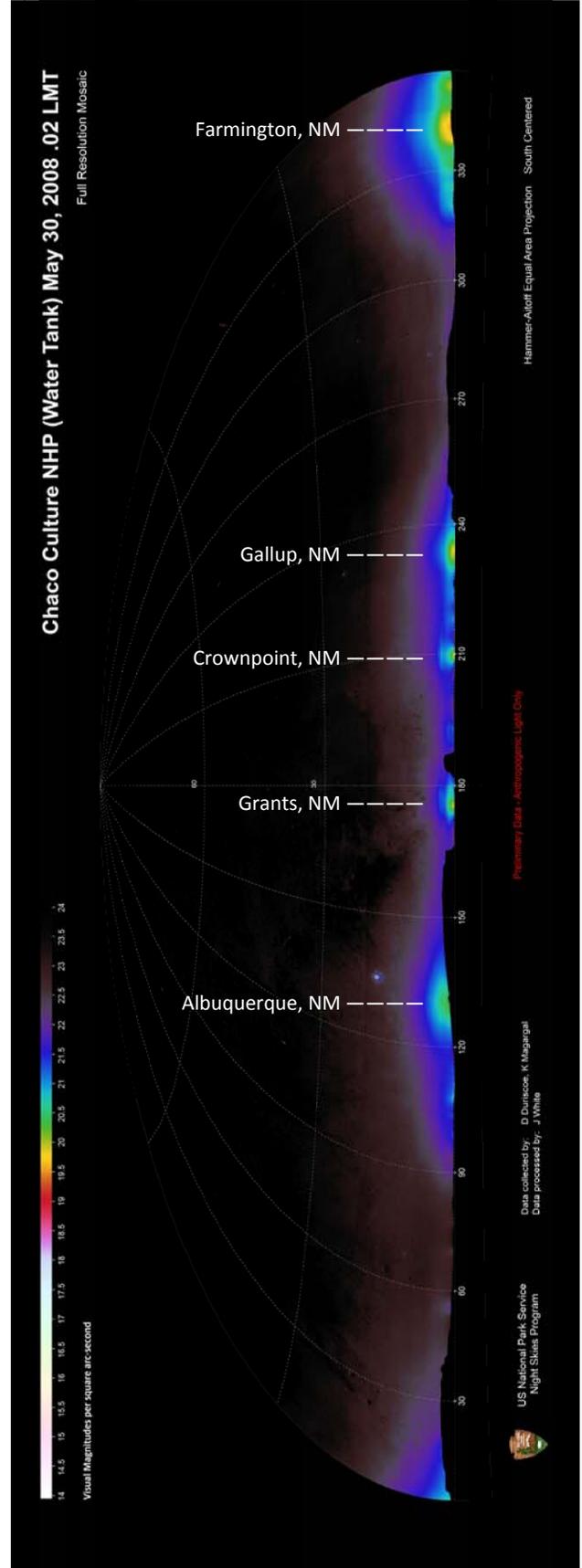


Figure 6: Panoramic map of anthropogenic sky luminance.

NPS-NSNSD

False-color Natural and Anthropogenic Sky Luminance at Chaco Culture NHP (figures 5-8)

Panoramic and hemispheric representations of night sky brightness data from the CCNHP raw water tank (located on Gallo Cuesta behind the park visitor center). Figures 5 & 7 represent both natural ambient light and artificial light. Figures 6 & 8 represent anthropogenic light only. Data was collected May 30, 2008 by NPS Night Skies Program staff using methods described by Duriscoe, Luginbuhl, and Moore (2007). Significant sources of light pollution include: the Albuquerque, NM metro area (130°); Grants, NM (176°); Crownpoint, NM (210°); Gallup, NM (232°); and the Farmington-Bloomfield-Aztec municipal area (345°).

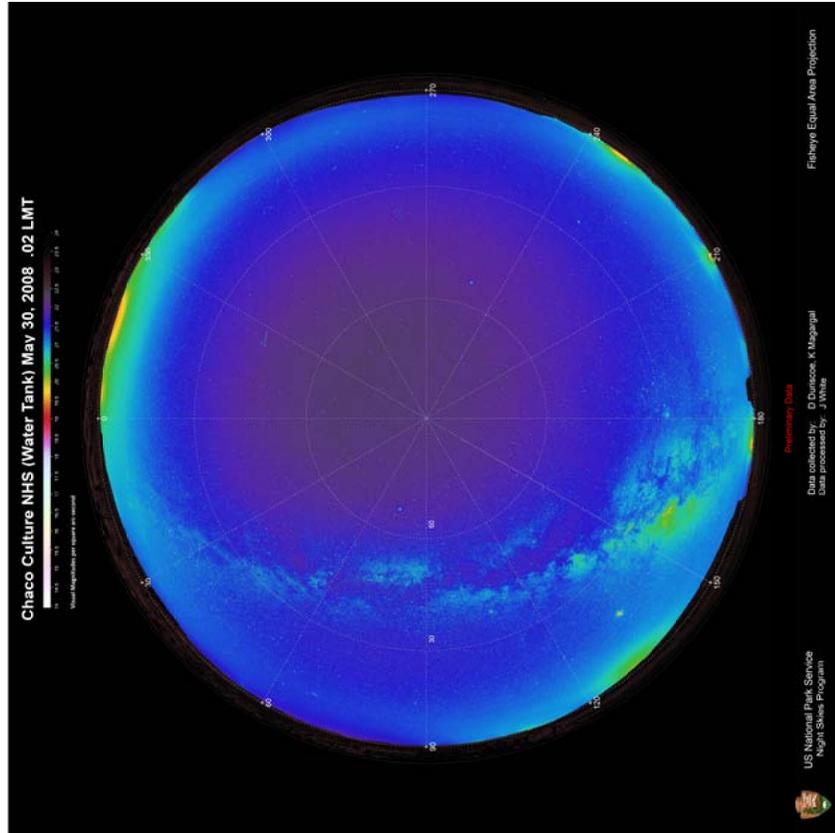


Fig. 7: Hemispheric map of natural and anthropogenic light. NPS-NSNSD

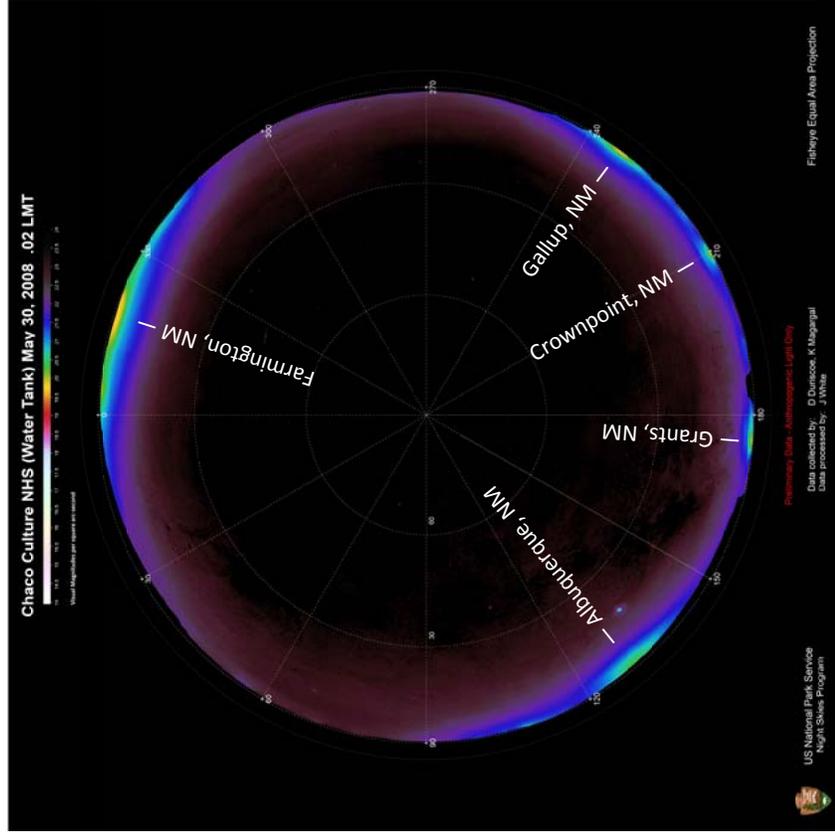


Fig. 8: Hemispheric map of anthropogenic light. NPS-NSNSD

Chaco Culture NHP Light Pollution Map from ClearDarkSky.com

ClearDarkSky.com provides graphics and predications of night sky conditions around the globe. This map from the *World Atlas of the Artificial Night Sky Brightness* shows light pollution in the vicinity of CCHNP. The central cross marks the location of the park. Since this map assumes an observer at sea level; an actual observer should see a slightly darker sky given that Chaco's elevation ranges from approximately 6000-6800 ft. Note the Farmington, NM-Durango, CO corridor to the north; Gallup, NM to the southwest; Grants, NM to the south; and the Albuquerque-Santa Fe metro corridor to the southeast. Though the park has remarkably clear dark skies, light pollution from these communities is sometimes visible along the horizon.

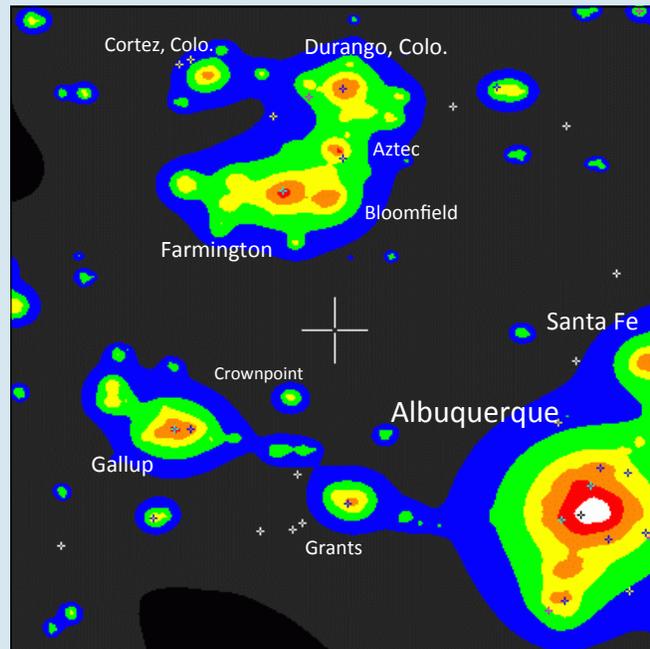


Fig. 9: Light Pollution Map



Source: ClearDarkSky.com

Color	Sky Brightness	Sky Brightness mags/arc-sec ²	Bortle Scale	Description
Black	< 0.01	22.00 to 21.99	1	Gegenschein visible. Zodiacal light annoyingly bright. Rising Milky Way confuses some into thinking it's dawn. Limiting magnitude 7.6 to 8.0 for people with exceptional vision. Users of large Dobsonian telescopes are very happy.
Dark Gray	0.01 to 0.11	21.99 to 21.89	2	Faint shadows cast by Milky Way visible on white objects. Clouds are black holes in the sky. No light domes. The milky way has faint extensions making it 50 degrees thick. Limiting magnitude 7.1 to 7.5.
Blue	0.11 to 0.33	21.89 to 21.69	3	Low light domes (10 to 15 degrees) on horizon. M33 easy with averted vision. M15 is naked eye. Milky way shows bulge into Ophiuchus. Limiting magnitude 6.6 to 7.0.
Green	0.33 to 1.0	21.69 to 21.25	4	Zodiacal light seen on best nights. Milky Way shows much dark lane structure with beginnings of faint bulge into Ophiuchus. M33 difficult even when above 50 degrees. Limiting magnitude about 6.2 to 6.5.
Yellow	1.0 to 3.0	21.25 to 20.49	4.5	Some dark lanes in Milky Way but no bulge into Ophiuchus. Washed out Milky Way visible near horizon. Zodiacal light very rare. Light domes up to 45 degrees. Limiting magnitude about 5.9 to 6.2.
Orange	3.0 to 9.0	20.49 to 19.50	5	Milky Way washed out at zenith and invisible at horizon. Many light domes. Clouds are brighter than sky. M31 easily visible. Limiting magnitude about 5.6 to 5.9.
Red	9.0 to 27.0	19.50 to 18.38	6 or 7	Milky Way at best very faint at zenith. M31 difficult and indistinct. Sky is grey up to 35 degrees. Limiting magnitude 5.0 to 5.5.
White	>27.0	<18.38	8 or 9	Entire sky is grayish or brighter. Familiar constellations are missing stars. Fainter constellations are absent. Limiting magnitude from 3 to 4. Telescopic visual observation is usu-

Figure 10: Night sky quality scale

Source: ClearDarkSky.com

Map Credit: Cinzano, P., F. Falchi, C. D. Elvidge Copyright Royal Astronomical Society.

Light Pollution Threats

Despite Chaco's excellent night sky conditions, the park faces some significant light pollution threats. Regional urbanization—particularly in the Albuquerque and Farmington, NM areas and along the Interstate Highway 40 corridor from Grants to Gallup, NM—has been a growing concern of the park for some time. Long-time park staff and amateur astronomers report that light domes from both nearby towns and more distant urban areas have grown in size and intensity over the years, and can be seen more frequently today. While these light domes have not yet diminished the visibility of most astronomical phenomena in the Chaco sky, the domes, themselves, are becoming a more frequent intrusion in the park's nighttime viewscape and an adverse impact to its visitor experience.

Another emerging threat to Chaco's dark night skies is energy development in the San Juan Basin, a geographic region that has long been a center for petroleum production. Though the Basin has experienced a recent decline in oil & gas production, the resource potential of the Mancos shale layer has renewed industry interest in development near Chaco. A combination of abundant supply, new drilling technologies, and attractive economics could lead to widespread drilling activity in the area; with it could come intensive artificial lighting, gas flaring, and a general increase in development-related activity such as increased vehicle traffic and the construction and operation of support facilities. At the park's higher elevations, nearby exploratory wells are already having an effect on Chaco's night sky conditions in the form of bright artificial lights, gas flares, and nighttime vehicle traffic. More development could lead to significant effects on sky quality conditions at the canyon floor where most of the park's after-dark programs take place.

The management and staff of CCNHP are dedicated to preserving Chaco's natural darkness and will continue to work with sister agencies, governments, and other landowners to avoid, minimize, and mitigate adverse impacts to the night sky. Assessments of existing sky conditions at Chaco enable the park to provide context and useful information concerning the potential impacts of urbanization, energy development, and other sources of light pollution on the nighttime landscape.

Sky Quality Monitoring

Taking advantage of more than a decade of night sky inventory work at the park, Chaco is working to fully implement a night sky quality monitoring program first envisioned in the early 1990s. At the center of this program, repeat sky luminance measurements will be collected on a five-year monitoring cycle using the methods employed by the NPS Night Skies Program. Chaco has established good baseline measurements for the park and will continue to track changes in sky quality conditions. Should specific light pollution threats require more frequent monitoring, Chaco will work to expedite its moni-



NPS scientists check CCD equipment on June 1, 2013 prior to a night of monitoring at Chaco Culture NHP.

toring schedule accordingly.

In addition to the repeat sky luminance measurements described above, CCNHP will monitor night sky conditions using a variety of other techniques. Next year, the park will participate in the citizen science project, *GLOBE at Night*, as part of the 2014 project campaign. Using a handheld Unihedron™ Sky Quality Meter, Chaco will periodically measure sky quality in magnitudes per square arcsecond (mags/arc-sec²) and report those results to globeatnight.org. Readings will be taken during the park's Night Sky programs between March and October, giving visitors an opportunity to learn about, and participate in, night sky quality monitoring. The park will also evaluate the benefits of permanently installing a sky quality meter at the visitor center & observatory area, or another location within the park.

The park encompasses a total of 33,974 acres divided between four park units. At approximately 32,181 acres, the main unit comprises the vast majority of the park. The detached units of Kin Bineola, Pueblo Pintado, and Kin Ya'a—13.3 miles west, 13.6 miles southeast, and 27 miles southwest of the Chaco Canyon Visitor Center, respectively—have an approximate total area of just 1,826 acres (see figure 1). In addition to making up only a very small part of the park's overall land area, the three detached units are closed to the public between sunset and sunrise and are not part of the park's after-dark interpretive programming. Though the park hopes to expand its monitoring program into these small detached units and other remote locations within the main park unit in coming years, to date all night sky monitoring activities have taken place within the main park unit near its development zone and central interpretive area.

The park's two smallest units, Kin Ya'a (255 acres) and Pueblo Pintado (161 acres), are located immediately adjacent to the small New Mexico communities of Crownpoint and Pueblo Pintado. While these remote sites don't possess the same near-pristine dark sky qualities as the main park unit, they are still relatively dark locations and represent future opportunities to work with communities on mitigating light pollution effects. The park hopes to build upon its International Dark Sky Park designation by working with neighboring communities such as these on lightscape management and dark sky preservation.

V. Chaco Astronomy

Ancient Practices and Traditions

Chaco Canyon has a long history of stargazing, going back at least as far as its occupation by the Chacoan people. In recent decades, Chaco has been the focus of substantial inquiry into cultural astronomy, and most experts recognize many examples in the park where manmade and natural features were used to mark the positions of the sun and moon, and symbolize other astronomical phenomena. In concert with this focus on Chaco, the field of archaeoastronomy has grown to become a prominent lens through which many questions and answers have been generated about the Chacoan people and their world, including their intimate knowledge of the sky.



A blade of sunlight marks summer solstice at the "Sun Dagger" atop Fajada Butte

NPS photo

Researchers have studied alignments of Chacoan buildings and other cultural sites, discovering numerous associations with celestial events and cosmic cycles. Orientation to the four cardinal directions in prominent buildings such as Casa Rinconada—the largest excavated great kiva in the Chacoan system—is found throughout the Chaco, and many of the park's best known greathouse sites are described by scholars as possessing a variety of astronomical, lunar, and other cosmic alignments. Another well-known astronomical device is the *sun dagger* site atop Fajada Butte, that—until disturbed in the late 1980s—marked the midday summer solstice. Each year at solstice, Chacoans would likely have witnessed a shaft of sunlight slice across the center of a spiral petroglyph as it passed through several large sandstone blocks. Some experts have suggested that a prominent pictograph near Peñasco Blanco depicts another astronomical event that would surely have been witnessed by the Chacoans—a 1054 A.D. supernova so bright it would have been visible in the daytime sky for 23 straight days. These examples highlight just a few of the ancient astronomical depictions that can still be seen in Chaco Canyon.

Contemporary Astronomy at Chaco

For more than two decades, the park has enjoyed a vibrant partnership with the astronomy community, and in 1988 astronomy programs began to be a part of Chaco's official public programs. In the early 1990s, a partnership with The Albuquerque Astronomical Society (TAAS) was forged through which annual star parties were made part of Chaco's official interpretive programming. The modern connection with the night sky is a substantial recreation interest and a way for the public to connect with and better understand the ancient culture that once thrived in the canyon. Today's night skies are essentially the same as what the Chacoans would have witnessed a thousand years ago. The early and enthusiastic response from the public over astronomy programming became an incentive to improve the park's exterior lightscape in the early 1990s.



The Chaco Canyon Observatory

NPS photo

The Chaco Canyon Observatory

In 1997, an astronomy enthusiast named John Sefick moved to the Southwest from Chicago. He began looking for dark skies and a place where he could build an observatory to support his interest. He approached TAAS and asked members to show him a dark sky, and they brought him to Chaco. Over a period of several months he explored the night sky at the park and searched nearby for a suitable location to build an observatory. Eventually, John proposed to park management that he build the observatory in Chaco Canyon as a public donation. This way, he could still enjoy visiting the facility, and others could as well. Believing that Chaco's public programs would be enhanced by the addition of the observatory, the park accepted his generous donation. Today, the Chaco Canyon Observatory is still believed to be the only astronomical observatory operated by the U.S. National Park Service.

In May 1998, the observatory opened its door with its first public program. Ever since, a mostly volunteer staff has guided visitors to a spectacular view of the dark night sky. From March to October, the observatory is opened to the public three nights a week. Chaco's Night Sky programs typically begin with a presentation on archaeoastronomy or the significance of dark skies, segue to a naked-eye tour of the constellations and other features, and conclude with a chance for park visitors to view distant objects through telescopes.

Astrophotography

Thousands of space images have been collected at the Chaco Canyon Observatory through the years, and are regularly used in its public programs. Making use of its specialized charged coupled device (CCD) imaging system, the park has hosted investigations of binary star systems, as well as a project searching for near-earth objects (NEOs). Chaco was asked by NASA to participate in a 2009 project called *Lunar CRater Observation and Sensing Satellite (LCROSS) Shepherding Spacecraft Observations*, in which observatories with CCD imaging capabilities helped the nation's space agency to monitor the impact of the *Centaur* rocket on the moon's *Cabeus* crater in a search for evidence of lunar water ice.



M16 (Eagle Nebula)

NPS photo



M27 (Dumbbell Nebula)

NPS photo



M81

NPS photo



M46 (Orion Nebula)

NPS photo

Figure 11: Several of the thousands of CCD images captured at the Chaco Canyon Observatory.

Chaco Astronomy in Publications and Popular Media

An expansive collection of books, articles, films and other media have featured Chaco's associations to both ancient and modern astronomy, as well as its spectacular dark night skies. NASA highlighted the cultural connections to astronomy in the book and website *Traditions of the Sun* (2004). The astronomical sophistication of the ancient Chacoans was further explored in the documentary film, *The Mystery of Chaco Canyon*, produced by Anna Sofaer and the Solstice Project (2003); now a decade old, this film featuring the influence of astronomy on the Chacoan's constructed world and is still frequently shown on PBS stations across the country.

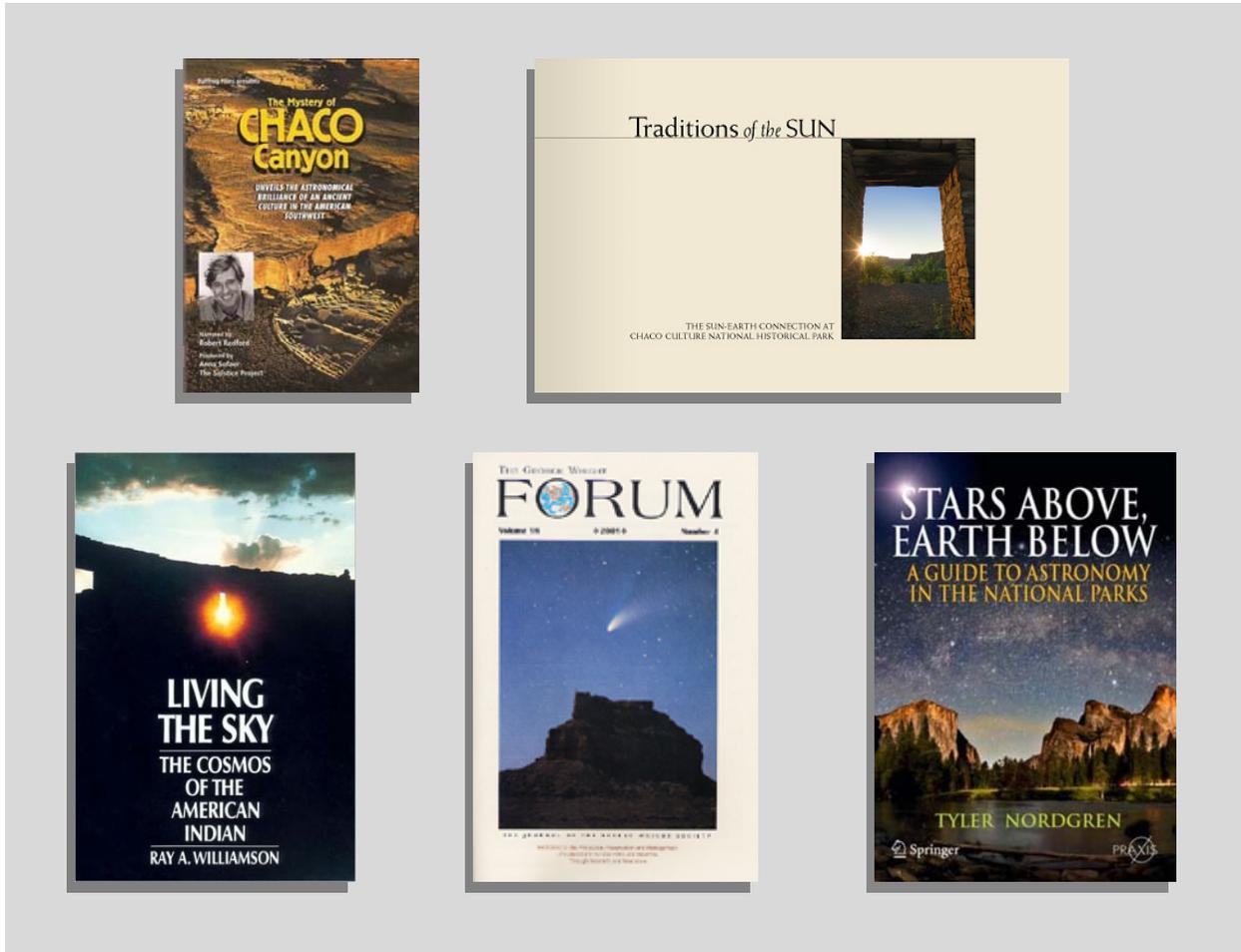


Figure 12: A sample of the many books, articles, and films that feature Chaco's connections to the nighttime sky.

Publications highlighting Chaco's dark skies and the preservation of the resource include a George Wright Forum (GWF) article titled *Let There Be Dark: The National Park Service and the New Mexico Night Sky Protection Act*, that highlights the park's role in New Mexico's early efforts to curb light pollution (2001). Another 2001 GWF article, *Chaco's Night Lights*, by GB Cornucopia and Brad Shattuck, underlines the importance of the dark sky at Chaco as a way to connect to ancient cultures. Two books that feature the human experience in Chaco astronomy are *Living in the Sky: The Cosmos of the American Indian* by Ray Williamson (1987) and *Stars Above, Earth Below: A Guide to Astronomy in the National Parks* by Tyler Nordgren (2010).

VI: Interpretive and Educational Programs at CCNHP

Established Night Sky Programming

Since 1988, Chaco has been providing astronomy programming as part of the park's official interpretation. Evening programs dedicated to dark skies and archaeoastronomy typically occur three times a week from March to October, and attendance at these programs is usually high. Following an one-hour presentation, the public is invited to observe various astronomical features and phenomena through the park's 25-inch Dobsonian telescope in the observatory, and through one or more of the park's smaller portable telescopes stationed outside.

Established after-dark programs include:

- *Archaeoastronomy of Chaco* focusing on architectural/celestial alignments and sun-watching traditions found in Chaco (Friday and Saturday evenings)
- *Public telescope viewing* (Tuesday, Friday, and Saturday nights)
- *Pueblo Bonito full moon walks* featuring oral traditions and patterns of the moon; held at Chaco's largest great house (monthly)
- *Campfire astronomy* held by volunteer astronomers (occasional)



Ranger-led archaeoastronomy program

NPS photo

Over 3,000 visitors participate in Night Sky programming each year. Due, in part, to the popularity of these programs, the park regularly exceeds the seating capacity of its small, 40-seat amphitheater. Chaco plans to construct a new 250-seat amphitheater near the visitor center and observatory within the next several years. Upgrades to the observatory are also planned, including a new building shell that will contain the park's large Dobsonian telescope, CCD imaging systems, and storage for portable telescopes and equipment.

Special Astronomy Events

Numerous visitors have been drawn to Chaco through the years because of its special relationship with astronomical phenomena, particularly at solstice and equinox. On these special days of the solar calendar, the park regularly sponsors sunrise events at prominent archaeological sites and other locations believed to commemorate the position of the sun. The natural and human-made alignments featured in these well-attended programs are interpreted using the principles of archaeoastronomy.

Special astronomical events such as eclipses and meteor showers are also interpreted for the public at CCNHP. The park commemorated the International Year of Astronomy in 2009 by hosting a public star party. For the annular eclipse of May 20, 2012, more than 500 park visitors enjoyed a full range of special programming at Chaco, including special guest presentations, eclipse viewing at four designated locations, and telescope viewing at the park's observatory.

In conjunction with the upcoming October 4-5, 2013 Chaco Canyon Star Party, a formal public dedication of Chaco's International Dark Sky Park status is planned. This special event will feature guest speakers, dark sky preservation messaging, and special interpretive programs in addition to stargazing throughout the night. A commemorative poster has been commissioned and will be given away to visitors during the event.



Figure 13: Special astronomy event posters created for CCNHP by Dr. Tyler Nordgren (University of Redlands)

VII. Partnerships and Community Outreach

Despite Chaco's remote location and lack of an obvious gateway community, the park has forged strong relationships with dedicated volunteers and partner organizations. This is no more true than with Chaco's corps of amateur volunteers and various astronomical clubs and societies, most notable of which is The Albuquerque Astronomical Society (TAAS). Astronomy volunteers from across the country come to Chaco to experience its renowned night skies and participate in the park's well-known public astronomy programs. Many are drawn here by books and magazines, or through tips they receive from blogs, message boards, or friends who have visited Chaco. Though, individually, these volunteers may not be affiliated with any particular club or group, they collectively make up the Chaco Astronomer-in-the-Parks corps. Both long- and short-term volunteers help conduct park programs, maintain and operate the observatory, and provide specialized services such as solarscope operation and astrophotography.

The park began its formal partnership with TAAS in 1991. This organization of avid astronomers has remained a strong partner to the park ever since, contributing greatly to the construction and operation of the Chaco Canyon Observatory, as well as helping to conduct outreach and education activities in support of the park's mission. TAAS members regularly give talks and other programs at CCNHP, and help to organize and conduct star parties and other special events. Other nearby astronomy groups such as the Rio Rancho Astronomical Society (RRAS) and the New Mexico Institute of Mining and Technology astronomy club have also contributed to Chaco's astronomy programs and outreach efforts. School groups of all ages have made the trip to the park specifically to take part in its observatory programs, and park staff have utilized the park's portable telescopes to take Chaco's astronomy programs out to schools, scout camps, and other organizations. With help from its astronomy volunteers, park staff have also traveled to nearby communities, including Farmington, Pueblo Pintado and Dzilth-Na-O-Dith-Hle, to give astronomy programs and facilitate star parties.



Amateur astronomers getting ready for the Chaco Canyon Star Party, June 2013

NPS photo

New Dark Skies Outreach and Education for 2013

Chaco's new dark night sky outreach and education programming enhances the park's existing interpretive programming. This outreach will be implemented in four components over the next year and beyond. Additional programming will be considered if resources are available.

Component I: *The Dark Night Sky* interpretive program

In May 2013, the park began offering a new weekly interpretive program, *The Dark Night Sky*. Developed by a Student Conservation Association (SCA) intern, the program focuses on global light pollution, the importance of the night sky as a natural and cultural resource, and a discussion of steps Chaco is taking to preserve its own dark night skies. In addition, park staff are working with licensed elementary school teachers through the NPS Teacher-Ranger-Teacher program in order to bring this program to nearby schools this fall in a format that meets state education standards.



Component II: Night skies traveling trunk

Chaco is currently working with The Albuquerque Astronomical Society (TAAS) to create a portable educational kit focused on the dark night sky. Since Chaco is remote and does not have a typical gateway community, this will be an efficient way to disseminate information to surrounding communities. The trunk will have multiple components, including an exhibit that can be used for special events, festivals and fairs, and educational gatherings. The kit will contain a facilitator's guide specifically geared toward NPS employees, TAAS members, and teachers. The guide will explain the trunk's various demonstrations and activities which can be used to illustrate the scientific principles and significance of dark nighttime skies. Materials such as the *Earth at Night* maps (NASA 2012), Chaco Culture NHP metrics and graphics (NPS Night Skies Program, 2013), and a simple sky quality meter will be included.

Component III: International Dark Sky Park portable exhibit

Upon its designation as an International Dark Sky Park, Chaco will produce a traveling promotional exhibit featuring the IDA designation, the dark sky qualities of Chaco Canyon, and the public programs available to the visiting public at CCNHP. The exhibit will be primarily promotional and informational and will be loaned to organizations such as community centers, museums, and tourism departments.

Component IV: Annual community star party

In addition to TAAS' standing pledge to help the park conduct the Chaco Canyon Star Party twice each year, this strong park partner has offered to assist Chaco in conducting one additional star party each year at a location of the park's choosing. This level of sup-

port will enable CCNHP to take its night sky preservation messaging and other interpretive programs out into nearby communities that might not otherwise benefit from a visit to Chaco Canyon. This represents an expansion of existing outreach on the part of both Chaco and TAAS, and an increased focus on light pollution awareness and dark sky preservation for both organizations. The programs will typically include a dark sky interpretive program, followed by a guided tour of the night sky with both naked-eye observations and telescope viewing.

Component V: Future outreach goal

Chaco is also very interested in establishing a stronger relationship with the Navajo Technical College in Crownpoint, NM, its closest small town. Park staff are hoping to provide opportunities for students to learn about light pollution, the means of measuring and monitoring natural and anthropogenic light, and the ways in which they can affect and mitigate light pollution in their homes and communities. This represents a potential opportunity to enhance the park's night sky monitoring program while providing opportunities for students to develop technical, science, and conservation skills.



Ranger-led night sky program

NPS photo



Moths and other insects assemble under the Chaco Canyon Visitor Center's bright white lights.

NPS photo

VIII. Chaco Culture NHP Outdoor Lighting Guidelines

Adopted July 2013

Purposes and Goals

These guidelines serve as the foundation for preserving naturally dark sky conditions at Chaco Culture NHP and for mitigating to the extent possible the effects of the park's outdoor artificial lighting on the natural and cultural environment. The guidelines provide a sound basis for decisions about lightscape management, and may serve to guide a future, more-detailed lighting management plan. The National Park Service defines lightscape management as "the effective use of good design to appropriately light areas and minimize or eliminate light clutter, the spill-over of light into areas where light is not wanted, and light pollution, all of which wastes energy and impacts park visitors, neighbors and resources."

The 2007 CCNHP *Foundation for Planning and Management* includes "Archaeoastronomy and the Dark Night Sky" as a Fundamental Resource/Value: "The dark night sky provides visitors with an opportunity to make astronomical observations and experience the same sky the Chacoans observed and incorporated into their landscape, buildings, and culture. Chaco provides habitat for many wildlife species, such as amphibians, mammals, migrating birds, moths, and other insects, and large cats, that depend on dark skies for existence and ecological processes. Increased light pollution not only affects plants and animals and their ecological relationships, but impacts the ability to see celestial bodies while making astronomical observations."

Chaco's outdoor lighting guidelines will help ensure that the location, duration, and intensity of all artificial lighting will be limited to only that which is needed to achieve a basic level of safety, security, and convenience for NPS employees, residents, and visitors. Additionally, Chaco has delineated a *Natural Darkness Zone* within the park, an area that currently does not contain any permanent artificial lighting and will be protected from future lighting development.

CCNHP first formally addressed outdoor lighting management in the 1995 Resource Management Plan with a night sky preservation plan. Park managers displayed early insight to dark sky issues, encouraging the development of a dark sky monitoring program that would be used to influence and improve dark sky preservation both inside and outside the park. To reduce light pollution emanating from within, new light fixtures were installed in the 1990s within the housing, maintenance, and campground areas with the goal of shielding the park's outdoor lighting and reducing operation time with the use of motion sensors. However, since these first significant efforts the park has been inconsistent with its lighting choices and management.

Chaco has committed to reestablish the vision of the 1995 RMP by adopting these Outdoor Lighting Guidelines and by undertaking a series of tangible mitigations to the park's exterior lighting. The principles and prescriptions referenced in these guidelines have helped the park to begin mitigating ineffective lighting treatments identified in the course of the 2013 outdoor lighting inventory. For example, construction began on the new Chaco Canyon Visitor Center in 2009, though lighting selected for the building did not meet IDA standards or other established best practices for outdoor lighting. To mitigate the effects of artificial lighting of the visitor center onto the nearby natural and cultural landscape, a lighting retrofit project is being undertaken [see pages 42-43 of this application for more details]. The need to mitigate new light-

ing fixtures underscores the importance of establishing comprehensive lighting guidelines to avoid similar problems in the future.

Currently, 78% of the park's exterior light fixtures comply with Chaco's new Outdoor Lighting Guidelines. This figure incorporates those lights that have been permanently disabled and are in the process of being removed. All nonconforming lights were addressed individually and were prescribed specific mitigations to bring them into full conformance with both IDA and CCNHP lighting standards [see pages 44-65 of this application]. By the end of next year, the park expects to bring 100% of its outdoor lighting into conformance with these guidelines.

National Park Service Guidance

The National Park Service Night Skies Program has developed draft outdoor lighting guidelines based on the International Engineering Society's Outdoor Lighting Standards (Interim Guidance for Outdoor Lighting in National Parks, 2013). The draft guidelines include extensive information on the reasons for protecting dark night skies, the science of artificial light, human vision, and the role of the National Park Service in providing leadership in lighting science and policy. In addition, the guidelines outline principles for exterior lighting in park settings, as well as mitigation approaches for designing, selecting and operating exterior lighting. A goal of these guidelines is to help park's realize effective lighting solutions while minimizing light pollution. Chaco's outdoor lighting guidelines draw heavily on the NPS guidance.

Outdoor Lighting Principles

The following principles, adapted from the Interim Guidance for Outdoor Lighting in National Parks (2013) and other sources, provide the basic foundation for lightscape management decisions at the Chaco Culture National Historical Park.

- ⇒ *Permanent outdoor lighting should only be installed and operated for specific needs*
The need for illumination must be warranted.
- ⇒ *Delineate areas where no permanent outdoor lighting is allowed*
Parks with sensitive natural resources should designate a natural darkness zone.
- ⇒ *Outdoor environments in parks are not lighted for maximum safety*
Visitors, employees, and residents of national parks assume a certain level of risk.
- ⇒ *Lighting for physical security should be reasonable and practical*
Security lighting should not outweigh resource preservation and visitor enjoyment.
- ⇒ *Lighting industry recommended practices are seldom appropriate for parks*
Industry standards lack the environmental sensitivity required for dark sky parks.
- ⇒ *The darker the environment, the less illumination is necessary*
Reduced (low-level) lighting provides adequate contrast in darker settings.
- ⇒ *Energy efficiency is not enough*
Energy efficiency alone does not make a light fixture appropriate and sustainable.
- ⇒ *Keep lighting impacts on-site*
Lighting should be limited to intended areas and should not be visible elsewhere.

Lighting Management Zones

In accordance with the NPS Interim Guidance on Outdoor Lighting Zones, 4th revision (2013), Chaco has assigned all park areas to one of three designated lighting management zones (see figure 14). Over 99% of the park has been included in the park's Natural Darkness Zone, with the Standard Lighting Zone and Minimal Lighting Zone comprising less than one percent of the park. Zone descriptions and standards follow.

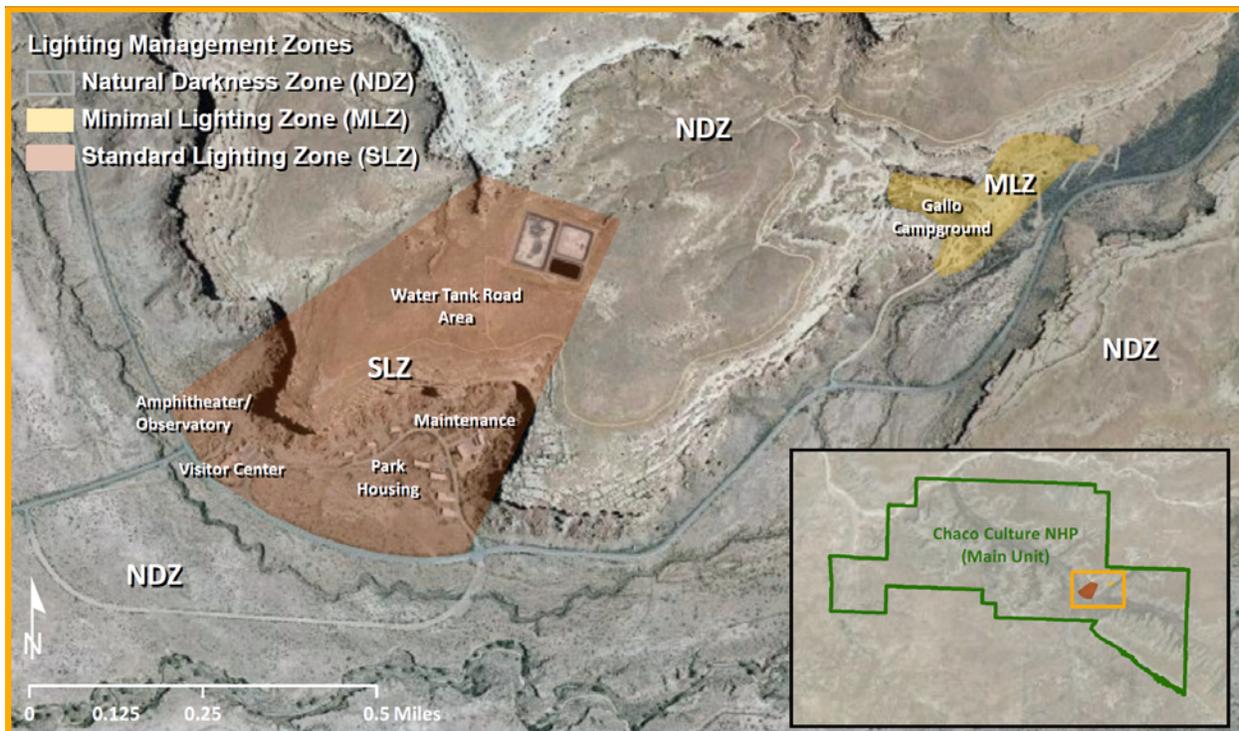


Figure 14: CCNHP Lighting Management Zones (Standard and Minimal Lighting Zone Focus Area)

A. Standard Lighting Zone (SLZ). The Chaco Canyon Visitor Center, amphitheater and observatory, housing area, maintenance yard, and water tank road area are in this zone, which supports the basic operational needs of the park. Some lighting is necessary for orientation, safety, and security but should be restricted both spatially and temporally.

Standards: Permanent exterior fixtures are allowed. Lighting is limited to immediate task areas only, and only a moderate amount of light is expected. No exterior lights are left on all night. Lights on safety and security alarms may be unshielded due to their infrequent, emergency use.

B. Minimal Lighting Zone (MLZ). Gallo Campground is in this zone. Nighttime activities are oriented to a basic level of darkness and there is minimal expectation of night lighting other than essential, isolated spots such as restroom facilities.

Standards: Permanent outdoor lighting is limited in application, such as egress lights on restroom facilities. Interior lighting is controlled to minimize light trespass. Lights on safety and security alarms may be unshielded due to their infrequent, emergency use.

C. **Natural Darkness Zone (NDZ)**. All areas of the park not listed above are in this zone; these include the main park loop drive, backcountry areas, and detached park units. This zone is managed to maintain the naturally dark environment and is generally closed after sunset except for Law Enforcement patrols, special park-led programs, infrequent resource management work, and permitted special uses. There is currently no electrical service in this zone.

Standards: No permanent exterior or interior light fixtures are allowed. Temporary, portable lighting is considered on a case-by-case basis with an emphasis on avoiding, minimizing, and mitigating artificial light use. Vehicle lights are not used for illumination other than what is required for normal vehicle operation. All efforts are made to eliminate light trespass into this zone from other lighting zones within the park or from sources outside the park.

Mitigation Strategies

The following six mitigation strategies provide a basis for limiting the location, timing, duration, spatial extent, color temperature, intensity, and energy consumption of outdoor artificial lighting. These should be utilized in order to minimize the amount of light pollution that the park produces, and to ensure that artificial lighting choices serve their intended purpose.

1. Light only *where* you need it

Fixtures should be placed where light is needed for specific tasks—not away from actual intended activity. Architectural aesthetics, unspecifiable security, or continuity for convenience sake are insufficient reasons to warrant night lighting.

2. Light only *when* you need it

Lights should be controlled with manual switches, or with automated motion sensors or timers. Most light fixtures should have the capacity to be turned off completely (full manual override). A voluntary park-wide lighting curfew (similar to a noise curfew) should be established to minimize the effects of artificial lighting on the nighttime environment.

3. Use *shielded* fixtures and direct them downward

Light fixtures should be full cutoff and shielded to minimize glare and light trespass. Light should not be emitted at the horizontal plane or greater.

4. Select lamps with *warm colors*

Amber bulbs (color temperature $\leq 2500\text{K}$) should be used wherever possible. Full spectrum white lighting (color temperature $\leq 3500\text{K}$) should only be used where color rendition is required. Nighttime lighting should be aesthetically uniform.

5. Use the *minimum amount* of light necessary

Maximum output of individual light fixtures should normally be limited to 1000 lumens. Exceptions for safety, security, operations, or special uses should be based on actual need.

6. Consider *energy efficiency* when selecting lamps and fixtures

The most energy efficient light is *no* light (or a light that is turned off). The standard bulb in simple fixtures will be a low-wattage compact fluorescent (CFL) or light-emitting diode (LED). LED lamps are preferred for energy efficiency, but can be too bright; dimming capabilities should be utilized where possible and appropriate. Incandescent bulbs should only be used in special circumstances.

Lighting Prescriptions

These targeted actions developed for specific locations and situations within the park will guide Chaco in its lighting choices, including new light selection, replacements, and retrofits. [Prescriptions for specific light fixtures can be found in the *Lighting Inventory and Mitigations* section starting on page 44.] For all permanent or temporary exterior lighting, impacts to the natural lightscape should be addressed, with a focus on avoiding, minimizing, and mitigating light pollution. Restrictions on artificial lighting do not apply in emergency situations.

Outdoor Lighting Curfew

- A voluntary park-wide lighting curfew will be established approximately between the hours of 10:00PM and 6:00AM. Continuous use of exterior lights should be avoided during these hours, though limited use of exterior lighting for immediate needs is to be expected. Chaco's lighting curfew is a tangible way for all park visitors, residents, and employees to contribute to the park's night sky preservation goals.
- During the curfew period, all interior lights should either be turned off, or window and door blinds should be closed to prevent light trespass outdoors. All park-owned facilities will be furnished with light-blocking window shades or other coverings that minimize light trespass into the outdoor environment.

Chaco Canyon Visitor Center (Standard Lighting Zone)

- Exterior lighting on the visitor center is oriented primarily toward convenience and security. Convenience lighting will consist of fully-shielded lights located near building entryways. Security lighting is oriented toward illuminating sensitive equipment and areas hidden from view; these spaces include walled-in areas containing the HVAC units, the emergency generator, and electrical panels. Motion sensors will be employed on all permanent exterior lighting.
- No light fixture will remain continuously illuminated throughout the night, including orientation or information lights. Lighting will be limited to immediate tasks only.
- Restroom facilities will be fitted with motion-activated interior lights and light-blocking window coverings to minimize light trespass to the outdoors. Exterior light fixtures will be fitted with motion sensors.

Observatory/Amphitheater (Standard Lighting Zone)

- Because its lighting requirements differ from other facilities, the observatory will be given special consideration. While visitor use is often high in this area, activities are generally darkness-oriented and depend on the ability to transition to night vision. All observatory buildings will be fitted with red-colored, low-wattage bulbs.
- Dedicated pathway lighting may be utilized for evening programs. Ranger-led and other public programs concentrate visitors, which may require additional lighting to ensure safe conditions. Permanent, low-wattage pathway lights will be installed for the new amphitheater and observatory; these will be shielded and manually controlled.
- In conformance with NPS Management Policies 9.3.1.4, any stage lighting in the amphitheater area will be kept to a minimum and carefully directed to either to the presenters, podium, or other necessary locations.

Housing Area (Standard Lighting Zone)

- Except for special needs lighting, light fixtures will be limited to egress points, including exterior doorways and garage doors; exterior lights will be fitted with manual switches.
- Light bulbs will be standardized. The standard bulb will be a low-wattage amber-colored CFL, LED, or equivalent. Maximum output will be 1000 lumens.
- To preserve the park's natural lightscape, all permanent and temporary housing residents will be encouraged to limit their use of artificial exterior lighting after nightfall and adhere to Chaco's park-wide lighting curfew (from approximately 10:00PM to 6:00AM).
- The park will provide light-blocking window shades or other coverings that minimize light trespass from interior sources into the outdoors. Privately-owned RVs will provide their own window shades when stationed in the housing area.
- Campfires (including social and cooking fires) are not considered artificial lighting.

Maintenance Area (Standard Lighting Zone)

- Security and safety alarms may have unshielded lights due to their infrequent, emergency use and need to be seen from distances; light output may exceed other standards.
- Frequently-used permanent buildings (e.g., curation facility, maintenance offices, workshops, wood shed, well house) should have fully-shielded motion-activated convenience lights at primary exterior doorways. All light fixtures will have full manual override.
- Fixtures will be added, removed, or relocated as needed to reflect actual needs and uses.
- Portable high-intensity lighting can be used as needed for immediate work tasks.

Water Tank Road Area (Standard Lighting Zone)

- Currently, no permanent exterior lighting is installed in this area. New lighting will be considered on a case-by-case basis as the need to access this area after dark is rare.
- Minimal temporary lighting may be utilized as needed for specific after-hours park operations; use of lights in this high elevation area should be limited due its high visibility.

Gallo Campground (Minimal Lighting Zone)

- Restroom facilities are currently the only permanent buildings in Gallo Campground. Fully-shielded, motion-activated, amber-colored, low-level lighting (1000 lumens maximum) should be provided at each bathroom doorway.
- Campers will be encouraged to manage their use of artificial light in concert with the voluntary park-wide lighting curfew which will be in effect approximately between the hours of 10:00PM and 6:00AM (ideally mirroring quiet hours). The park will discourage the use of bright lanterns and exterior lights on campers, trailers and RVs during this period. Campers will be reminded to turn down interior lights or close window and door shades during these hours to minimize light trespass into the outdoor environment. Personal light sources such as flashlights and headlamps are appropriate at any time, though park staff or volunteers may ask visitors to limit their use during programs.
- If desired, the on-duty campground host may utilize a shielded amber exterior light no greater than 1000 lumens between nightfall and curfew to provide visitor orientation.
- Campers will be informed of the expectation of darkness in the campground and will be encouraged to limit their use of artificial lights in order to reduce their visual footprint. This will not only promote a naturally dark sky for other campers, but will also help to minimize the effect of artificial lighting on park wildlife.

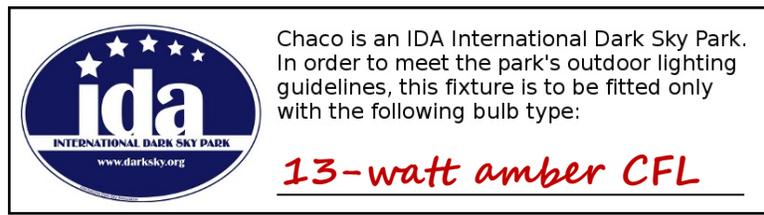
- Campfires are not considered artificial lighting and are not covered in these guidelines.

Loop Road, Backcountry Areas, and Detached Units (Natural Darkness Zone)

- No permanent lighting is allowed in this zone. This zone currently does not have electrical service, and the park does not plan to introduce electrical service in the future.
- Use of portable artificial lights will be considered on a case-by-case basis. For all proposed lighting, effects on natural darkness will be considered. The preference will first be to avoid, then minimize, then mitigate effects on the natural lightscape.
- Activities that may require temporary lighting include interpretive programs, special park uses, facilities maintenance, research, resource management, search and rescue, and law enforcement activities.

Lighting Replacement and Maintenance

- Bulbs and fixtures will be replaced as needed in accordance with these guidelines.
- To the extent possible, bulbs will be standardized to ensure appropriate light intensity, color, quality, visual uniformity, and ease of replacement.
- Unnecessary light fixtures will be either removed or relocated.
- Except for lights that are part of an emergency alarm system, all exterior lights will be controlled by manual switches, timers, or motion sensors.
- A label specifying the appropriate replacement bulb will be affixed to exterior lights.



Employee and Visitor Education

- Through its website, information kiosks, and other sources, the park will inform visitors of the expectation of natural darkness and the need to provide personal lighting (e.g., flashlights) after dark. Park staff will provide information on Chaco’s park-wide lighting curfew, including etiquette for use of bright lanterns and other exterior lighting, as well as the benefits of controlling light trespass from interior sources (i.e., from RVs, camping trailers, or similar structures).
- Visitors to the observatory will be instructed on the use of red lamps during astronomy programs to facilitate the transition to scotopic (night) vision. Due to the close proximity of the parking lot to the observatory and telescope viewing area, visitors will also be reminded of the impacts that vehicle headlights have on the park’s Night Sky program activities.
- Through a variety of methods, park employees, residents, and visitors will be reminded that many people come to Chaco to experience its dark night sky, and that unnecessary nighttime lighting can negatively affect their experience. The importance of protecting park wildlife from the effects of light pollution and the preservation of natural ecological processes will also be part of Chaco’s night sky preservation education messaging.

IX. CCNHP Lighting Inventory & Mitigations

July 2013

(Pages 34-65)

Chaco Culture National Historical Park

Outdoor Lighting Inventory

July 2013

Facilities Overview: Visitor Center, Observatory and Campground Areas



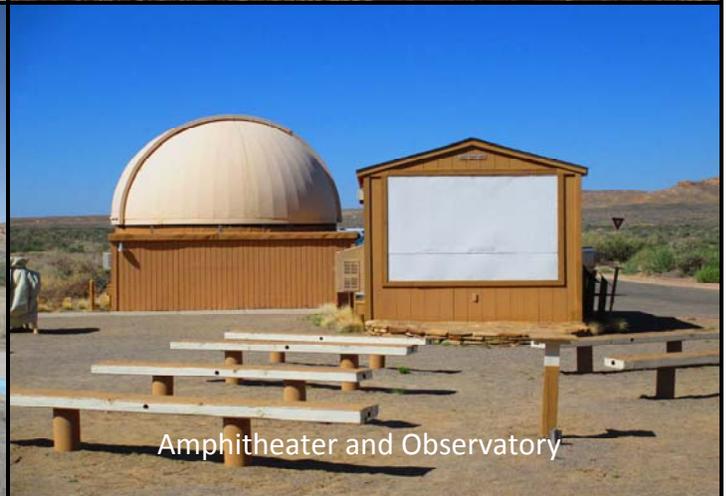
Visitor Center, Front Side (East)



Visitor Center, Rear Side (West)



Visitor Center Restrooms



Amphitheater and Observatory



Campground Restrooms, East



Campground Restrooms, West

Chaco Culture National Historical Park

Outdoor Lighting Inventory

July 2013

Facilities Overview: Maintenance and Housing Area



The Yurt



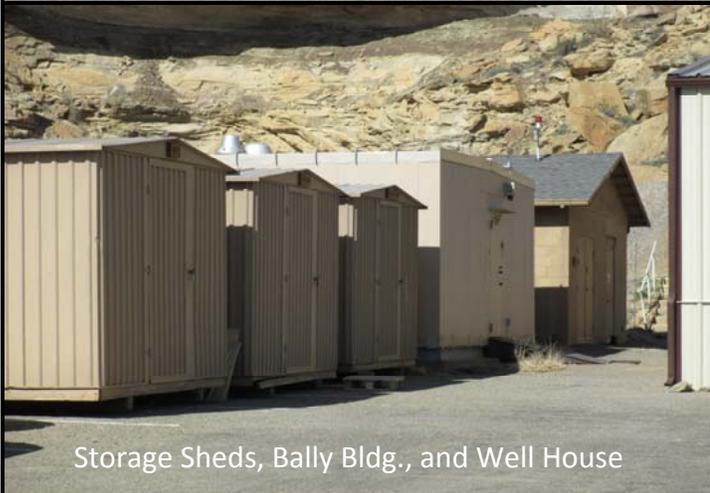
Volunteer Campground: Showers and Kitchen



Curation Facility and Maintenance Offices



Maintenance Shops



Storage Sheds, Bally Bldg., and Well House



Upper Sewage Lift Station

Chaco Culture National Historical Park

Outdoor Lighting Inventory

July 2013

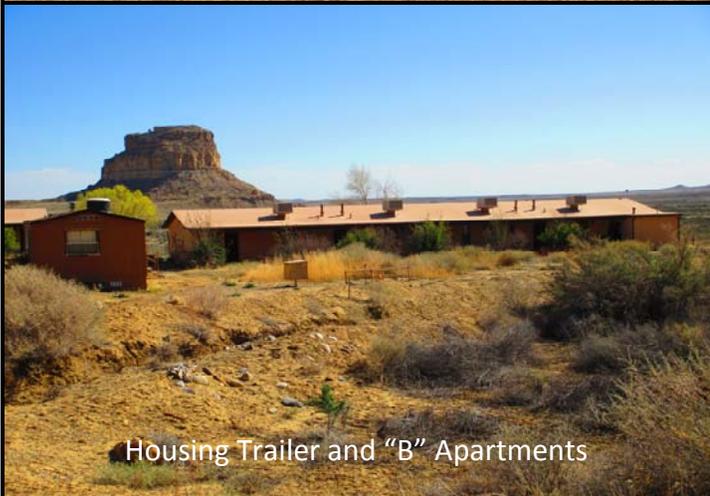
Facilities Overview: Maintenance and Housing Area



Residence 7



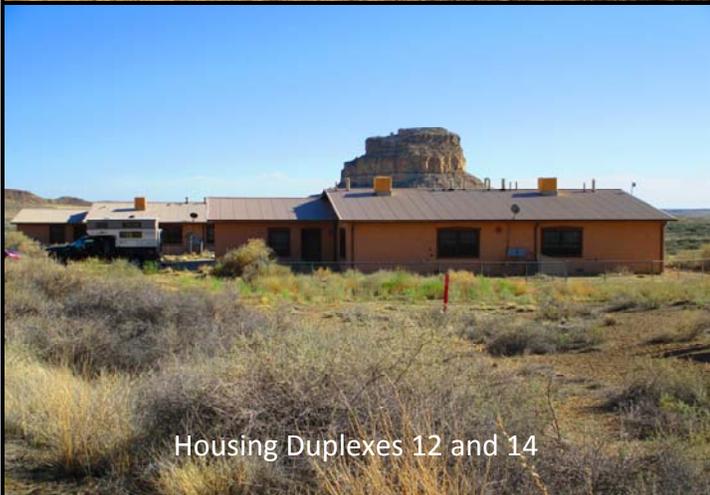
Residence 11



Housing Trailer and "B" Apartments



"A" Apartments



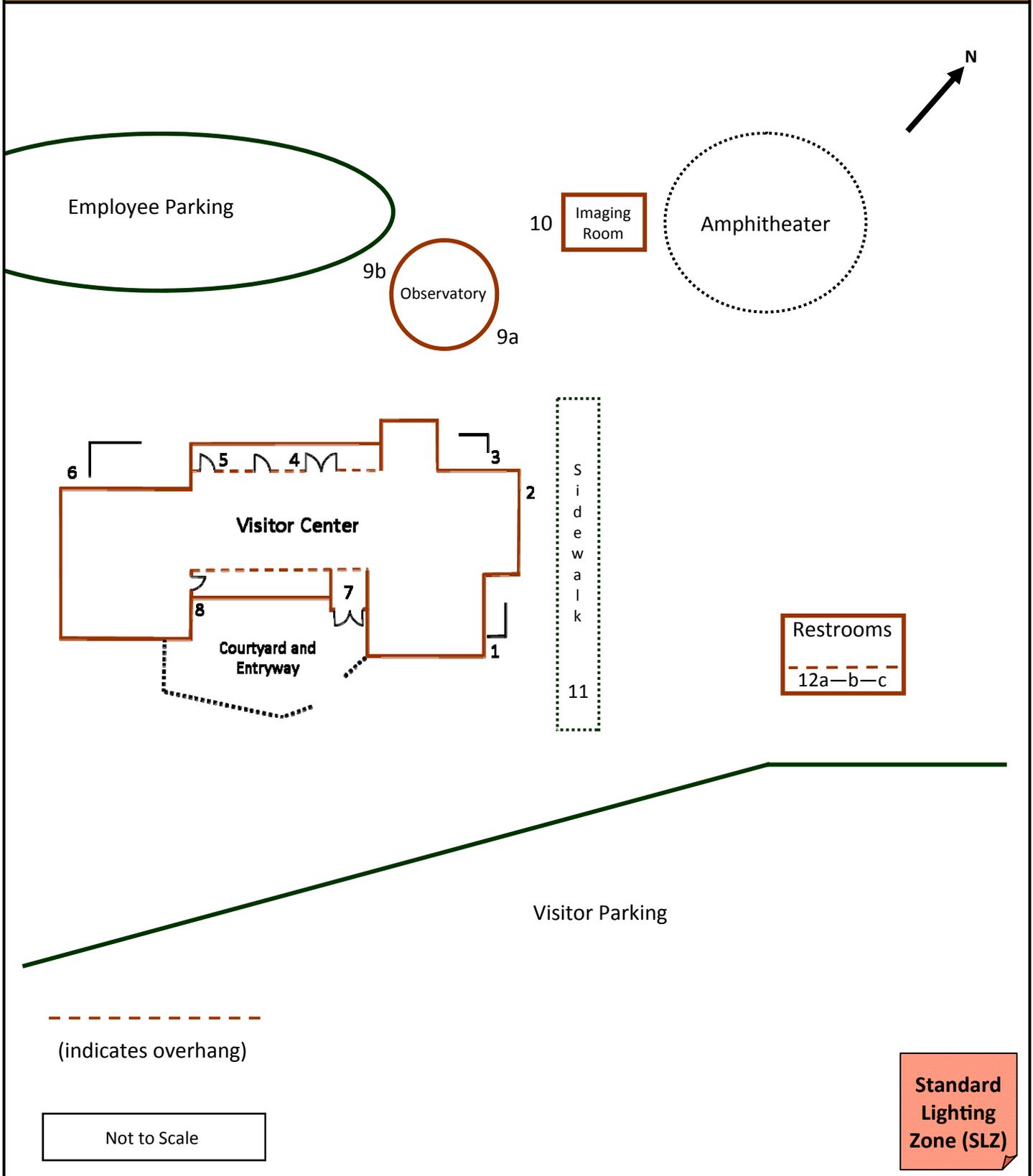
Housing Duplexes 12 and 14



Residences 10 and 6

Chaco Culture National Historical Park

Visitor Center and Observatory Area Map

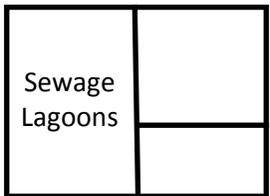


Chaco Culture National Historical Park

Water Tank Area Map



Utility Building



Sewage Lagoons

Weather Station



Water Tank



To Main Park Road



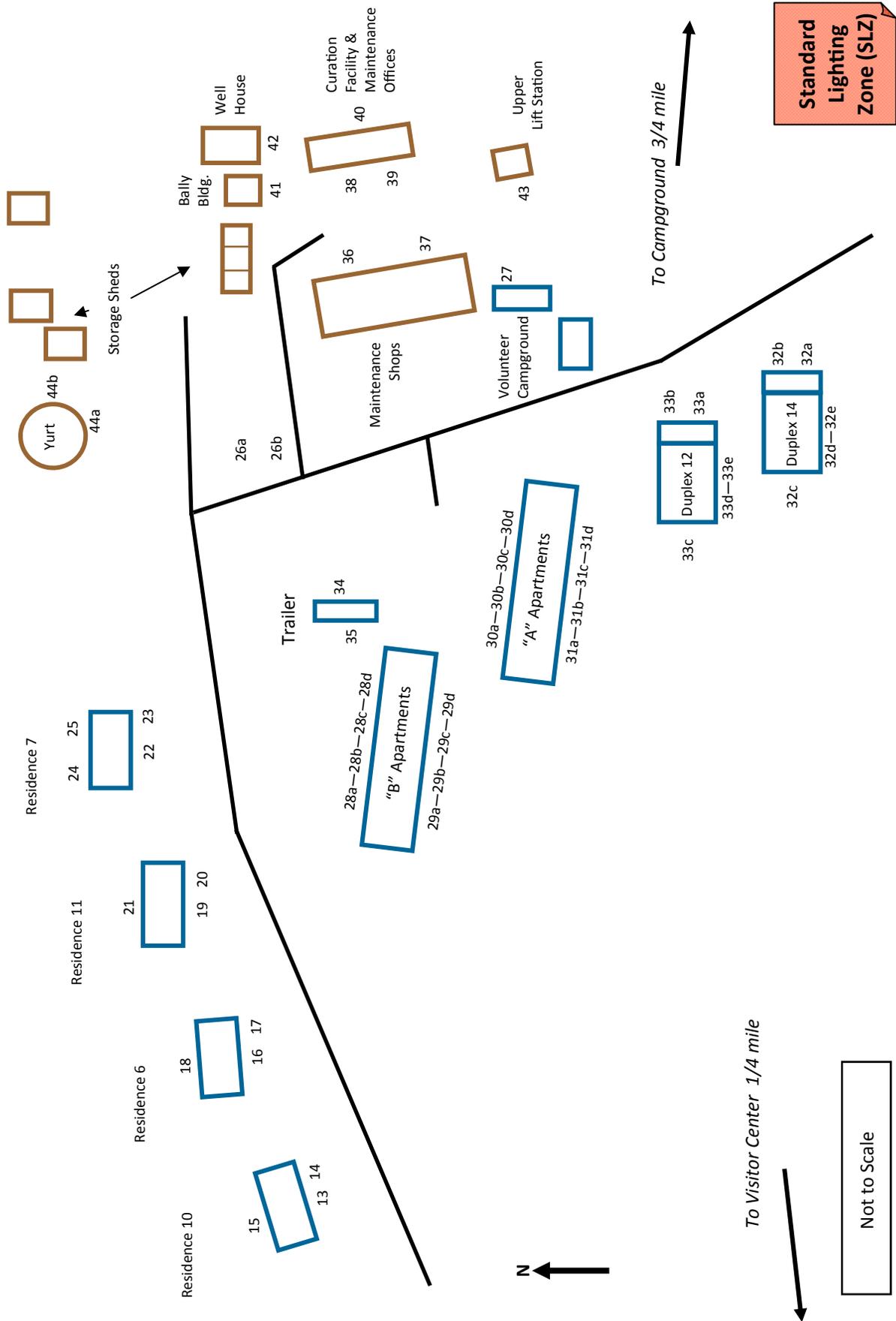
Not to Scale

Note: There are no permanently installed outdoor lighting fixtures in this area. These facilities are not included in the outdoor lighting inventory.

Standard Lighting Zone (SLZ)

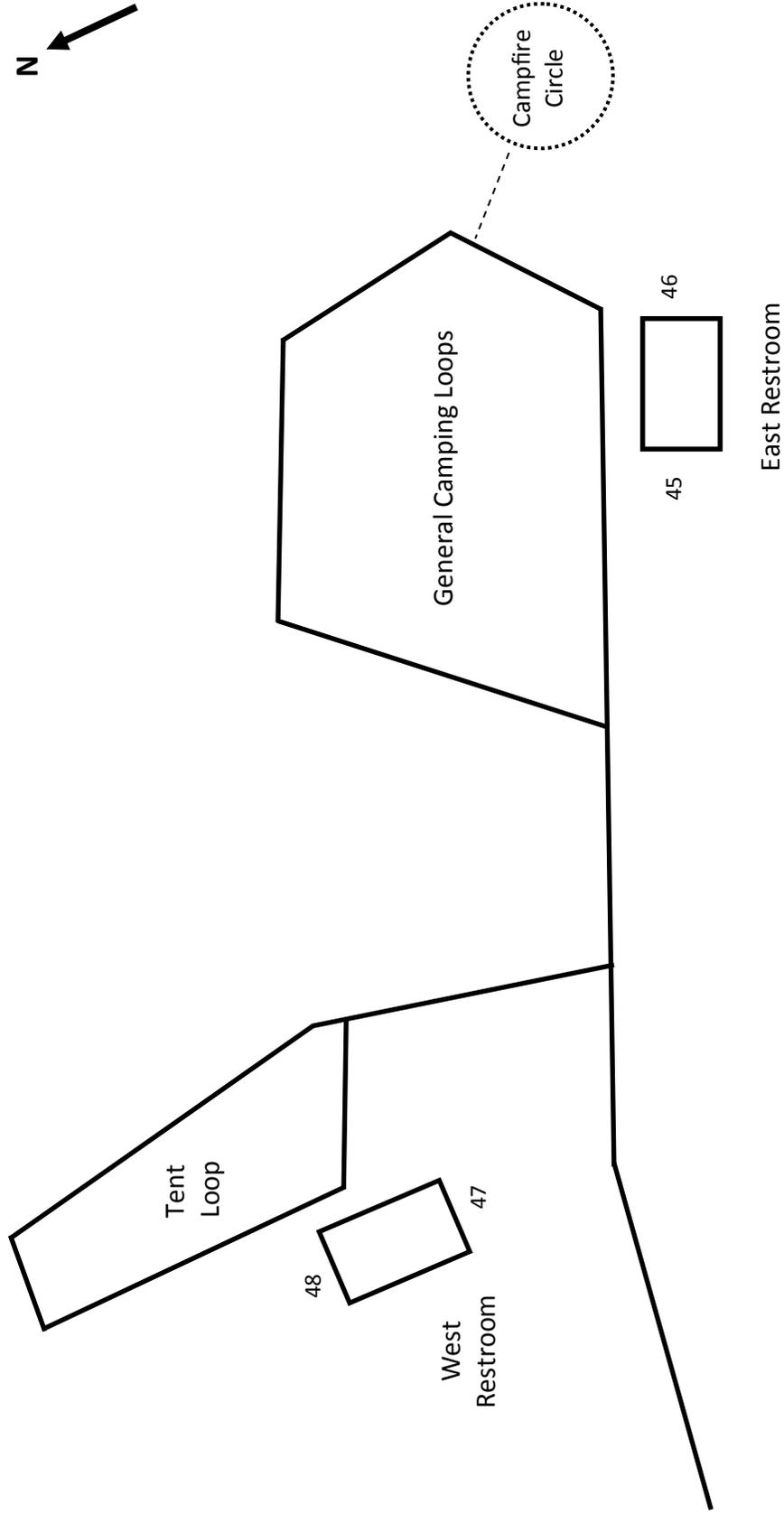
Chaco Culture National Historical Park

Housing and Maintenance Area Map



Chaco Culture National Historical Park

Gallo Campground Map



To Visitor Center, Housing Area and Maintenance Area

Not to Scale

Minimal
Lighting
Zone (MLZ)

Special Demonstration Project: Visitor Center Lighting Retrofit

The new Chaco Canyon Visitor Center, the park's main visitor contact hub by day, is also the park's single most problematic structure in terms of its production of nighttime light pollution. The visitor center is located adjacent to the main park road within direct sight of the park housing area, and has become an unnecessary beacon throughout the night for visitors and park residents alike. In an otherwise dark setting, the visitor center also has a significant effect on area wildlife; its continuously operating bright white lights serve as an attractant to both flying and crawling insects, as well as a host of other wildlife species that feed upon them, disrupting natural ecological patterns and cycles.

The nighttime illumination of the visitor center violates many of the park's central outdoor lighting principles regarding the location, intensity, color, timing, duration, and shielding of light fixtures. This project aims to reduce the adverse effects of inappropriate exterior light fixtures, while simultaneously improving the overall functionality and aesthetics of exterior lighting in concert with the park's *Outdoor Lighting Guidelines*.



NPS photo

Photo of existing visitor center lighting taken from map location A

For this project, the following mitigation approaches are being implemented:

- Removal of unnecessary lights and addition of fixtures where the need exists;
- Replacement of existing luminaires with fully-shielded light fixtures;
- Selection of lamp output, color, and type to conform with park lighting guidelines;
- Addition of motion sensors to improve usefulness and limit lighting duration;
- Addition of manual switches to control of the timing and duration of lighting;
- Improvement of lighting uniformity and aesthetics; and
- Addition of indoor motion sensors and wall sconce shielding (not depicted) to reduce trespass of interior lighting into the outdoor environment.

Thanks to a generous grant from the Friends of Chaco, this project is currently in progress and on schedule for completion by September 30, 2013. The problem of the park's existing visitor center lighting has already been incorporated into Chaco's existing Night Sky programming as an example of the adverse effects of inappropriate lighting choices. As the restoration project comes to completion, the park will further interpret the specific improvements made to the park environment through this project. "Before" photos and light level measurements were collected on June 2, 2013, prior to the project start date; "after" measurements will be taken once the retrofit is completed. A poster demonstrating the visitor center retrofit will be created for display in the visitor center lobby during the October 4-5, 2013 Chaco Canyon Star Party, at which the park hopes also to publicly celebrate its IDA International Dark Sky Park designation.

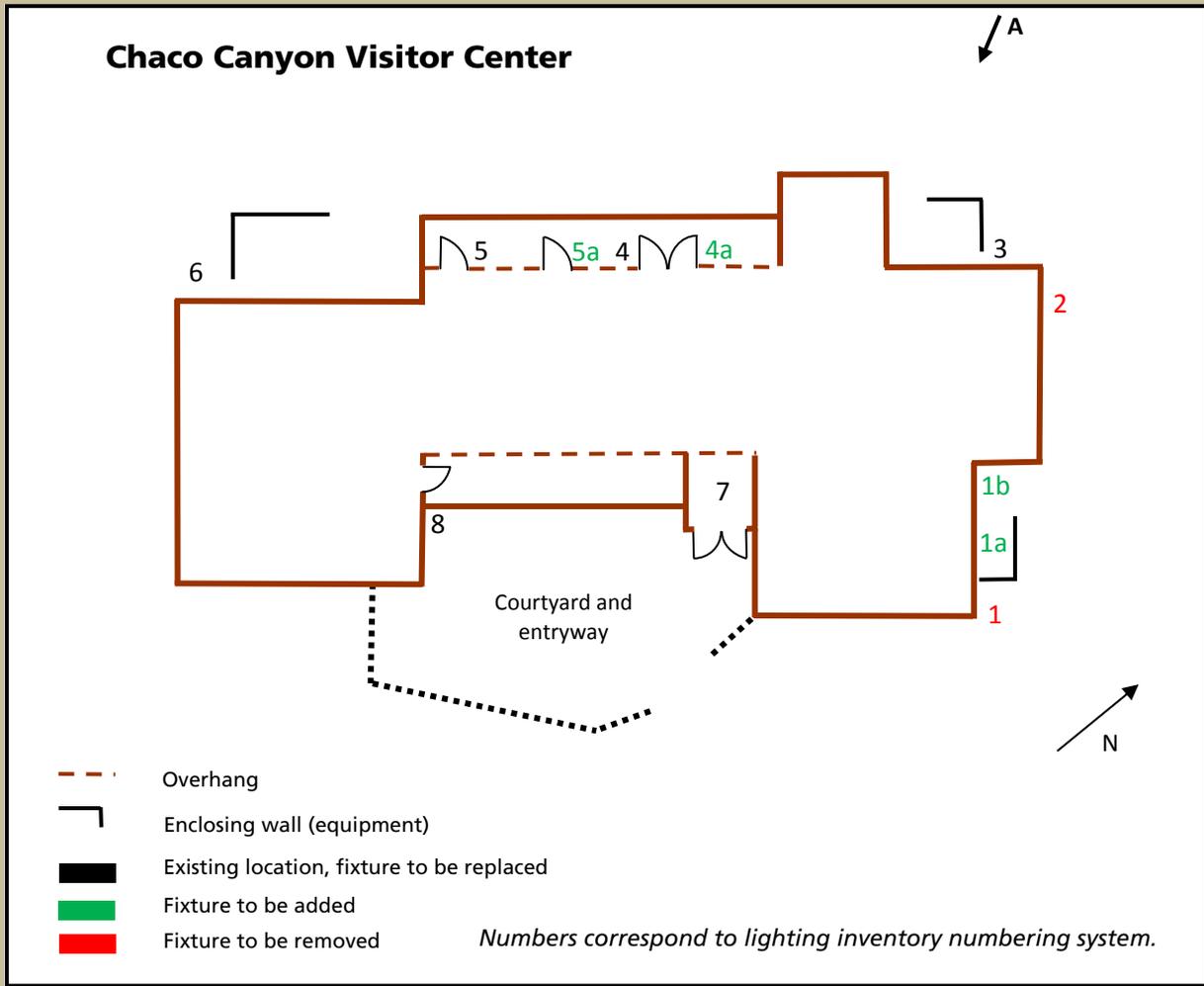


Figure 15: Map of Chaco Canyon Visitor Center exterior lighting retrofit.

Fixture	Fixture Status	Switch Type	Purpose	Fixture type
1	remove	x	x	x
1a	add	motion sensor	security	shielded flood
1b	add	motion sensor	convenience	canister
2	remove	x	x	x
3	replace	motion sensor	security	shielded flood
4	replace	motion sensor	convenience	canister
4a	add	motion sensor	convenience	canister
5	replace	motion sensor	convenience	canister
5a	add	manual switch	convenience	shielded flood
6	replace	motion sensor	security	shielded flood
7	replace	manual switch	convenience	ceiling
8	replace	motion sensor	convenience	canister

Figure 16: Fixture prescriptions for Chaco Canyon Visitor Center exterior lighting retrofit.

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Location	Fixture Number ¹	Photograph	Description/Function	Specifications/ Technical Information
Visitor Center Area	1		Visitor Center, NE corner. Partial cut-off shield. Photocell sensor & motion activated.	Lithonia Lighting OWL14. 1,400 Lumen LED, 5700k.
	2		Visitor Center, north-center wall. Partial cut-off shield. Photocell sensor & motion activated.	Lithonia Lighting OWL14. 1,400 Lumen LED, 5700k.
	3		Visitor Center, NW corner. Partial cut-off shield. Photocell sensor & motion activated.	Lithonia Lighting OWL14. 1,400 Lumen LED, 5700k.
	4		Visitor Center, west wall. Partial cut-off shield. Photocell sensor activated. Under 6' overhang.	Lithonia Lighting OWL14. 1,400 Lumen LED, 5700k.
	5		Visitor Center, west wall. Partial cut-off shield. Photocell sensor activated. Under 6' overhang.	Lithonia Lighting OWL14. 1,400 Lumen LED, 5700k.
	6		Visitor Center, SW corner. Partial cut-off shield. Photocell sensor activated.	Lithonia Lighting OWL14. 1,400 Lumen LED, 5700k.

¹ See inventory map for fixture location (pp. 38-42)

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Fixture Conforms with Lighting Guidelines?	Mitigation Strategies ²	Mitigations/Prescriptions	<i>Outdoor Lighting Inventory & Mitigations</i>
NO Fixture too bright, too white, improperly shielded, and does not illuminate intended area.	1,3,4,5	Fixture will be removed completely. A new motion-activated security fixture will be added nearby to the electrical panel/exit doors area.	
NO Fixture too bright, too white, improperly shielded, and purpose not warranted.	1,3,4,5	Fixture will be removed completely. The location only serves to illuminate a portion of pathway, but the area does not warrant a need for such convenience lighting.	
NO Fixture too bright, too white, improperly shielded, and motion sensor faces wrong direction.	1,3,4,5	Fixture will be changed to ensure intended security purpose, adequate shielding, and the motion sensor will be directed to reflect actual area of activity.	
NO Fixture too bright, too white, improperly shielded, and constantly illuminated at night.	2,3,4,5	To be replaced with two fully-shielded, motion-activated canister fixtures on either side of main rear entry doors; will be fitted with amber CFL or LED bulbs < 1000 lumens. Full manual override switch for main exterior lights.	
NO Fixture too bright, too white, improperly shielded, and constantly illuminated at night.	2,3,4,5	To be replaced with a fully-shielded, motion-activated canister fixture fitted with amber CFL or LED bulb < 1000 lumens. Full manual override switch for main exterior lights.	
NO Fixture too bright, too white, improperly shielded, and motion sensor faces wrong direction.	1,3,4,5	Fixture will be changed to ensure intended security purpose, adequate shielding, and the motion sensor will be directed to reflect actual area of activity.	

² See Outdoor Lighting Guidelines, p. 30

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Location	Fixture Number ¹	Photograph	Description/Function	Specifications/ Technical Information
Visitor Center Area	7		Visitor Center, front entry (east side). Overhead. Deeply recessed into ceiling. Photocell sensor activated.	White light > 1000 Lumens
	8		Visitor Center, front courtyard service door. Partial cut-off shield. Photocell sensor activated.	Lithonia Lighting OWL14. 1,400 Lumen LED, 5700k.
	9a		Observatory, NE corner. Manually controlled from interior. Used during astronomy programs.	Red 40w incandescent, mostly shielded.
	9b		Observatory, SW corner. Manually controlled from interior. Used during astronomy programs.	Red 40w incandescent, mostly shielded.
	10		Observatory, above walk-in door. Manually controlled from interior. Used during astronomy programs.	Red 40w incandescent, mostly shielded. Bulb currently broken.
	11		Walkway between Visitor Center and Amphitheater/Observatory. Photocell sensor activated. Six (6) lights total.	Low voltage solar lights, Dusk to dawn.

¹ See inventory map for fixture location (pp. 38-42)

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Fixture Conforms with Lighting Guidelines?	Mitigation Strategies ²	Mitigations/Prescriptions	<i>Outdoor Lighting Inventory & Mitigations</i>
NO Fixture too bright, too white, improperly shielded, and constantly illuminated at night.	2,3,4,5,6	Will be replaced with fully shielded, manually controlled fixture with an amber CFL or LED bulb. Full manual override switch for main exterior lights.	
NO Fixture too bright, too white, improperly shielded, and constantly illuminated at night.	2,3,4,5	Will be replaced with fully shielded, motion-activated canister fixture with an amber CFL or LED bulb < 1000 lumens. Full manual override switch for main exterior lights.	
YES	NONE	Bulb to be replaced with red low-output bulb only.	
YES	NONE	Bulb to be replaced with red low-output bulb only.	
YES	4,5	Bulb to be replaced with red low-output bulb only.	
YES	2,3	To be replaced with permanent manually controlled, fully shielded low-output pathway or bollard lighting.	

² See Outdoor Lighting Guidelines, p. 30

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Location	Fixture Number ¹	Photograph	Description/Function	Specifications/ Technical Information
Visitor Center Area	12a		Visitor Center restroom, entryway ceiling. Manually controlled from rear service closet. Paired with heater on circuit.	50w incandescent flood
	12b		Visitor Center restroom, entryway ceiling. Manually controlled from rear service closet. Paired with heater on circuit.	50w incandescent flood
	12c		Visitor Center restroom, entryway ceiling. Manually controlled from rear service closet. Paired with heater on circuit.	50w incandescent flood
Housing Area	13		Residence 10, front entry. Fully-shielded canister. Manually controlled from interior.	13w fluorescent
	14		Residence 10, above garage door. Fully-shielded canister. Manually controlled from interior.	40w incandescent
	15		Residence 10, rear door. Fully-shielded canister. Manually controlled from interior.	13w fluorescent

¹ See inventory map for fixture location (pp. 38-42)

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Fixture Conforms with Lighting Guidelines?	Mitigation Strategies ²	Mitigations/Prescriptions	<i>Outdoor Lighting Inventory & Mitigations</i>
YES	2,6	Bulb to be replaced with CFL or LED recessed lamp. Electrical circuit will be fixed to include exterior lights only to ensure manual override. Motion sensor will be added to circuit.	
YES	2,6	Bulb to be replaced with CFL or LED recessed lamp. Electrical circuit will be fixed to include exterior lights only to ensure manual override. Motion sensor will be added to circuit.	
YES	2,6	Bulb to be replaced with CFL or LED recessed lamp. Electrical circuit will be fixed to include exterior lights only to ensure manual override. Motion sensor will be added to circuit.	
YES	4	Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	6	Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	4	Replacement bulb standard: amber CFL or LED < 1000 lumens.	

² See Outdoor Lighting Guidelines, p. 30

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Location	Fixture Number ¹	Photograph	Description/Function	Specifications/ Technical Information
Housing Area	16		Residence 6, front entry. Fully-shielded canister. Manually controlled from interior.	13w amber fluorescent
	17		Residence 6, above garage. Fully-shielded canister. Manually controlled from interior.	13w fluorescent
	18		Residence 6, rear door. Fully-shielded canister. Manually controlled from interior.	13w fluorescent
	19		Residence 11, front entry. Fully-shielded canister. Manually controlled from interior.	40w incandescent
	20		Residence 11, above garage. Fully-shielded canister. Manually controlled from interior.	13w fluorescent
	21		Residence 11, rear door. Fully-shielded canister. Manually controlled from interior.	13w fluorescent

¹ See inventory map for fixture location (pp. 38-42)

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Fixture Conforms with Lighting Guidelines?	Mitigation Strategies ²	Mitigations/Prescriptions	<i>Outdoor Lighting Inventory & Mitigations</i>
YES	NONE	Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	4	Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	4	Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	6	Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	4	Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	4	Replacement bulb standard: amber CFL or LED < 1000 lumens.	

² See Outdoor Lighting Guidelines, p. 30

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Location	Fixture Number ¹	Photograph	Description/Function	Specifications/ Technical Information
Housing Area	22		Residence 7, front entry. Fully-shielded canister. Manually controlled from interior.	13w fluorescent
	23		Residence 7, above garage. Fully-shielded canister. Manually controlled from interior.	13w fluorescent
	24		Residence 7, rear. Fully-shielded canister. Manually controlled from interior.	13w fluorescent
	25		Residence 7, rear door. Fully-shielded canister. Manually controlled from interior.	13w fluorescent
	26a		Old volleyball court near maintenance yard. Partially shielded. Manually controlled. Not used for 3+ years.	150w mercury vapor. No longer operational.
	26b		Old volleyball court near maintenance yard. Partially shielded. Manually controlled. Not used for 3+ years.	150w mercury vapor. No longer operational.

¹ See inventory map for fixture location (pp. 38-42)

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Fixture Conforms with Lighting Guidelines?	Mitigation Strategies ²	Mitigations/Prescriptions	<i>Outdoor Lighting Inventory & Mitigations</i>
YES	4	Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	4	Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	4	Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	4	Replacement bulb standard: amber CFL or LED < 1000 lumens.	
N/A	N/A	Will be completely removed due to lack of use and non-conformance with guidelines.	
N/A	N/A	Will be completely removed due to lack of use and non-conformance with guidelines.	

² See Outdoor Lighting Guidelines, p. 30

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Location	Fixture Number ¹	Photograph	Description/Function	Specifications/ Technical Information
Housing Area	27		Volunteer Campground shower building. Fully enclosed and shielded. Photocell sensor & motion controlled.	25w incandescent
	Apts. "A" & "B"		"A" and "B" Apartments, portico ceiling. Beneath overhang. Eight (8) fixtures total.	Note: Fixtures have been permanently disabled. No longer functional.
	28a		Apartment B-1, front entry. Fully-shielded canister. Manually controlled from interior.	13w fluorescent
	28b		Apartment B-2, front entry. Fully-shielded canister. Manually controlled from interior.	13w fluorescent
	28c		Apartment B-3, front entry. Fully-shielded canister. Manually controlled from interior.	low wattage amber
	28d		Apartment B-4, front entry. Fully-shielded canister. Manually controlled from interior.	13w fluorescent

¹ See inventory map for fixture location (pp. 38-42)

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Fixture Conforms with Lighting Guidelines?	Mitigation Strategies ²	Mitigations/Prescriptions	<i>Outdoor Lighting Inventory & Mitigations</i>
YES	6	Replacement bulb standard: amber CFL or LED < 1000 lumens.	
N/A	N/A	Fixtures replaced with shielded canisters in 1990s; disabled but not yet removed. Will remove completely due to lack of use and non-conformance with guidelines.	
YES	4	Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	4	Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	6	Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	4	Replacement bulb standard: amber CFL or LED < 1000 lumens.	

² See Outdoor Lighting Guidelines, p. 30

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Location	Fixture Number ¹	Photograph	Description/Function	Specifications/ Technical Information
Housing Area	29a 29b 29c 29d		"B" Apartments, rear porches. Manually controlled from interior. Beneath overhang. Four (4) fixtures total.	40w incandescent
	30a		Apartment A-1, front entry. Fully-shielded canister. Manually controlled from interior.	13w fluorescent
	30b		Apartment A-2, front entry. Fully-shielded canister. Manually controlled from interior.	13w fluorescent
	30c		Apartment A-3, front entry. Fully-shielded canister. Manually controlled from interior.	13w amber fluorescent
	30d		Apartment A-4, front entry. Fully-shielded canister. Manually controlled from interior.	13w fluorescent
	31a 31b 31c 31d		"A" Apartments, rear porches. Manually controlled from interior. Beneath overhang. Four (4) fixtures total.	40w incandescent

¹ See inventory map for fixture location (pp. 38-42)

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Fixture Conforms with Lighting Guidelines?	Mitigation Strategies ²	Mitigations/Prescriptions	<i>Outdoor Lighting Inventory & Mitigations</i>
<p style="text-align: center;">NO (x4) Not properly shielded.</p>	3,6	<p>To be replaced with shielded ceiling fixtures. Replacement bulb standard: amber CFL or LED < 1000 lumens.</p>	
YES	4	<p>Replacement bulb standard: amber CFL or LED < 1000 lumens.</p>	
YES	4	<p>Replacement bulb standard: amber CFL or LED < 1000 lumens.</p>	
YES	NONE	<p>Replacement bulb standard: amber CFL or LED < 1000 lumens.</p>	
YES	4	<p>Replacement bulb standard: amber CFL or LED < 1000 lumens.</p>	
<p style="text-align: center;">NO (x4) Not properly shielded.</p>	3,6	<p>To be replaced with shielded ceiling fixtures. Replacement bulb standard: amber CFL or LED < 1000 lumens.</p>	

² See Outdoor Lighting Guidelines, p. 30

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Location	Fixture Number ¹	Photograph	Description/Function	Specifications/ Technical Information
Housing Area	32a		Duplex 14, above "A" unit garage door. Fully-shielded ceramic sconce. Manually controlled from interior.	60w incandescent
	32b		Duplex 14, above "B" unit garage door. Fully-shielded ceramic sconce. Manually controlled from interior.	Currently unused (no bulb)
	32c		Duplex 14, side door entry. Fully-shielded ceramic sconce. Manually controlled from interior.	13w fluorescent
	32d		Duplex 14, "A" unit front entry. Fully-shielded ceramic sconce. Manually controlled from interior.	13w fluorescent
	32e		Duplex 14, "B" unit front entry. Fully-shielded ceramic sconce. Manually controlled from interior.	13w fluorescent
	33a		Duplex 12, above "A" unit garage door. Fully-shielded ceramic sconce. Manually controlled from interior.	40w incandescent

¹ See inventory map for fixture location (pp. 38-42)

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

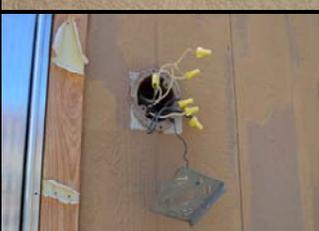
Fixture Conforms with Lighting Guidelines?	Mitigation Strategies ²	Mitigations/Prescriptions	<i>Outdoor Lighting Inventory & Mitigations</i>
YES	6	Ceramic sconce will be painted to reduce glow. Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	4,6	Ceramic sconce will be painted to reduce glow. Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	4	Ceramic sconce will be painted to reduce glow. Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	4	Ceramic sconce will be painted to reduce glow. Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	4	Ceramic sconce will be painted to reduce glow. Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	6	Ceramic sconce will be painted to reduce glow. Replacement bulb standard: amber CFL or LED < 1000 lumens.	

² See Outdoor Lighting Guidelines, p. 30

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Location	Fixture Number ¹	Photograph	Description/Function	Specifications/ Technical Information
Housing Area	33b		Duplex 12, above "B" unit garage door. Fully-shielded ceramic sconce. Manually controlled from interior.	13w fluorescent
	33c		Duplex 12, side door entry. Fully-shielded ceramic sconce. Manually controlled from interior.	13w fluorescent
	33d		Duplex 12, "A" unit front entry. Fully-shielded ceramic sconce. Manually controlled from interior.	13w fluorescent
	33e		Duplex 12, "B" unit front entry. Fully-shielded ceramic sconce. Manually controlled from interior.	13w fluorescent
	34		Residential trailer, front entry. Canister light (fully-shielded) to be repaired. Manually controlled from interior.	No fixture/bulb
	35		Residential trailer, rear entry. Fully-shielded canister. Manually controlled from interior.	13w fluorescent

¹ See inventory map for fixture location (pp. 38-42)

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Fixture Conforms with Lighting Guidelines?	Mitigation Strategies ²	Mitigations/Prescriptions	<i>Outdoor Lighting Inventory & Mitigations</i>
YES	4	Ceramic sconce will be painted to reduce glow. Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	4	Ceramic sconce will be painted to reduce glow. Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	4	Ceramic sconce will be painted to reduce glow. Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	4	Ceramic sconce will be painted to reduce glow. Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	4,6	Damaged canister light to be repaired. Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	4	Replacement bulb standard: amber CFL or LED < 1000 lumens.	

² See Outdoor Lighting Guidelines, p. 30

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Location	Fixture Number ¹	Photograph	Description/Function	Specifications/ Technical Information
Maintenance Area	36 37		Maintenance shops, above garage bay doors. Manually controlled from interior. Two (2) fixtures total.	Incandescent, unknown wattage
	38		Curation facility entry. Photocell sensor & motion controlled. Manual override from interior.	60w incandescent
	39		Maintenance offices, front entry. Photocell sensor & motion controlled. Manual override from interior.	60w incandescent
	40		Maintenance offices, rear entry. Photocell sensor & motion controlled. Manual override from interior.	60w incandescent
	41		Resources lab (Bally Building), front side above door. Security alarm light.	Low wattage red. Seldom in use.
	42		Well House, above roof. Safety alarm light.	Red revolving alarm light. Seldom in use.

¹ See inventory map for fixture location (pp. 38-42)

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Fixture Conforms with Lighting Guidelines?	Mitigation Strategies ²	Mitigations/Prescriptions	<i>Outdoor Lighting Inventory & Mitigations</i>
YES (x2)	5,6	Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	6	Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	6	Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	6	Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	NONE	No change required: Emergency alarm lights are lighting guidelines exceptions.	
YES	NONE	No change required: Emergency alarm lights are lighting guidelines exceptions.	

² See Outdoor Lighting Guidelines, p. 30

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Location	Fixture Number ¹	Photograph	Description/Function	Specifications/ Technical Information
Maintenance Area	43		Upper sewage lift station, above retaining wall. Safety warning light.	Low wattage red light. Seldom in use.
	44a 44b		Yurt, at front and side entries. Manually controlled from interior. Used rarely. Two fixtures total.	60w incandescent
Campground Area	45		Gallo Campground, east restroom, men's entry. Fully-shielded canister. Manually controlled from interior.	Light bulb has been removed. Not used in 3+ years.
	46		Gallo Campground east restroom, women's entry. Fully-shielded canister. Manually controlled from interior.	Light bulb has been removed. Not used in 3+ years.
	47		Gallo Campground west restroom, women's entry. Fully-shielded canister. Manually controlled from interior.	Light bulb has been removed. Not used in 3+ years.
	48		Gallo Campground west restroom, men's entry. Fully-shielded canister. Manually controlled from interior.	Light bulb has been removed. Not used in 3+ years.

¹ See inventory map for fixture location (pp. 38-42)

Chaco Culture National Historical Park

Outdoor Lighting Inventory & Mitigations

July 2013

Fixture Conforms with Lighting Guidelines?	Mitigation Strategies ²	Mitigations/Prescriptions	<i>Outdoor Lighting Inventory & Mitigations</i>
YES	NONE	No change required: Emergency alarm lights are lighting guidelines exceptions.	
NO (x2) Not shielded properly	3,6	Fixture will be replaced with fully shielded, canister fixture with an amber CFL or LED bulb < 1000 lumens.	
YES	1,2,5,6	Fixture will be removed and replaced with a fully shielded, motion-activated canister fixture directly adjacent to restroom doorway. Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	1,2,5,6	Fixture will be removed and replaced with a fully shielded, motion-activated canister fixture directly adjacent to restroom doorway. Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	1,2,5,6	Fixture will be removed and replaced with a fully shielded, motion-activated canister fixture directly adjacent to restroom doorway. Replacement bulb standard: amber CFL or LED < 1000 lumens.	
YES	1,2,5,6	Fixture will be removed and replaced with a fully shielded, motion-activated canister fixture directly adjacent to restroom doorway. Replacement bulb standard: amber CFL or LED < 1000 lumens.	

² See Outdoor Lighting Guidelines, p. 30

“Indeed, the night sky at Chaco has long been recognized as a precious natural resource—one that is in more and more danger of being lost as we spend more and more of our energy on developments that are lit to such a degree that they literally outshine the stars in the sky in terms of brightness.” (Cornucopia 1999, p. 73)

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“For many people, seeing a truly dark night sky for the first time is thrill enough. For others, the added knowledge that they are looking up into what is essentially the same sky that was seen by the Chacoans a thousand years ago provides a direct and almost spiritual link between our modern world and the time of the ancients.” (Cornucopia 1999, p. 76)



"Moon and Venus, Casa Rinconada"

Photo: Stan Honda

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Acknowledgements

The staff of Chaco Culture National Historical Park wish to thank the following groups and individuals who helped make this application possible:

- ⇒ *The Albuquerque Astronomical Society (TAAS)* for nominating Chaco to become an IDA International Dark Sky Park, and for TAAS' continued support of Chaco's astronomy program.
- ⇒ *Friends of Chaco* for providing important financial support for the visitor center lighting retrofit project and for the Friends' support for dark night sky preservation and interpretation work.
- ⇒ *The National Park Service Night Skies Program* for their technical assistance and advice, their decade-long support of dark sky preservation at CCNHP, and for their leadership in night sky science & policy.
- ⇒ *Astronomer-in-the-Parks Volunteer Steve Speth* for his help in conducting Chaco's outdoor lighting inventory.
- ⇒ *Stan Honda, NPS Artist-in-the-Parks* for allowing the use of his 'stellar' photographs in this application package and for his strong support of southwestern national parks.
- ⇒ *Mike Dedman, Education Specialist at Whitman Mission National Historic Site*, for providing supporting materials and program advice for Chaco's dark night skies educational outreach.
- ⇒ *Ameé Hennig, IDA Program Manager*, for her guidance and encouragement in preparing this application.
- ⇒ All those groups and individuals who over more than forty years have contributed to preserving the dark night sky over Chaco and sharing its wonders with thousands of park visitors.

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