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NIGHT SKY MONITORING PROGRAM

SOUTHEAST UTAH GROUP
Arches National Park
Canyonlands National Park
Hovenweep National Monument
Natural Bridges National Monument

2003

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EXECUTIVE SUMMARY

NIGHT SKY MONITORING PROGRAM

Southeast Utah Group

Arches and Canyonlands National Parks
Hovenweep and Natural Bridges National Monuments

Project Funded by the
National Park Service and
Canyonlands Natural History Association

This report lays the foundation for a Night Sky Monitoring Program in all the park units of the Southeast Utah Group (SEUG). Long-term monitoring of night sky light levels at the units of the SEUG of the National Park Service (NPS) was initiated in 2001 and has evolved steadily through 2003. The Resource Management Division of the Southeast Utah Group (SEUG) performs all night sky monitoring and is based at NPS headquarters in Moab, Utah. All protocols are established in conjunction with the NPS National Night Sky Monitoring Team.

This SEUG Night Sky Monitoring Program report contains a detailed description of the methodology and results of night sky monitoring at the four park units of the SEUG. This report also proposes a three pronged resource protection approach to night sky light pollution issues in the SEUG and the surrounding region. **Phase 1** is the establishment of methodologies and permanent night sky monitoring locations in each unit of the SEUG. **Phase 2** will be a Light Pollution Management Plan for the park units of the SEUG. It will assess current conditions in the park units of the SEUG and present solutions for areas where light pollution can be minimized. It will also list lighting design considerations that management can use in future development. **Phase 3** will be the development of educational outreach materials for local park interpreters and non-NPS groups. The materials will present the importance of the night sky and the issues that threaten its integrity. They will also present the known and postulated social and natural resource ramifications of light pollution on a local, national, and worldwide scale. It is intended that these three phases will be developed concurrently.

PHASE 1: **SEUG Night Sky Monitoring Program**
PHASE 2: **SEUG Night Sky Light Pollution Management Plan**
PHASE 3: **Night Sky Educational Material Packet**

The objectives of the Long-Term Night Sky Monitoring Program at NPS units of the Southeast Utah Group are:

- Develop protocols and gather baseline data on night sky light pollution levels at the four units of the Southeast Utah Group.
- Monitor condition and trend of night sky light pollution in the park units of the Southeast Utah Group.
- Provide a resource information base to guide park management in the preservation and protection of our night sky resources.
- Establish standardized procedures and data elements for describing, classifying, and comparing regional light pollution in the night sky.
- Present an integrated and organized database of night sky information to facilitate present and future analyses and evaluations.
- Predict and analyze impacts of surrounding communities and land development on night sky resources within and in the region surrounding our park units.
- Encourage night sky data interchange with other federal agencies, state agencies, and private or academic institutions.
- Provide data for the verification of existing light pollution models.

DESCRIPTION OF EXISTING SKY QUALITY

We have established our monitoring methodology in tune with the national protocols of the NPS Night Sky Monitoring Team. Permanent night sky monitoring locations have been selected at each of the four park units of the Southeast Utah Group. We have approximately 80 percent of a complete baseline data set from each of these stations.

Arches National Park, Balanced Rock Area

This site is generally quite dark, except for the glow coming from the town of Moab, Utah, 10 miles to the south and the glow of Grand Junction, Colorado, 75 miles to the east. Unfortunately, the glow from Moab washes out the Scorpius Milky Way and extends15 degrees altitude and encompassing roughly 15 degrees of azimuth. Despite the large impact from these two major light sources, the sky above Arches is typically a 6.8/6.9 limiting magnitude and a Bortle Class 3.

Canyonlands National Park, Grandview Point

The view of the sky from Grandview point is essentially unobstructed and nearly pristine. The most significant light sources that can be seen from Grandview Point at night appear to be the towns of Blanding and Monticello, Utah, to the south, the town of Moab, Utah, to the east and the town of Green River, Utah, to the north. A few secondary light sources that can be seen include the junction at La Sal, the traffic headlights from I-70, Hwy. 191, and the recreational roads in the Needles District of Canyonlands. However, all of the light sources are far enough away from Grandview Point that a limiting magnitude of 7.1 and a Bortle Class of 2 are usually recorded at this site. These numbers indicate that this is one of the finest night sky sites in the National Parks.

Natural Bridges National Monument, Solar Building

The visual appearance of the sky from this location is stunning; Natural Bridges has the darkest sky of all four parks. While this is undoubtedly partly due to the location's topographic position, surrounded on three sides by mountains and plateaus so that the horizon is not clear, there are no primary sources of light pollution to affect this sky. The only light sources are secondary light sources, which are the Cortez, Colorado, and Shiprock, New Mexico, area to the Southeast and the town of Kayenta, Arizona, to the Southwest. It was assumed before data was collected at Natural Bridges that the town of Blanding, Utah, would have an impact on the sky, but from the solar building the light from Blanding is mostly blocked by the Bear's Ears, a prominent feature of the eastern horizon. Actually, the most significant light sources to be seen from the top of the solar building are the park housing, maintenance yard, and visitor center lights. Car headlights traveling on Hwy. 95 and into the park also show up in some images.

However, these light sources do not have a large impact on the sky. The appearance to the naked eye of the Scorpius Milky Way easily fit Bortle's description for Class 2 with intricate detail resembling veined marble, and the sky is quite dark to within 15 degrees of the horizon in all directions. With these conditions a limiting magnitude of 7.1/7.2 and a Bortle Class of 2 or 1 are reliably measured at Natural Bridges. This is a very dark and pristine sky worthy of aggressive protection.

Hovenweep National Monument, Square Tower Unit

Hovenweep has the most impacted sky of all four parks; twelve light domes can be seen consistently around the horizon. There are quite a few primary sources of light pollution affecting this sky. They are the towns of Monticello, Blanding, Bluff, Aneth and Montezuma Creek in Utah, Shiprock through Farmington in New Mexico, and Cortez and Dove Creek in Colorado. The secondary light sources come from neighboring reservation smaller towns such as Red Mesa, Arizona, Towaoc, Colorado, and White Mesa, Utah, as well as from individual yard lights on private residences. With these conditions a limiting magnitude of 6.6/6.7 and a Bortle Class of 3 or 4 is generally measured at Hovenweep.

CONTENTS

1. INTRODUCTION 1
   1.1 BACKGROUND INFORMATION 1
   1.2 NIGHT SKY PROGRAM AT THE SEUG 3
   1.3 OBJECTIVES OF THE SEUG NIGHT SKY MONITORING PLAN 3
   1.4 HISTORY OF NIGHT SKY MONITORING IN THE SEUG 4
   1.5 LIGHT POLLUTION SOURCES 6
   1.6 GENERAL PARK INFORMATION 7
      1.6.1 ARCHES NATIONAL PARK 7
      1.6.2 CANYONLANDS NATIONAL PARK 10
      1.6.3 NATURAL BRIDGES NATIONAL MONUMENT 14
      1.6.4 HOVENWEEP NATIONAL MONUMENT 17

2. METHODS 20
   2.1 FIELD PROTOCOLS FOR NIGHT SKY MONITORING 21
   2.2 DEFINITION OF A COMPLETE BASELINE DATA SET 37
   2.3 DATA ANALYSIS 38
   2.4 DATA MANAGEMENT 38

3. RESULTS 39
   3.1 SITES WHERE BASELINE DATA HAS BEEN COLLECTED 39
   3.2 DISCUSSION OF PRELIMINARY RESULTS 40
   3.3 MONITORING SITES, RESULTS, AND DESCRIPTIONS 43
      3.3.1 ARCHES NATIONAL PARK, BALANCED ROCK AREA 43
      3.3.2 CANYONLANDS NATIONAL PARK, GRANDVIEW POINT 48
      3.3.3 NATURAL BRIDGES NATIONAL MON., MAINTENANCE AREA 54
      3.3.4 HOVENWEEP NATIONAL MONUMENT, SQUARE TOWER 59

4. DISCUSSION 65

5. RECOMMENDATIONS 67

6. LITERATURE 69

APPENDIX 73

TABLES

TABLE 1. Equipment List for Night Sky Program. 21

TABLE 2. Data Collected for Southeast Utah Group as of December 31, 2003. 39

TABLE 3. Sky Brightness in Magnitudes Per Square Arc-Second in V-Band. 41

TABLE 4. Data Sets Needed for Complete Baseline Data Sets at the SEUG. 67

FIGURES

FIGURE 1. Map of the World with satellite view of light sources. 4

FIGURE 2. Map and Location of Arches National Park. 8

FIGURE 3. Map and Location of Canyonlands National Park. 12

FIGURE 4. Map and Location of Natural Bridges National Monument. 16

FIGURE 5. Map and Location of Hovenweep National Monument. 18

FIGURE 6. Description of the LX200 tripod. 23

FIGURE 7. Meade LX200 GPS telescope and accessories. 25

FIGURE 8. Camera attachment kit (a) and placement of washer (b). 26

FIGURE 9. The camera, 35mm lens and filter (a) and focus points on the lens (b). 27

FIGURE 10. The DC to DC converter (a) and the power inverter (b). 28

FIGURE 11. Location of Night Sky Monitoring Point at Balanced Rock in Arches National Park. 43

FIGURE 12. Polar projection all-sky mosaic of sky brightness images collected at Balanced Rock in Arches National Park. 46

FIGURE 13. Panoramic mosaic of sky brightness images collected at Balanced Rock in Arches National Park. 47

FIGURE 14. Location of Night Sky Monitoring Point at Grandview Point in the Island in the Sky District of Canyonlands National Park. 48

FIGURE 15. Polar projection all-sky mosaic of sky brightness images collected at Grandview Point in the Island-in-the-Sky District of Canyonlands National Park. 52

FIGURE 16. Panoramic mosaic of sky brightness images collected at Grandview Point in the Island-in-the-Sky District of Canyonlands National Park. 53

FIGURE 17. Location of Night Sky Monitoring Point on top of the Solar Building in the Maintenance area of Natural Bridges National Monument. 54

FIGURE 18. Polar projection all-sky mosaic of sky brightness images collected at Natural Bridges National Monument. 57

FIGURE 19. Panoramic mosaic of sky brightness images collected at Natural Bridges National Monument. 58

FIGURES (cont.)

FIGURE 20: Location of Night Sky Monitoring Point at the Square Tower Unit of Hovenweep National Monument. 59

FIGURE 21. Polar projection all-sky mosaic of sky brightness images collected at the Square Tower Unit of Hovenweep National Monument. 63

FIGURE 22. Panoramic mosaic of sky brightness images collected at the Square Tower Unit of Hovenweep National Monument. 64

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Thanks to the many NPS folks who have assisted with this project since 2001. Special thanks to the NPS National Night Sky Monitoring Team which includes Chad Moore, Dan Duriscoe, and Cindy Duriscoe. They have provided a tremendous amount of technical data collection assistance, photos, advice, and equipment, without which we would never have succeeded.

A huge thanks to the folks at the Canyonlands Natural History Association (CNHA) for their monetary support and their unfailing confidence and belief in the importance of this work. CNHA provided the initial funds for acquiring the essential and expensive technical equipment needed for an undertaking of this magnitude. For this we are very grateful.

To park staff and SCA volunteers at all the park units of the SEUG we cannot thank you enough for your support and volunteer efforts. On many occasions you cheerfully provided assistance in extreme weather conditions and on your own time, which provided the motivation to get the job done.

Special thanks to Dean Hardy for the long hours of hard work on volunteer time. We appreciate all of your assistance, curiosity, and enthusiasm.

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Kodak Corporation generously provided digital cameras and scanning equipment.

1. INTRODUCTION

Park Avenue area of Arches National Park.

1.1 BACKGROUND INFORMATION

This report lays the foundation for a Night Sky Monitoring Program in all the park units of the Southeast Utah Group (SEUG). Long-term monitoring of night sky light levels at the units of the SEUG of the National Park Service (NPS) was initiated in 2001 and has evolved steadily through 2003. The Resource Management Division of the Southeast Utah Group (SEUG) performs all night sky monitoring for the group and is based at NPS headquarters in Moab, Utah. All protocols are established in conjunction with the NPS National Night Sky Monitoring Team.

The Organic Act, which created the National Park Service, directs the agency "…to conserve the scenery, and the natural and historic objects and the wildlife 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." Contained in the act is a mandate for the NPS to allow the general environment to exist and evolve under natural conditions, and to manage human use so that it does not impair the long-term natural functioning of these ecosystems. Change is a part of all natural systems. It thus becomes imperative, for management purposes, to be able to distinguish between natural and human-caused change. Human-caused sources of light in the night sky are easily distinguished from natural sources. This Night Sky Monitoring Program has been established to measure baseline night sky light levels in the four park units of the Southeast Utah Group and to identify sources of light pollution from within and outside the park units.

The preservation of National Park Service lands cannot be achieved by the drawing of a boundary line on a map. Human activities, both external and internal, may cause serious threats to the environmental quality and integrity of our natural resources. The value of most units administered by the National Park Service lies in their continued naturalness, especially as humans increasingly develop lands outside the parks. Change may be subtle at first with rapid change occurring later on. Without baseline and follow-up monitoring, changes may be irreversible by the time they are documented.

For many years development along park borders has been a concern for NPS managers of many units of the National Park Service. Recently, there appears to be a surge in this type of activity as more and more people travel to visit the parks, retire, or purchase second homes in the beautiful areas surrounding our parks. Light pollution from neighboring developments and activities has started to become a serious problem and many visitors and employees of the parks complain that the night sky visibility seems to be getting worse. The National Park Service's Night Sky Initiative defines the night sky as a resource that is as precious as the natural wonders and cultural resources for which the parks were originally established. The four units of the Southeast Utah Group all identified dark night skies as an important and critical natural resource (Simon and Scott 1999).

Light pollution is most often caused by excessive or misdirected outdoor lighting and hinders the ability to view celestial features. Under ideal conditions in southeast Utah a viewer might observe a night sky with more than 15,000 visible stars plus the Milky Way, which itself contains billions of stars. Only about 10 percent of the U.S. population experiences these conditions regularly (Clarke 1999). National Park Service management policies address the protection of night skies and consider light pollution a serious problem in and around many National Parks. This issue is also indirectly addressed by the Wilderness Act. A large percentage of parks judge this problem to be "moderately serious" or "very serious", especially the parks of the SEUG (USDI-NPS CANY Resource Management Plan 1994, USDI-NPS ARCH Resource Management Plan 1994, USDI-NPS NABR Resource Management Plan 1994, USDI, NPS-SEUG Research Plan 1993, Simon 1999).

In the Southeast Utah Group there have been new developments, improvements to existing developments, and ambitious resort-type development plans on lands located adjacent to the parks. The State of Utah is undergoing a controversial plan to sell and help develop much of its state lands into resorts, housing communities, and other industrial uses. Many of these parcels are adjacent to the parks of the Southeast Utah Group. With the anticipated increased development, the night sky visibility is expected to decrease considerably.

The night sky is a primal element of our human heritage, perhaps the ultimate cultural entity. It is the eternal backdrop of human history, inspiration of thought and belief, source of some of the deepest questions human beings have posed about themselves and their place in the world (Flanagan 2003).

1.2 NIGHT SKY PROGRAM AT THE SEUG

This SEUG Night Sky Monitoring Program report concentrates primarily on Phase 1 of a three pronged resource protection approach to light pollution issues in the SEUG and the surrounding region. Phase 2 will be a Light Pollution Management Plan for the park units of the SEUG. It will assess current conditions in the park units of the SEUG and present corrective recommendations to areas where light pollution is excessive and unnecessary. It will also list lighting design considerations that management can use in future development. Phase 3 will be the development of educational outreach materials for park visitors, local municipalities, and the general public. The materials will present the importance of the night sky and the issues that threaten its integrity. They will also present the known and postulated social and natural resource ramifications of light pollution on a local, national, and worldwide scale.

PHASE 1: SEUG Night Sky Monitoring Program
PHASE 2: SEUG Night Sky Light Pollution Management Plan
PHASE 3: Night Sky Educational Material Packet

It is intended that these three phases will be developed concurrently.

1.3 OBJECTIVES OF THE SEUG NIGHT SKY MONITORING PLAN

The objectives of the Long-Term Night Sky Monitoring Program at NPS units of the Southeast Utah Group are:

- Develop protocols and gather baseline data on night sky light pollution levels at the four units of the Southeast Utah Group.
- Monitor condition and trend of night sky light pollution in the park units of the Southeast Utah Group.
- Provide a resource information base to guide park management in the preservation and protection of our night sky resources.
- Establish standardized procedures and data elements for describing, classifying, and comparing light pollution in the night sky in park units and other areas of the region.
- Present an integrated and organized database of night sky information to facilitate present and future analyses and evaluations.
- Predict and analyze impacts of surrounding communities and land development on night sky resources within and in the region surrounding our park units.
- Develop and distribute Night Sky educational material and encourage night sky data interchange with other federal agencies, state agencies, and private or academic institutions.
- Provide data for the verification of existing light pollution models.

1.4 HISTORY OF NIGHT SKY MONITORING IN THE SEUG

There are few places in the United States where the night sky visibility is as clear as in the southeast Utah area (see **Figure 1**). The lack of a nearby urban center, dry conditions, higher altitude, and paucity of nearby major sources of air pollution (power plants etc.) has contributed greatly to our remarkable night sky clarity.

FIGURE 1. Map of the World with satellite view of light sources.

Many have commented over the years on the incredible quality of the night sky in the parks of the SEUG. The NPS eventually recognized the dark night sky as a significant resource to be protected and monitored (USDI-NPS CANY Resource Management Plan 1994, USDI-NPS ARCH Resource Management Plan 1994, USDI-NPS NABR Resource Management Plan 1994, USDI, NPS-SEUG Research Plan 1993). Unfortunately, the technology to measure and monitor night sky light levels with high resolution was not available as an affordable and reliable system until very recently.

Until 2001, very little night sky monitoring had been done in any of the park units of the Southeast Utah Group. In 1985, M. Yocke, H. Hogo, and G. Lundberg investigated possible impacts on the night sky darkness in response to a proposal to establish a nuclear waste facility adjacent to the east boundary of Canyonlands National Park. Their work did not include a quantification of night sky light levels but they did emphasize the remarkable quality of the night sky and the likely degradation of this resource if the facilities were developed. They also developed a model for predicting night sky glow and based their conclusions on their predicted findings. Fortunately, the proposed facility was not established. Since the mid 1980's, visitation and immigration into the Southeast Utah area has increased substantially and the inevitable development of adjacent lands and expansion of local communities has led to a noticeable affect on the night sky darkness. This has prompted NPS scientists in the nearby parks to establish a monitoring program to collect night sky light levels baseline data before it is too late.

In the early 1990's, Dan Duriscoe, a physical scientist from Sequoia and Kings Canyon National Parks, was involved in a fledgling night sky monitoring program at Organ Pipe National Monument. He later teamed up with Chad Moore, a physical scientist with Pinnacles National Monument, and by the turn of the century they had initiated an NPS National Night Sky Monitoring Initiative. By 2001, they had developed a rudimentary working system and teamed up with Charles Schelz (2001), a biologist with the SEUG, to establish a program here in the Southeast Utah Group. In 2003, Angie Richman, a physical scientist, was hired as part of the program for the parks of the Southeast Utah Group and the surrounding region.

Charles Schelz and Angie Richman currently run the Night Sky Monitoring program at the Southeast Utah Group. They work very closely with Chad Moore and Dan Duriscoe of the NPS National Night Sky Monitoring Team. By 2003, the night sky had finally been recognized as an important resource and its condition is starting to be measured in many units of the National Park Service.

1.5 LIGHT POLLUTION SOURCES

Light pollution comes primarily from human development within and outside the parks. Lighting is a basic component of most human activities for many reasons, but primarily for security and safety. Distant towns and cities give off varying degrees of light pollution depending on their size and the number, type, and design of lighting equipment. Other sources include private rural homes, industrial complexes including factories and mining operations, drilling rigs, refineries, public and private utilities, airports, sports complexes, private businesses such as gas stations and campgrounds, billboards and signs, and roads, highways, and the accompanying vehicle headlights. The impacts of light pollution can be lessened considerably with a minimum of forethought and concern. It is surprising how much light pollution can be avoided by simple means such as shading outdoor lights so that light is directed to the ground but not to the sky.

Regional Light Pollution Sources:

1) Towns and Cities
2) Power Plants
3) Military Bases
4) Mining Operations
5) Factories
6) Refineries
7) Vehicle Headlights

Local Light Pollution Sources:

1) Residential Areas
2) Towns and Cities
3) Campgrounds
4) Roads and Highways
5) Gas Stations
6) Airports
7) Local Business Complexes
8) Office Complexes
9) Parking Lots
10) Local Parks and Ball Fields
11) Billboards and Signs
12) Vehicle Headlights

Park Specific Light Pollution Sources:

1) Residential Areas
2) Administrative Areas
3) Maintenance Areas
4) Parking Areas
5) Campgrounds
6) Facility Lighting (Bathrooms, etc.)
7) Vehicle Headlights

1.6 GENERAL PARK INFORMATION

1.6.1 ARCHES NATIONAL PARK

Park History and Purpose

Arches National Monument was established by Presidential Proclamation No. 1875 on April 12, 1929. The monument was specifically set aside due to its outstanding and unusual geologic features. The proclamation states that the monument was established "to protect extraordinary examples of wind erosion in the form of gigantic arches, natural bridges, "windows", spires, balanced rocks and other unique wind-worn sand-stone formations, the preservation of which is desirable because of their education and scenic value". Geologic research has since established that water is the primary agent of erosion involved, although wind does play a role.

Fiery Furnace area in Arches National Park.

In 1938, the Monument was enlarged to include a number of historic and prehistoric cultural sites. Boundary adjustments were made on November 15, 1938; July 26, 1960; January 21, 1969; and November 12, 1971. In 1971 the designation for Arches was changed from a national monument to a national park and the acreage was increased to 73,379 acres (29,708 hectares). In 1999 the Lost Spring section was added to the park, which increased the total area by 3,100 acres to 76,519 acres.

Location

Arches National Park is located in southeast Utah along and north of the Colorado River in Grand County (see **FIGURE 2**). The park is five miles (8.3 kilometers) north of Moab, Utah, 100 miles (166.7 kilometers) west of Grand Junction, Colorado, and 240 miles (400 kilometers) southeast of Salt Lake City, Utah. The park is readily

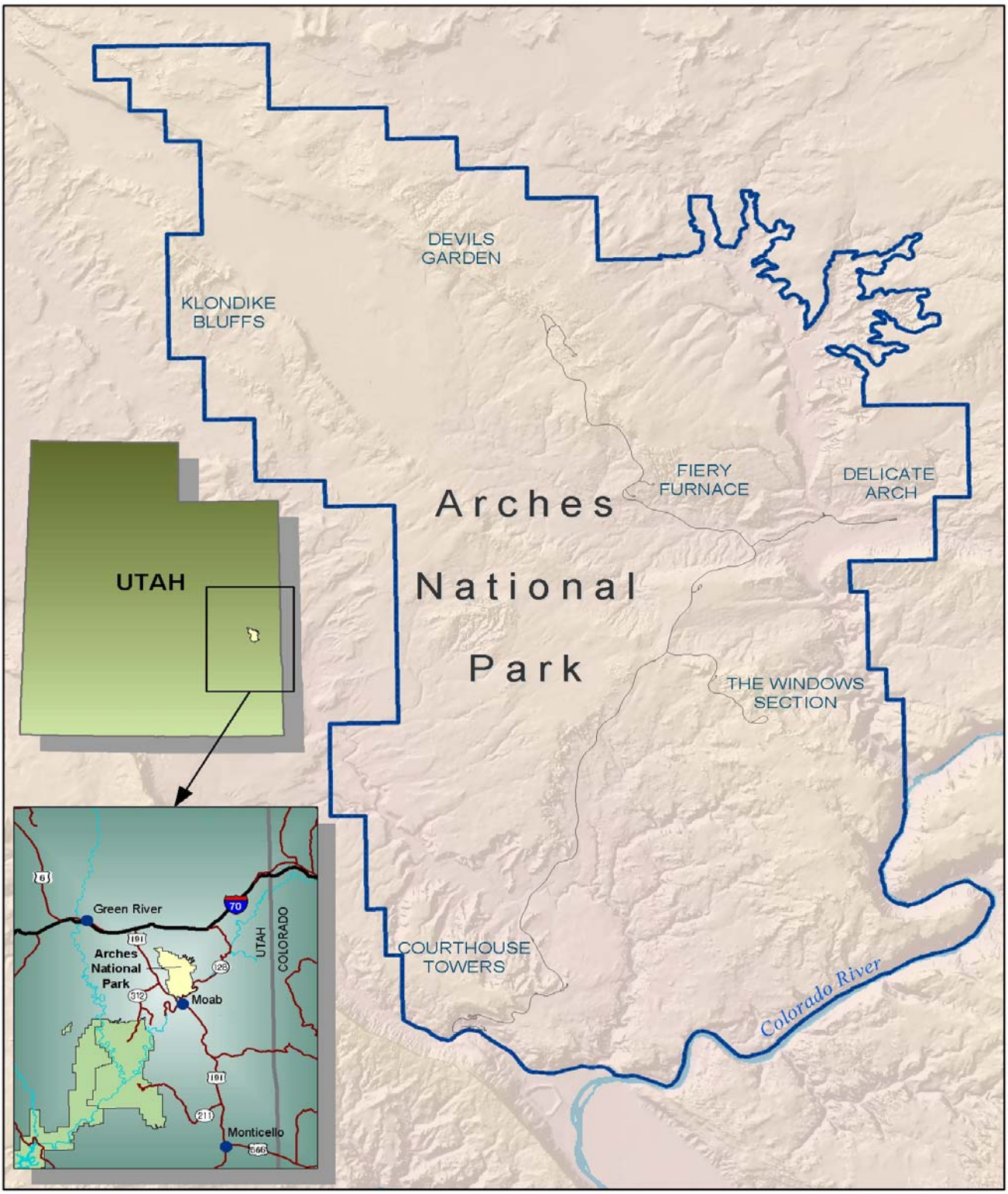


FIGURE 2. Map and Location of Arches National Park.

accessible by a major travel route, Interstate I-70, located 20 miles (33.3 kilometers) north of the park headquarters. Utah Highway 191 runs from Interstate I-70 south to the park entrance road, Moab and areas farther south. The area surrounding the park is sparsely populated, with a density of two people per square mile (0.8 people per square kilometer) in the surrounding Grand County. Tourism is currently the largest economic activity.

Elevation

The elevation within the park ranges from approximately 4,000 feet in the canyons to 5,200 on the rims.

General Description

Arches National Park has the largest concentration of natural stone arches in the world. Examples of developing, complete, and collapsed arches are all evident within the 114 square miles of the park. Several arches are particularly noted for their outstanding size and erosional history. Landscape Arch is probably the longest natural stone arch in the world. Delicate Arch, a freestanding arch carved from what was once a freestanding fin, is internationally recognized.

The park is 16 miles (26.7 kilometers) from north to south and 8 miles (13.3 kilometers) from east to west. There are a total of 76,519 acres (30,979 hectares) of land within the legislative boundaries of the park. The topography of the area is diverse, ranging from open flats to steep-walled cliffs. The area has been greatly effected by geologic activity associated with the salt intrusions of the Paradox Formation. The landscape has been carved by the effects of wind and water and preserved by the arid climate and lack of earthquake activity. This has produced a landscape dominated by red sandstone formations such as arches, fins, balanced rocks, mesas, canyons and spires. Major topographic features of Arches National Park are Courthouse Wash, Courthouse Towers, the Windows Section, Salt Valley, Klondike Bluffs, Devil's Garden and the Fiery Furnace. Some of the more famous geologic features in the park are Landscape Arch, Delicate Arch, Tower Arch, the Marching Men, Skyline Arch, the Three Gossips, the Three Penguins, the Windows, the Parade of Elephants, Balanced Rock and the Great Wall. There are more than 1800 catalogued arches within the park that have a span greater than three feet.

Arches National Park is largely covered by exposed bedrock, weakly developed soils and sand dunes. The park was established because of its unique geologic features, in particular the massive, spectacular natural rock arches formed in the Entrada Sandstone. The geology of Arches National Park is largely determined by the collapsed salt anticline in Salt Valley and to a lesser extent by the collapsed Moab and Cache Valley anticlines. There are ten major sedimentary formations exposed in the park ranging in age from the Pennsylvanian Paradox Formation to the Cretaceous Mancos Shale. In stratigraphic order, formations include Paradox, Honaker Trail, Cutler Group, Moenkopi, Chinle, Wingate Sandstone, Kayenta, Navajo Sandstone, Entrada Sandstone, Morrison, Cedar Mountain, Dakota Sandstone and Mancos Shale. The Paradox Formation of salt and gypsum evaporites is a highly plastic formation that has formed the salt anticlinal structures in the park. These anticlines collapsed when ground water dissolved the salt. The Navajo and Entrada Sandstones crop out over most of the park's surface, with the Entrada forming the majority of the outstanding geologic features. The cliff-forming Wingate Formation exposed along the Colorado River forms the south boundary of the park. Together with the associated Kayenta, Chinle and Moenkopi Formations, the Wingate forms impressive eight hundred foot cliffs.

Several areas of pictographs and petroglyphs are found in the park. Two archeological surveys have been completed and approximately 100 sites have been documented. The Courthouse Wash Rock Art Panel is listed on the National Register of Historic Places. The panel represents the easternmost known occurrence of the Barrier Canyon Style.

Physical remains of early ranching and mining pursuits, as well as traces of pioneer routes, exist within the park.

Climate

The climate of Arches National Park is arid. It is characterized by hot, dry summers and cool to cold winters. The average annual precipitation of the area is 7.95 inches (202 millimeters). Mean annual temperature is 56 degrees Fahrenheit (13.3 degrees Celsius) and the extreme temperatures measured are -16 degrees Fahrenheit (-26.7 degrees Celsius) and 112 degrees Fahrenheit (44.4 degrees Celsius). Potential evapotranspiration far exceeds precipitation, making effective soil moisture a critical environmental factor. Precipitation peaks most often occur in March and August. Snow commonly falls between November and March. But averages may be misleading; snowfalls in May, peak precipitation almost any month of the year except June, and generally extreme years are not uncommon.

1.6.2 CANYONLANDS NATIONAL PARK

Park History and Purpose

Efforts to turn southeast Utah's canyon country into a national park began about 1935 when Secretary of the Interior Harold Ickes proposed setting aside 7,000 square miles of southeast Utah as Escalante National Monument. This effort was doomed by opposition from state commercial interests and the demands of World War II (Smith 1991), but with the rise of the conservation movement in the 1960s, Senator Frank Moss, Secretary of the Interior Stewart Udall, Arches National Park Superintendent Bates Wilson, and locals such as Kent Frost took up the battle to preserve the "still untouched" canyon country near the confluence of the Green and Colorado Rivers. Their efforts resulted in Congress and President Lyndon B. Johnson setting aside Canyonlands National Park on September 12, 1964. As stated in Public Law 88-590, Canyonlands was established "...to preserve an area in the State of Utah possessing superlative scenic, scientific, and archeological features for the inspiration, benefit, and use of the public…" This is the overriding legal mandate which guides the resource management program of the park today.

Location

Canyonlands National Park is located in southeast Utah along the Colorado and Green Rivers in Grand, Garfield, San Juan and Wayne Counties. The park is southwest of nearby Moab, Utah, 110 miles (183 kilometers) southwest of Grand Junction, Colorado, and 240 miles (400 kilometers) southeast of Salt Lake City, Utah. Parts of the park are readily accessible from major travel routes including Interstate I-70 and Utah Highway 191. The area surrounding the park is sparsely populated with a density of 1.5 to 2 people per square mile (0.6-0.8 people per square kilometer). Tourism is currently the largest economic activity in the area.

Green River and Turks Head in Canyonlands National Park.

Elevation

The elevation within the Canyonlands National Park ranges from approximately 3,900 feet on the Colorado River south of Cataract Canyon to 7,180 feet above Big Pocket in the Needles District.

General Description

Canyonlands National Park has been expanded since it was originally established in 1964 to its present size of 337,370 acres, centered on the confluence of the Green and Colorado Rivers. The rivers divide the park into three geographical districts: the Island in the Sky District is the triangle of land between the two rivers, the Needles District lies east of the Colorado River and the Maze District lies to the west of the Colorado and Green Rivers. The Horseshoe Canyon Detached Unit is managed as part of the Maze District. In addition, the Green and Colorado River corridors are managed as a separate River District of the park. In summary, the park is divided into the Island in the Sky, Maze, Needles and River districts.

Geology

From prehistoric Native Americans searching for chert outcrops, to the 1860's and 1870's geological investigations of John Wesley Powell, to turn-of-the-century explorers, to oil explorers dating from the 1910's, to uranium miners of the 1950s, the geologic resources of Canyonlands have been of major interest and importance. As a result of these explorers, miners and recreationalists, geological publications on the park are widely available and the geological resources of the park are well-known (Baars and Molenaar 1971; Baars, 1989; Huntoon, Billingsley and Breed 1982).

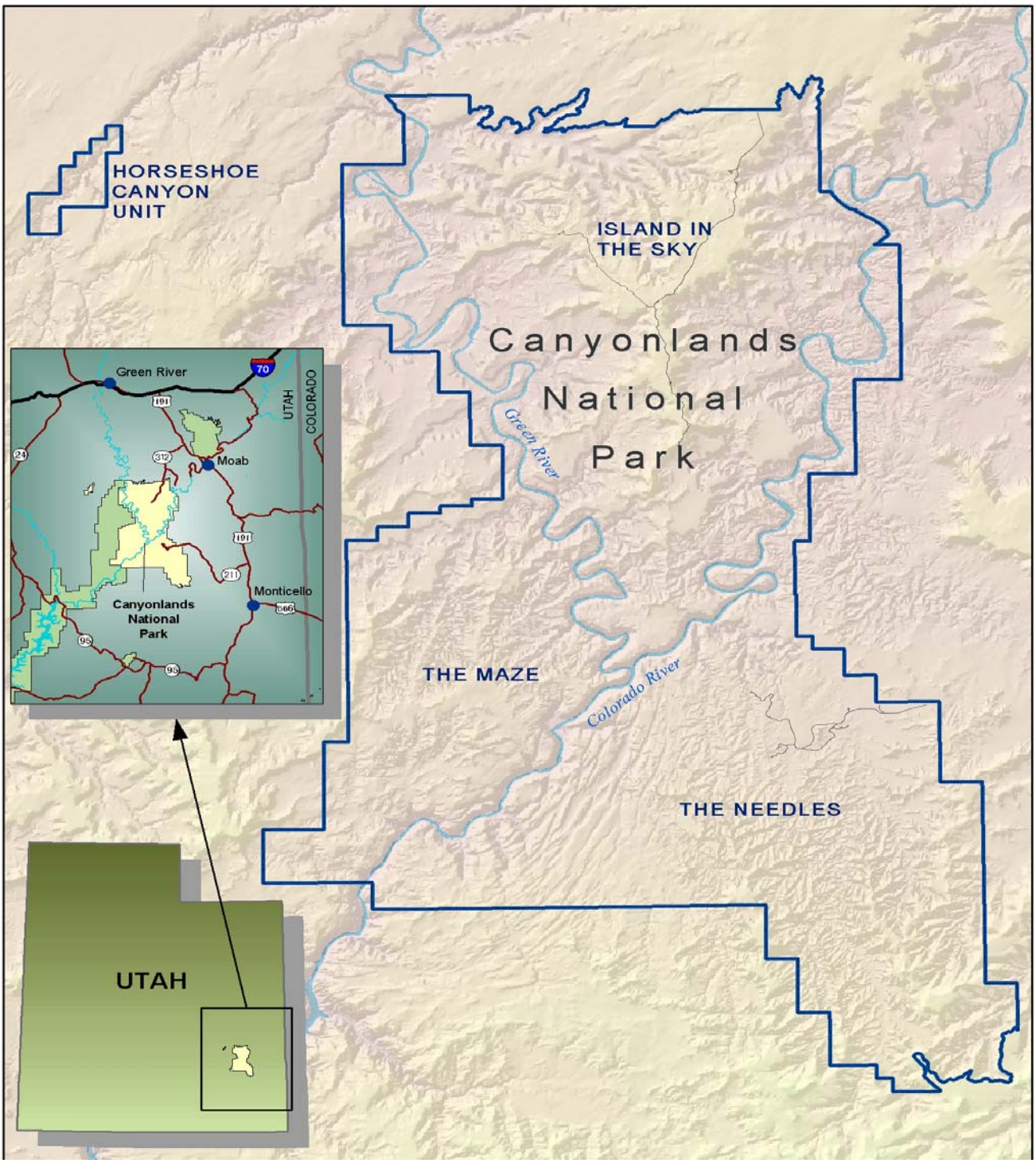


FIGURE 3. Map and Location of Canyonlands National Park.

For visitors, probably the three most striking geological formations of the park are the uniquely banded red and white sandstone of the Cedar Mesa Formation exposed in the Needles and Maze Districts, the sinuous White Rim Sandstone exposed on the platform rim between mesa top and rivers in the Island in the Sky District, and the vertical red cliffs of Wingate Sandstone, exposed high in the Island in the Sky District and above the Maze District.

The incredible features of the park include remote mesas, buttes, and deep canyons cut by the Green and Colorado Rivers and their tributaries. The park's name is derived from the geology term "Canyon Lands", which is defined as the province south of the Uinta Basin and between the High Plateaus to the west and the Rocky Mountains to the east. As explained by Stokes (1988), the park lies at the rugged and remote heart of the Canyon Lands section of the Colorado Plateau physiographic province in southeast Utah. The park is characterized by sedimentary rocks, which have been deformed into anticlines, synclines, monoclines, and salt tectonic structures. Uplift of the Colorado Plateau, with concurrent and subsequent water erosion, have produced the extensive, deep canyon systems which are the defining features of the park and of the physiographic section (Lammers 1991).

There are seven sedimentary formations plus a laterally varied group of formations exposed in the park, ranging in age from the Paleozoic Pennsylvanian Period to the Mesozoic Jurassic Period. In stratigraphic order starting with the oldest, these are the Paradox Formation, Honaker Trail Formation, Cutler Group, Moenkopi Formation, Chinle Formation, Wingate Sandstone, Kayenta Formation, and Navajo Sandstone.

The layers of the Permian Cutler Group represent varied and transitional environments. Red layers in easternmost Canyonlands are usually referred to as the Cutler Undivided. Several distinct formations in most of the park include, from the bottom up, the Halgaito Shale, Elephant Canyon Formation (a disputable unit among geologists), Cedar Mesa Sandstone, Organ Rock Shale and White Rim Sandstone.

The Permian Paradox Formation of salt and gypsum evaporites is highly plastic and played a key role in the many structures within and near Canyonlands. The buried salt flowed and formed domes and anticlinal structures. Erosion eventually led to ground-water dissolution of the salt, causing the collapse of overlying layers and the resulting valleys.

Climate

Canyonlands National Park is arid. It is characterized by hot, dry summers and cool to cold winters. Temperatures in the park vary with altitude and latitude (Brough, Jones and Stevens 1987). In the Needles District at an elevation of 5,040 feet, the average maximum temperature is 68.3^0 F, and the average minimum is 37.8^0 F. The average annual precipitation is 8.62 inches. In the Island in the Sky District at an elevation of 5,930 feet, the average maximum temperature is 64.1^0 F, and the average minimum temperature is 42.2^0 F. Temperatures can reach as high as 110^0 F and as low as -16^0 F. The average annual precipitation is 9.27 inches. Potential evapotranspiration far exceeds precipitation, making effective soil moisture a critical environmental factor. Precipitation peaks most commonly occur in March and in August. Snow commonly falls between November and March. Another generality is that climate statistics vary from year-to-year, extremes are common, and an average year or average season is rare.

1.6.3 NATURAL BRIDGES NATIONAL MONUMENT

Park History and Purpose

Established in 1908, Natural Bridges National Monument is Utah's oldest National Park Service area. A total of 120 acres were originally set aside around each of the three bridges based on President Theodore Roosevelt's original Proclamation No. 804, April 16, 1908, 35 Statute 2183. The main purpose for the Monument was stated by President Roosevelt as follows:

"Whereas, a number of natural bridges situated in southeastern Utah having heights more lofty and spans far greater than any heretofore known to exist, are of the greatest scientific interest, and it appears that the public interests would be promoted by reserving these extraordinary examples of stream erosion with as much land as may be necessary for the proper protection thereof..."

Owachomo Bridge at Natural Bridges National Monument.

Later, the Monument was enlarged to encompass 2,420 acres containing the three natural bridges, prehistoric structures, and cave springs, as stated in President William H. Taft's Proclamation No. 881, September 25, 1909, 36 Statute 2502:

"...at the time this Monument was created nothing was known of the location and character of the prehistoric ruins in the vicinity of the bridges, nor of the location of the bridges and prehistoric cave springs, also hereby reserved..."

The same area was resurveyed, and set aside by President Woodrow Wilson's Proclamation No. 1323, February 11, 1916, 39 Statute 1764:
"whose purpose is to conserve the scenery and the natural and historic objects and the wildlife 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."

In August of 1962, President John F. Kennedy's Proclamation No. 320 withdrew 320 acres of land around Snow Flat Spring Cave and Cigarette Spring Cave from the Monument since these caves: "...no longer contain features of archeological value and are not needed for the proper care, management, protection, interpretation, and preservation of the Monument." In this proclamation, he also expanded the size of the Monument, reiterated the public and scientific communities' interest in the preservation and protection of the bridges and prehistoric sites, and he set forth the main management objectives for the Monument.

Location

The Monument is located in San Juan County, Utah, 120 miles (200 kilometers) southwest of Moab, Utah. The area is accessible via Utah Highway 95 which connects Blanding, Utah with Hanksville, Utah. Blanding, Utah (population 3,100), is the nearest population center, located 40 miles (65 kilometers) east of the Monument. Surrounding San Juan County is sparsely populated, with a density of less than 1.5 people per square mile (0.6 people per square kilometer). The area surrounding the Monument has never been settled by Anglos and has been used only for extensive livestock grazing and small-scale mining activities.

Elevation

The elevation within the monument varies from approximately 5,700 feet in the canyons to 6,400 on the rims.

General Description

Nowhere else are three such extraordinary natural bridges found in such close proximity to one another. These three bridges show three different stages of development from youth (Kachina), to maturity (Sipapu), to old age (Owachomo). Together with the canyons in which they formed, these three bridges are excellent examples of the result of an entrenched meander stream system.

The Monument was also created because of its well-preserved Ancestral Puebloan standing architecture. While archaeologists now recognize that these structural sites are common throughout the region, the presence of these well-preserved structural sites, as well as a range of archaeological sites from Archaic through historic times, make the Monument highly significant. The cultural resources of Natural Bridges are outstanding and the monument provides the opportunity, found in few other places, to study the interaction among indigenous cultural groups. There are numerous sites with religious and historical significance to American Indians.

Two major canyons, White and Armstrong, traverse Natural Bridges National Monument. Both are deeply incised into the Cedar Mesa Sandstone, and they meet in the southwest part of the monument. They host outstanding examples of ephemeral streams and associated high desert riparian vegetation. Water-loving flora thrive in the riparian corridors, which also provide food, shelter, and travel paths for wildlife. Small pockets of Douglas fir and associated mesic vegetation grow in sheltered areas along the canyon rims. A year-round supply of standing water results from numerous seeps. Moist alcoves shelter hanging garden communities, where rare plants find refuge. The Monument's hanging gardens preserve one of the few locations of a very rare plant, the Kachina daisy (*Erigeron kachinensis*). The upland vegetation of the area is predominately pinyon-juniper woodland, a vegetation type common to most of southeast Utah at elevations of approximately 4,000 to 8,000 feet (1220-2440 meters).

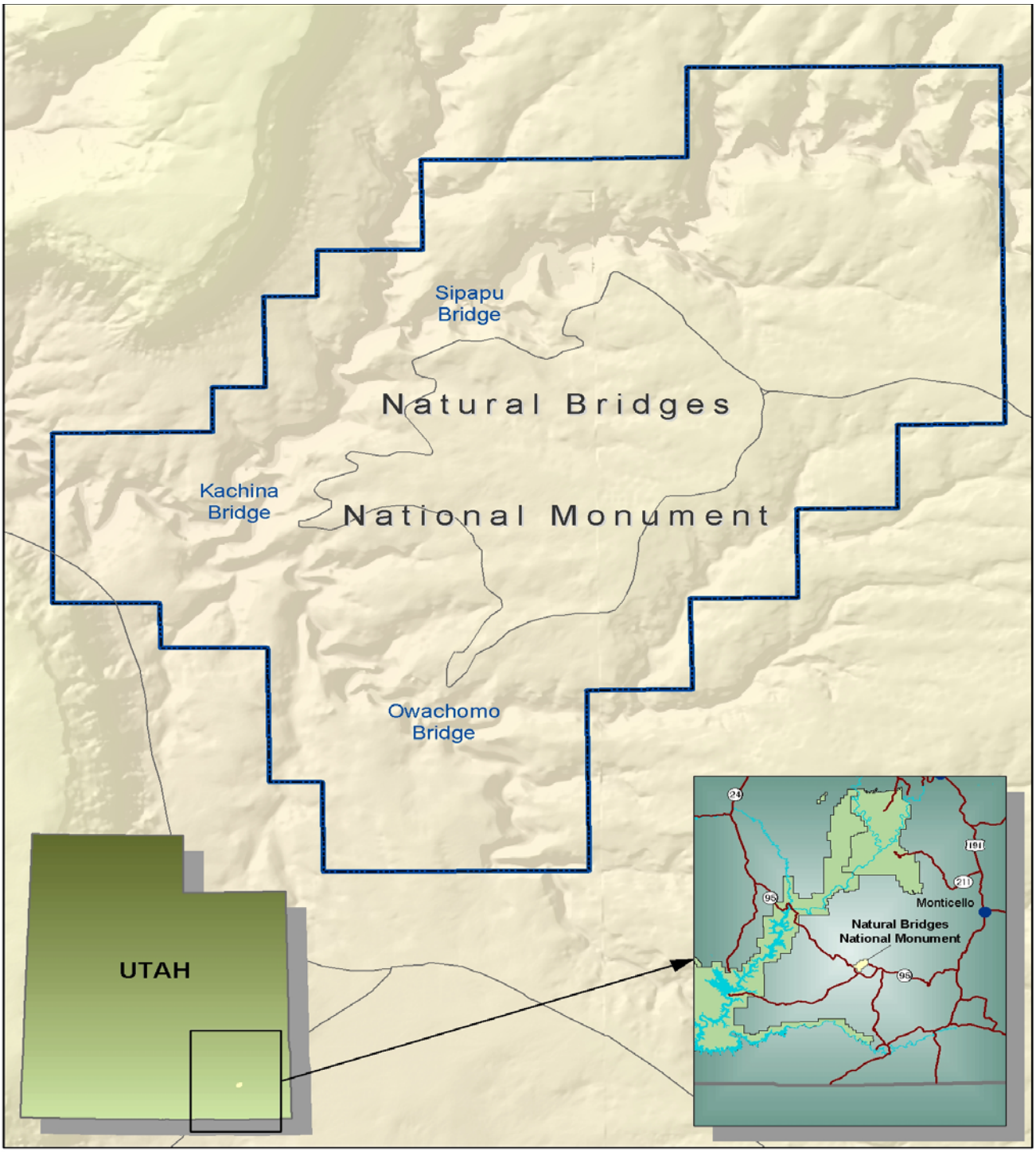


FIGURE 4. Map and Location of Natural Bridges National Monument.

The fauna of the Monument is typical of the Cedar Mesa area of southeastern Utah. Large mammals commonly seen are mule deer, coyote and desert cottontail. Conspicuous birds are the common raven, turkey vulture, red-tailed hawk and scrub jay. A variety of lizards can be seen during the warmer months, and the Monument is home to a large population of midget prairie rattlesnakes. The Monument provides a breeding ground for peregrine falcons, is home to at least 15 species of bats, and has extensive public lands surrounding it that are candidates for Wilderness designation. The ecological processes and biological diversity of this area are found in few other places.

Pristine air quality at Natural Bridges ensures extensive vistas and, combined with the absence of artificial light, provides outstanding opportunities to view night skies. The absence of human-generated sound leaves the visitor to confront the natural silence that is the hallmark of canyon country.

1.6.4 HOVENWEEP NATIONAL MONUMENT

Hovenweep National Monument was first established by Warren G Harding in 1923 by Presidential Proclamation 1654 (42 Statute 2299). The Proclamation states in part:
"Whereas, there are in southwestern Colorado and southeastern Utah four groups of ruins, including prehistoric structures, the majority of which belong to unique types not found in other National Monuments, and show the finest prehistoric masonry in the United States; and …. It appears that the public good would be promoted by preserving these prehistoric remains as a National Monument with as much land as may be necessary for the proper protection thereof, … that there is hereby preserved, subject to prior valid claims and set apart as a National Monument to be known as Hovenweep National Monument …"

Subsequent Presidential Proclamations 2924, April 29, 1951; 2998, November 20, 1952, 3132, April 6, 1956; and Public Land Order 2604, February 5,1962, added other areas and adjusted the boundaries of the monument. Given the proclamations listed above and the Organic Act of August 25, 1916 (Public Law 235, 39 Stat. 535), the National Park Service's mandate is to preserve and protect the cultural and natural resources associated with the six ruin groups, and to assist visitors in understanding the life and culture of the prehistoric inhabitants and their adaptation to the environment.

Resource values at Hovenweep National Monument consist of significant cultural resources and their associated pristine natural settings. Five of the six units comprising the Monument, Cajon, Square Tower, Holly, Cutthroat, and Hackberry/Horseshoe, contain clusters of Ancestral Puebloan pueblos and towers situated near permanent springs at canyon-head locations on Cajon Mesa. These canyon rim towers and villages are the best preserved and protected, most visually striking, and accessible examples of 13th century Ancestral Puebloan architecture and community locations within the San Juan River Basin. Other archeological sites representative of Paleo–Indian, Archaic, and early Puebloan occupation are also found in the Monument. Hovenweep is significant because of the large number of structures possessing a high degree of physical and locational integrity. In addition, the towers are noteworthy because of their many stylistic variations.

Location

Hovenweep National Monument contains six distinct units situated in the Four Corners area of the United States. The Square Tower and Cajon units are located in San Juan County, Utah. The Goodman Point, Hackberry/Horseshoe, Holly, and Cutthroat units are located in Montezuma County, Colorado.

Elevation

Elevation within the monument varies from 5,200 feet at the Cajon unit to 6,760 at the Goodman Point unit.

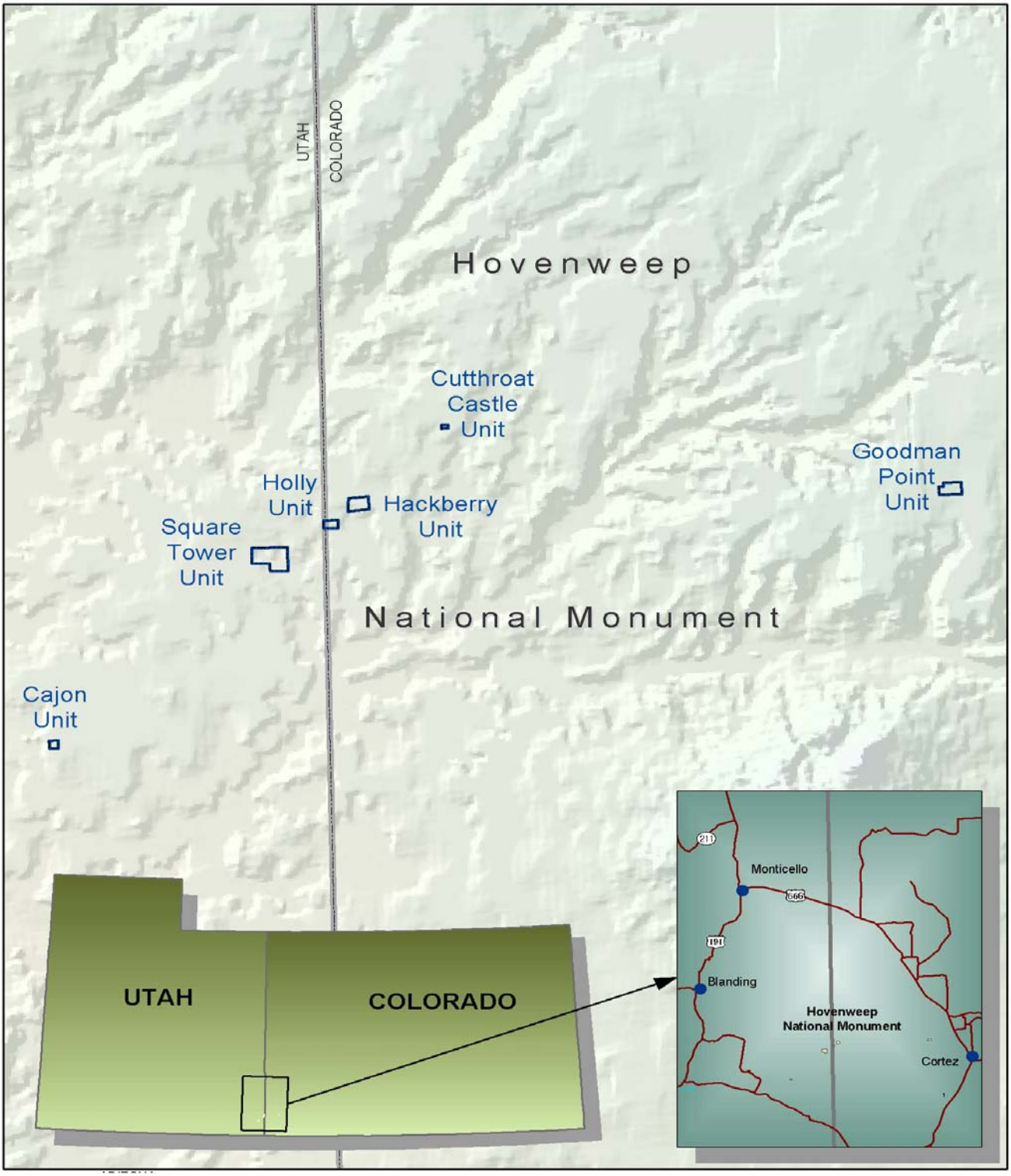


FIGURE 5. Map and Location of Hovenweep National Monument.

General Description

The natural environment at Hovenweep National Monument is characterized by rugged topography, with small canyons divided by narrow mesa tops. The primary geologic formation is Cretaceous-age Dakota Sandstone. Shallow to deep aeolian soils are found on the mesa tops, with shallow colluvium on the canyon slopes, and shallow to deep alluvium in the canyon bottoms. While permanent water sources are limited, a few springs and seeps located at the canyon-heads produce water year-round. Residual water trapped in potholes or flowing in washes after rains or snowmelt is seasonally available.

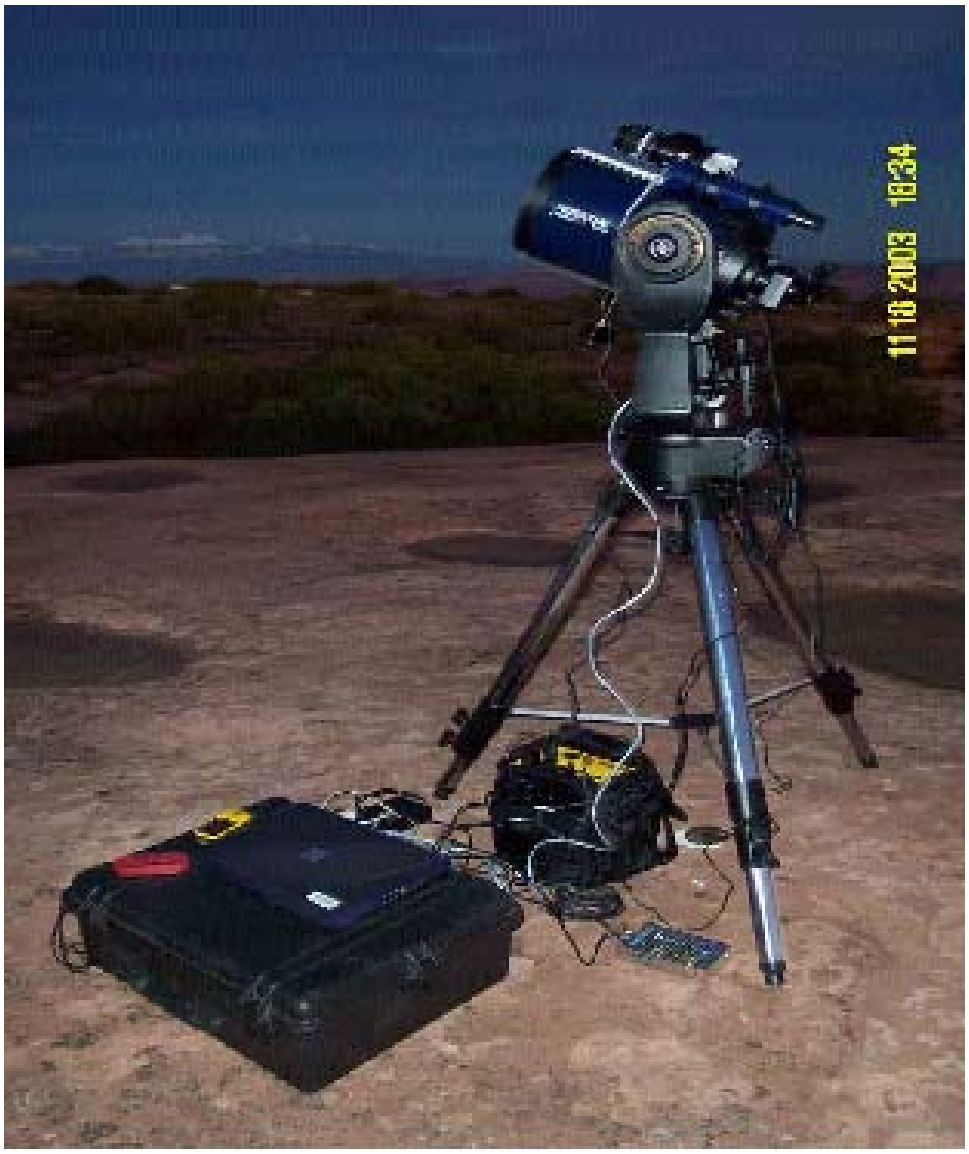
Hovenweep is on Cajon Mesa, which covers approximately 300 square miles on the Colorado-Utah border near the Four Corners. The mesa extends from the base of the Southern Rockies southwest to the San Juan River. All of the canyons have seasonal or ephemeral streams, which flow into the San Juan River. Permanent springs or seeps are common at canyon-heads and along arroyos where the streambed contacts aquifer strata (Litzinger 1976a). Although the topography is fairly uniform, variations in rainfall, soil type, and plant associations occur through minor elevation and drainage pattern differences. The northern half of Cajon Mesa is higher, cooler, and wetter, supporting a pinyon-juniper forest. This part of Cajon Mesa is agriculturally very productive, supporting dryland pinto beans, winter wheat, and alfalfa. Most of Hovenweep's units are in the juniper-sage and sage areas in the mid-section of the mesa.

Climate

The climate in this high desert environment is dry, with an average of 12 inches of precipitation per year. Moisture arrives in two pulses, in winter-spring and in summer. About 25-30 percent of the moisture occurs in summer because the area lies within the northern sector of the Sonoran Summer Monsoons. June is the driest month. Winter-spring moisture makes up about 65-70 percent of the total moisture and is the result of Northern and Southern Pacific storms that sweep across the landscape at that time. Temperatures range from winter lows of –10 to 0 degrees Farenheit to summer highs of 100 to 105 degrees Farenheit, with a mean annual temperature of 52 degrees Farenheit. The evaporation potential is very high. In winter, when evaporation is low, any available moisture is able to penetrate the soil and is thus stored and made available to plants during the high drought stress period of late spring and early summer (Litzinger 1976a).

2. METHODS

The Night Sky Monitoring Program is new and evolving at both the Southeast Utah Group and national level, thus we are continuously improving protocols and equipment. New technology arises or new ideas based on ongoing field experience are presented and the procedures evolve. Following is a description of the methodology and equipment we used up to January 2004 to attain baseline night sky data sets for park units of the SEUG.



Equipment set-up for night sky monitoring at Grandview Point in Canyonlands National Park.

2.1 FIELD PROTOCOLS FOR NIGHT SKY MONITORING

The basic system includes a **Meade LX200GPS** telescope and **FLI MaxCam** CCD camera in conjunction with **Astronomer's Control Program (ACP), SkyMap Pro, and MaxIm DL** software packages. All equipment is stored at SEUG headquarters in Moab, Utah.

2.1.1 Equipment List:

TABLE 1. Equipment List for Night Sky Program

Large Pelican Case
- Meade LX200GPS
- Autostar II handbox
- Autostar holder
- Diagonal prism
- 26mm plossel eyepiece

Medium Pelican Case
- Carpenters level
- Aluminum rail
- 2 lb. counter weight
- DC to DC converter
- 11mm Nagler eyepiece
- Meade finder scope
- GPS Unit
- Weather Meter
- AC to DC outlet adapter
- Telescope power cord
- RS232 power cord (connects telescope to laptop)
- USB to serial adapter cable (assists in connecting the telescope and laptop)
- Allen key set

Small Pelican Case
- FLI MaxCam CCD camera
- 35mm Nikon lens
- Johnson V green filter
- Camera interface
- Camera attachment kit
- Telephone cord (connects camera to interface)
- Camera power cord (2 pieces)
- Off-white USB power cord (connects computer to camera interface)
- Silver inverter
- DC adapter for inverter
- Lens wipes
- Circle bubble level

Laptop Case
- Laptop
- Laptop DC power adapter
- Extra battery or
- CD drive

Small Black Plastic Case
- Extra eyepieces
- Extra cords
- Extra screws and washers
- Wrench
- Extra batteries for GPS unit
- Rings (for optional manual focuser for telescope)
- Flashlight

Batteries
- Two Kendrick 12 Volt batteries
- Accompanying Battery chargers

Gray Bag
- Meade LX200 tripod

Miscellaneous
- Flashlight
- Red flashlight
- Limiting magnitude star charts
- Bortle sky class chart
- Data sheets
- NPS radio
- Pencil and pen
- Canned air
- Chair
- Warm clothes
- Hot chocolate or coffee
- Snacks

2.1.2 Office Procedures - Before Data Acquisition:

Performing these steps in the office before going out into the field will prevent unnecessary waste of battery power while in the field. It will also prevent your fingers from freezing before the data set even begins.

Step 1:

On the laptop, find the file for the location that will be monitored, i.e. **CANY\grandview** for Grandview Point in Canyonlands National Park. In this file make a new folder with the current date, Example: August 27, 2003 would be named **030827**. If more than one data set will be acquired in a single night name the folders 030827a, 030827b, etc. Use the start date of the monitoring night. For example, if a sample started at 1am on August 28, the folder date would still be 030827.

Step 2:

Go to the start menu under programs and accessories and open WordPad. In WordPad open the field script that will be used to acquire the dark and bias frames, ex: darks8.vbs. In the written part of the script scroll down until the following command is found.

Camera.SaveImage

("C:\Night Sky Data 2003\field data 2003\HOVE\031028\dark1.fit")

Highlight the site name and date. In this case "HOVE\031028" would be highlighted. Go to the edit menu then replace. This allows you to replace this information with the current information, "CANY\grandview\031127", then hit the *replace all* command. This scans the entire script and replaces this information in all the save image commands. Repeat this process for any dark scripts that may be used on a particular night. Make sure to save the changes before you exit the file. This only pertains to the scripts used for dark and bias frames; the light frames will be saved in a different folder entirely and will require moving after they are acquired.

NOTE: This step is extremely important!!! If this step is ignored it will overwrite and erase an entire set of existing data when a script is run. Make sure the destination folder is empty

Step 3:

On the laptop, click the right button on the mouse pad. Go to the properties menu in the window that appears. Under the ***appearance*** tab a new window will pop up. About halfway down on the left is a ***Scheme*** option. Click the drop menu and select ***night vision***. This will dim the computer screen to a night friendly red color, which will have less impact on the data. Click the ***apply*** command, and then close the window.

Step 4:

Perform an equipment check before leaving for the field to make sure you haven't forgotten anything. Make sure the Kendrick batteries and Laptop batteries are fully charged. Check sunset time, moonrise times, and constellations. You are now ready for a night of data collection.

2.1.3 Field Set-Up Procedure

Step 1:

Locate the site to be monitored.

Use the GPS unit or any other descriptive information, photographs, or field markers to find the exact location of the site to be monitored. Once at the site the first thing you should do is use the weather meter and get a reading on the relative humidity. If it is over 70 percent you should not collect data. If it is under 70 percent carry all of the equipment out to the site, including three pelican cases, one small plastic case, the gray bag, the laptop case, and at least one of the 12V batteries.

Note: If you choose to use the shoulder strap while carrying the batteries, wrap one arm around the battery and hold it from the bottom. This should prevent a mess if the shoulder strap breaks, and prevent the lead/acid battery from falling.

Step 2:

Set up the tripod (see FIGURE 6).

It is important to set up the tripod in the same place on every visit to a site. If possible, set up the tripod on firm ground; otherwise, push down on the top of the tripod base to make sure it is firmly in place. Be careful to fully separate the three legs of the tripod. Then loosen all six lock-knobs at the bottom of the legs and raise each leg about 6 inches. Then tighten one of the lock-knobs on each leg.

Note: Raising the legs will make it easier to center stars located high overhead during the alignment process.

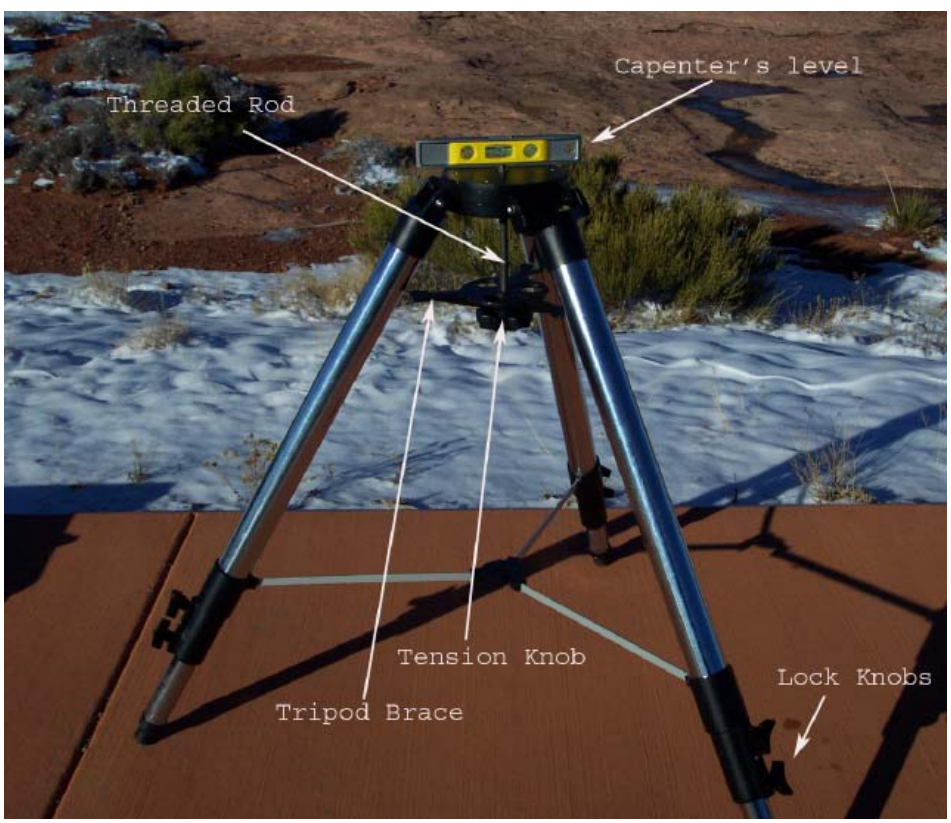


FIGURE 6. Description of the LX200 tripod.

Step 3:

Level the tripod.

Place the carpenter's level on top of the tripod base and slightly raise or lower the tripod legs until level. Turn the level 90 degrees and level the tripod again. Double-check both positions and re-level as necessary. Once the tripod is precisely level, tighten all 6 lock-knobs so there is no movement during the data collection process.

Step 4:

Install the telescope on the tripod.

Open the telescope case and remove the Autostar handbox, the handbox holder, diagonal prism, and the 26mm eyepiece. Set them aside. Remove the foam surrounding the telescope and mount. Carefully lift the Meade LX200GPS telescope from the pelican case and place it on top of the tripod. Make sure to align the threaded rod on top of the tripod with the central hole in the bottom of the base of the mount. Once the telescope is sitting properly on the tripod, move the base of the mount so **the control panel is facing south**. The North Star is a good tool to use for this purpose. Now tighten the tension knob so that the tripod brace contacts tripod legs evenly. This should firmly secure the telescope. Place all the foam pieces back in the case. Remove the dust cover from the front of the telescope and place it in the case as well.

Step 5:

Adjust the telescope.

Adjust the telescope so it is in its approximate home position **(see FIGURE 7)**. To do this loosen the declination (DEC) lock on the right arm of the mount and position the telescope horizontally at about 0 degrees declination, then tighten the DEC-lock again. Next loosen the right ascension (RA) lock at the base of the mount and point the telescope optical tube north. Tighten the RA-lock. Now you are ready to start assimilating.

Note: There is also a RA slow-motion control on the base of the mount and a DEC slow-motion control on the back of the right arm of the mount. These can be used for fine-tuning when centering an object during alignment.

Step 6:

Attach telescope accessories (see FIGURE 7).

Slide the finder scope into the plastic rail located at the back left on top of the optical tube, and remove the lens cap. Remove the film case from the opening in the back of the optical tube and put the diagonal prism in its place. Tighten the thumbscrew to secure the diagonal. Insert the 26mm plossel eyepiece into the diagonal and tighten the thumbscrews. Attach the Autostar holder to the handle bar on the left arm of the mount. Insert the Autostar II handbox into the holder.

Step 7:

Attach the counterweight.

Find the 2-lb. counterweight and slide it into the rail on the bottom of the optical tube. Position it to be just opposite of where the main body of the camera will rest on the top of the optical tube. Tighten it in place.

Note: Make sure the Dec-lock is tight. Otherwise the optical tube could swing down fast because of the added weight, perhaps causing damage to the gears or the mirror.

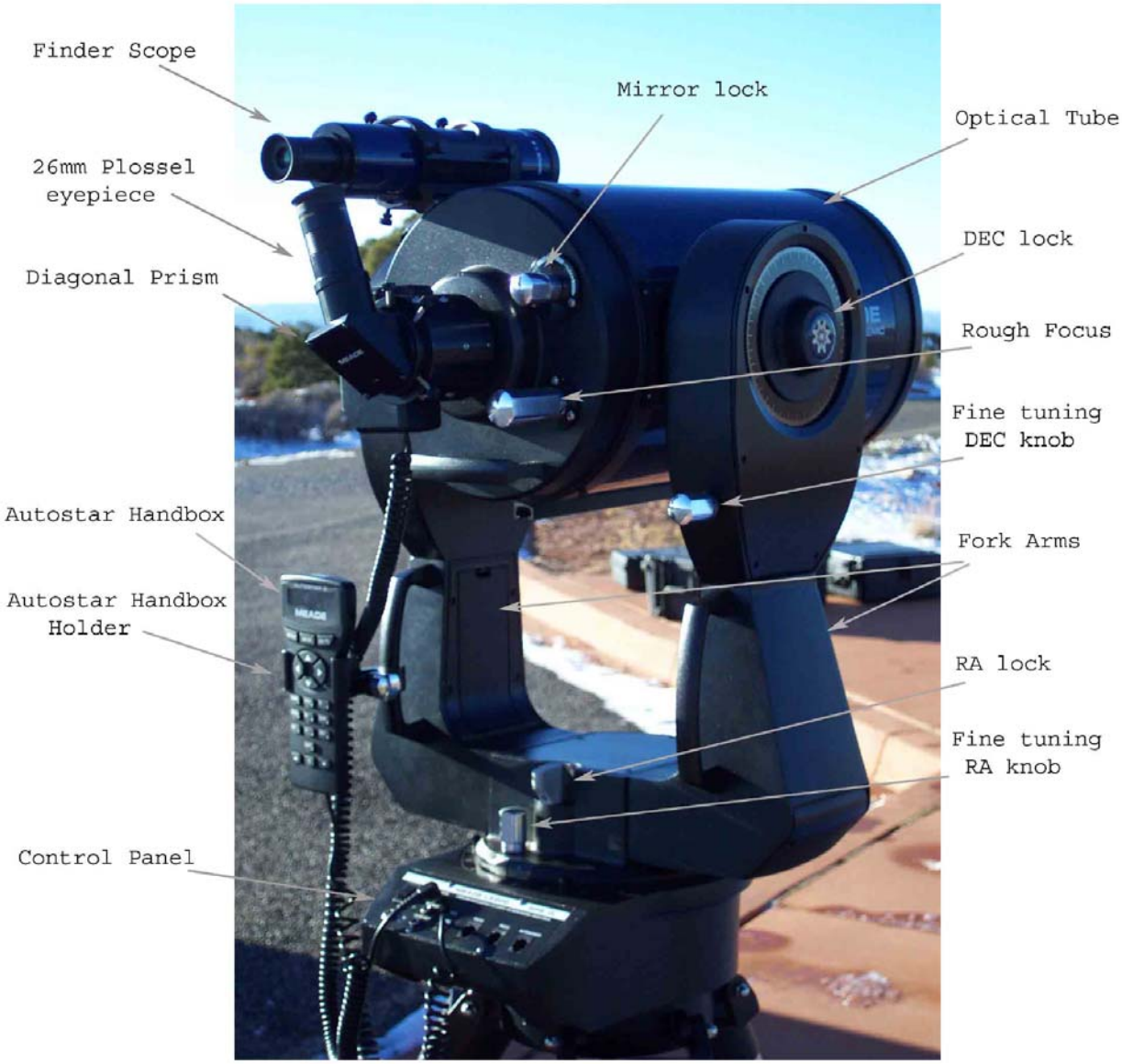


FIGURE 7: Meade LX200 GPS telescope and accessories

Step 8:

Position the power source.

Position the 12V battery on the ground just below the telescope control panel on the south side. The telescope, camera, and laptop will eventually all be plugged into the battery. If all three of these things are not turned on until they are needed, the battery, when fully charged, will last long enough to collect two data sets back-to-back. When deciding whether to plug each item into a 10Amp or 5Amp slot, you should consider which piece of equipment is going to have the highest draw. There should be enough power for the equipment to draw its maximum power if needed. The laptop has the highest draw; it can draw up to 7Amps. Therefore it should be plugged into a 10Amp slot. The camera has the second highest draw at 4Amps. It could be plugged into a 5Amp, but a 10Amp slot is recommended to be on the safe side. The telescope has the smallest draw at about 2Amps and therefore should be plugged into a 5Amp slot.

Step 9:

Attach various cords.

Plug the Autostar handbox into the port on the control panel that is labeled **HBX**. Unwind the focuser cord and plug it into the port-labeled focus. Get out the telescope power cord and plug one end into the **12vDC IN** port and plug the other end into a 5Amp slot in the battery. Get out the **RS232** cord and attach the end with the telephone jack into the control panel in the first port labeled **RS232**. This is right next to the port the handbox is plugged into. Attach the other end to the **USB to serial adapter** cable. There is also another adapter connected to this cable that the cord will screw into. The USB portion of the cable will connect into either USB port at the back of the laptop computer. **Do not turn on the computer yet**. When everything is plugged in, turn on the power switch on the telescope control panel. This will give the handbox and internal GPS some time to initiate while you are assembling the camera.

a.

b.

FIGURE 8. Camera attachment kit (a) and placement of washer (b).

Step 10:

Attach the CCD camera.

Get out the aluminum rail, the camera, and the camera attachment kit **(see FIGURE 8)**. Find the thickest and fattest screw and the larger of the two Allen keys. Align the hole in the bottom of the camera with the hole on the flat side of the aluminum rail that is marked with arrows in permanent marker. Look for two tiny holes in the side of the rail, and place the front of the camera pointed towards them. When all is in place, insert the screw in the bottom of the rail to tighten the camera in place. When tightening the screw, try to get the rail as straight as possible, which will help when aligning the camera. Find the thumbscrew and washer. Set the rail on top of the optical tube, aligning the rail with the screw holes on the top of the tube. Attach the thumbscrew to the rail at the hole to the back of the camera. Tighten it down as well as you can. Take out the last screw, the accompanying Allen key, and the large metal washer. Attach the screw to the rail and optical tube in front of the camera. When everything is aligned, place the washer under the small groove in the rail and make sure that the end of the washer reaches to the end of the optical tube. When all is in place tighten down the screw as tight as you can with the Allen key.

a.

b.

FIGURE 9. The camera, 35mm lens, and filter (a). Focus points on the Nikon 35 mm lens (b).

Step 11:

Attach the 35mm lens and green filter.

Once the camera is securely in place, take out the 35mm lens and the green filter. Make sure the lens and filter are free from dust or fingerprints. If they need to be cleaned use wipes that are specifically meant for cleaning lenses.

NOTE: Do not use a paper towel, a shirtsleeve, or any other fabric for cleaning, as they may scratch the lenses. These expensive lenses have an extremely fragile coating.

Attach the filter to the end of the lens and attach the lens-filter set to the end of the camera. Once they are tightly on the camera check that the lens is at f-stop 2 and it is defocused to the line that is marked with white-out and a green line **(see FIGURE 9)**. Approach the line from an infinity focus position. If you forget to put the lens in its proper place and it is shifted by a large amount, you will notice it when you take your first pictures. However, if the lens is shifted by a small amount only, it will be hard to notice until the data is processed, so it is very important to check the position of the lens.

Step 12:

Adjust work space.

In order to give yourself some room to maneuver, move the large pelican case to the left side of the12V battery, back about two feet Place the laptop on top of this case. Take out the DC power adapter cord and plug one end into the laptop and the other end into a 10Amp slot in the battery. **DO NOT turn on the laptop yet**.

Step 13:

Attach additional cables.

Take out the gray telephone cord and the camera interface. Plug one end of the telephone cord into the left side of the camera and plug the other end into the camera interface, in the port-labeled camera connection. Take out the off-white USB cord and plug one end into the laptop and the other end into the port on the camera interface labeled USB port.

Step 14:

Attach the DC to DC converter.

Take out the DC to DC converter. Plug one cord into the left side of the camera and plug the other cord, with the DC adapter into a 10Amp slot in the battery. Then place the converter in a safe location on the ground next to the battery. Once this is plugged in it will power up the camera. At this time the camera will automatically start its cool down process.

a.

b.

FIGURE 10. The DC to DC converter (a) and the power inverter with a DC adapter cable (b).

Note: A silver inverter with a DC adapter cord and a camera regulator power cord are also included in the equipment set (see FIGURE 10). The DC to DC converter is the preferred piece of equipment to use, but if something should go wrong with it, the silver inverter can be used as a back-up. To use these instead, unscrew the black and red knobs on the back of the inverter and attach the two cords on one end of the DC adapter to these screws, making sure the wires correspond to the proper color. Tighten the screws back in place. Plug the other end of the DC adapter into a 10Amp slot in the battery. Get out the camera power cord, which is in two pieces. Attach the two cords. One end plugs into the camera and the other end has a regular 3-prong head that plugs into the silver inverter. Flip on the switch on the front of the inverter to power up the camera and start the cool down process.

Step 15:

Focus adjustments on the telescope.

Set the focus knob to make it easier when you are ready to use the telescope. The auto-focus system is easier to use if it is positioned halfway to its fully extended point. On the Autostar keypad, the **#4 button** is also labeled ***focus***. Press this key to move the focuser out from the rear of the optical tube, using the left and right arrow keys at the top of the keypad. Watch carefully as you extend the focusing ring out fully. Make a mental note of the halfway point and move the focusing ring back to it. Center the telescope on any star. There are two knobs located on the rear of the optical tube. One locks the primary mirror in place and the other is a manual focusing knob. When the telescope centers on a star, unlock the mirror knob and use the manual focus knob to get a rough focus. Tighten the mirror knob once more, then use the auto-focus function on the keypad to get a precise focus. This step will help the alignment process flow smoothly. Then hit the ***mode*** **button** to get out of focus mode.

Step 16:

Turn on the laptop computer.

When all is in place, turn on the laptop and let in run through its start-up process. Make sure the telescope is in its approximate home position. You are now ready for the data acquisition process.

2.1.4 Data Acquisition Process

Step 1:
Align the telescope.

A. Open the **SkyMap Pro** software and make sure it is located around the North Star. On the toolbar on the left of the window click on the icon of the earth. When asked to set the location, put in the latitude, longitude, and elevation as it is shown on the hand held GPS. On the toolbar at the top of the window click on the icon that looks like a red bulls eye. A circle will appear on the screen that shows what can be seen through the finder scope. Move the circle so it is centered on true north. True north is located at the cross-section nearest Polaris and this is where the telescope must be centered. Once true north is in the center of the circle, click outside of the square, which will allow you to draw a square the size of the window you would like to see. This will zoom in on the section of the sky you are interested in. Once you have zoomed in, click on the telescope icon on the toolbar, to the left of the bulls eye. This will put a circle in the middle of the finder field of view that represents the eyepiece field of view. Center this circle on true north as well. You may increase the magnitude of the sky to better see the star pattern. To do this click on the icon on the toolbar that looks like a compass face. Now at the telescope, release the RA-lock and DEC-lock and use the finder scope to center the North Star in the eyepiece. Loosely clamp both locks again. Now going back and forth from the SkyMap screen and the finder scope, use the star patterns to find where you believe true north is located. Use the RA and DEC fine-tuning knobs to center true north in the finder scope. Now take a look at the star pattern on the SkyMap screen that you should see in the eyepiece and go to the eyepiece and center true north in the eyepiece. When you are satisfied the telescope is pointed as close to true north as possible, lock the RA fine-tuning knob. Then bring the optical tube down to 0 degrees declination and place the small circle bubble level on top of the aluminum rail to find its leveling point in declination only. Lock the DEC fine-tuning knob. Check that both knobs are locked tightly.

B. On the Autostar handbox select the two star alignment method (Telescope>Setup>two star align). It will prompt you to find north and level. Since you have already completed these tasks in the above step, you can press *enter*. Next it will ask you to center a star. Select a bright star that you know and center it using the top arrow keys on the handbox, press *enter*. Pressing the *speed* button followed by a number key can change the slew speed. Number 6 (0.5 degrees per second) usually works well. Again the handbox will ask you for a star to center. Try to pick a star on the opposite side of the sky from the first star, center it and press *enter*. If the stars you pick are more than a degree off of center, leveling and north alignment should be repeated. If the alignment worked you will hear a beep and the handbox will display the message "alignment successful".

Note: There are many different options for aligning the telescope, but after much experimentation and frustration in the field, the two-star align has proven the only reliable method. Therefore it is recommended that it always be used, despite the extra time it takes in setting up.

C. Close the **SkyMap Pro** software on the laptop. Then using the *go to* command, slew the telescope to a few objects in the sky to make sure the alignment worked. It is important once the telescope is aligned that you NOT LOOSEN either axis lock. Use the *go to* function to move to objects in the sky.

D. Slew the telescope back to the North Star and make sure it is centered. Once it is centered hold down the *enter* button for a couple of seconds and let go. You should hear a beep and the handbox will prompt you to center the star. This should already be done and you should press the *enter* key again. This will sync the telescope to the North Star and the handbox will display the message "synchronized." This is just an extra precaution to make sure the telescope is aligned.

Step 2:

Set up observatory in ACP and synchronize computer's clock. The computer, ACP, and the telescope must match in order for everything to be aligned and for the telescope to slew accurately.

A. To set up the observatory, open ACP. On the toolbar click on ACP and select the *preferences* option from the drop-down menu. Once in preferences there are eight tabs to choose from. Select the *observatory* tab. Enter the name of the site; and from the GPS enter the latitude, longitude, and elevation in meters. The temperature field is unecessary. Click *OK* to set this information as the **current observatory**. Minimize the ACP window, but do not close it.

B. Double-click on the time in the lower right of the computer's window. Confirm that the date and time zone are correct. Then set the hour, minutes, and seconds of the clock as close as possible to that on the GPS (within a couple of seconds).

Step 3:

Align camera.

A. Make sure the telescope is centered on the North Star. Open the MaxIm DL software and on the toolbar click the camera icon to connect to the camera. Once the *MaxIm CCD* control window opens, click *connect* to establish a link between the computer and camera. At this point make sure the proper camera name, Fingerlakes, is displayed. Check the cool-down status of the camera. Select the *expose* tab and set the exposure time to 2 seconds. Click on the *expose* command to take an image. The North Star should appear roughly in the center of the frame; this is when you find out if you completed Step 10 in the set-up procedure correctly. If the washer was placed correctly, the camera should not need to be shifted up or down, and if the camera was attached to the aluminum rail straight it should not need to be shifted left or right. However, these steps are difficult, so there is usually some adjustment needed. To see how close you are, center the mouse over the top of the North Star and read the numbers in parentheses on the task bar at the bottom of the screen. The center of the image is (128, 128). If the star is within one or two pixels of the center, leave it. If it is more than one or two pixels off, move the mouse to see in which direction the camera needs to be shifted. To shift the camera up or down you need to adjust the position of the metal washer under the front of the aluminum rail. To shift the camera left or right you will adjust the actual position of the camera on the aluminum rail. Move the camera or the washer in small increments and expose an image after each adjustment to see if you are moving in the right direction and how much more movement needs to take place. After the camera is aligned, check to make sure that it is still firmly in place.

Note: A small nudge is all that is needed. If you move the camera too much, you will spend a lot of time moving it back and forth. Or worse yet, the camera will loosen too much from the screw holding it in place and it will shift during the imaging process.

Check to confirm that the image is focused. After the camera is aligned, go back to the set-up tab in the MaxIm CCD control window and disconnect the camera, then close MaxIm.

Step 4:
Start imaging.

A. Maximize the ACP window again and under the *camera* option on the toolbar select *connect* from the drop-down menu. This should open MaxIm DL and connect the camera to the ACP software. Again make sure MaxIm is showing Fingerlakes as the type of camera.

B. Under the *telescope* option on the toolbar select *setup* from the drop-down menu and confirm that the telescope selected is the Meade LX200 and Autostar. After this is verified select the *connect* option from the telescope drop-down menu. You are now ready to collect data.

C. First collect the dark and bias frames. To run a script, on the top right in ACP, there is a script window. Hit the *browse* command to pull up the appropriate script, such as "darks8.vbs." On the bottom right click on the *main* button, which will execute the script. Just above the *main* button is the console output section. This section will show the command lines as the script executes. If there are any errors while running the script, they will also show in this area.

D. After dark and bias frames are collected repeat this process but this time run the script that will take the light images, "lx104.vbs." This is the newest script for the LX200; it takes 104 images to cover the entire sky. After you click on the *main* command, this script will prompt you to enter some information that will be saved to the FITS header of each image. The images will be saved under "C:/images/raw" and they need to be moved out of this folder and into the proper date folder at the end of the data acquisition. If you do not move the images you run the risk of overwriting them the next time you run the script. However, at the beginning of the script it will ask you if you have done this and it will give you 20 seconds to abort if old images need to be moved. During the first two rows of images, watch the readings for RA and DEC on the upper left of the ACP window. Confirm that the telescope is slewing to the proper coordinates. Stay low enough to the ground that you will not get in the way of any of the images. This is most likely during the first two rows of images. The entire imaging process should take about 55 minutes.

Note: While the telescope is slewing around to collect all the images pay close attention to all of the cords. If they are not positioned properly they may get tangled under the arms of the telescope mount, which could either unplug the camera or cause the telescope problems in accurate positioning.

E. Be cautious of flashlights, car headlights, etc. Light within a 90^0 cone of where the camera is pointing can cause lens flares and other internal reflections which will ruin the frame. The laptop computer screen should be dimmed as much as possible and shrouded as the camera points near it, especially during the first and lowest run of imaging.

Step 5:
Collect the limiting magnitude data.

After watching the equipment successfully run through the first two rows of images, you have time to collect the limiting magnitude data. This data will give an estimate of the sky quality based on visual observations, rather than digital. Detailed methods were organized by Chad Moore and are available from the NPS National Night Sky Team**.** You will need the limiting magnitude star charts, Bortle sky class chart, a pencil, the data sheets, the GPS readings, the weather meter, and a red flashlight. Because you will be using the flashlight quite a bit, it is recommended that you move a short distance away from the telescope. **(See Appendix 1 for a copy of the data sheet, the Bortle sky class and a discussion on the methods of limiting magnitude.)**

A. Turn on the GPS and the weather meter, and set them aside nearby.

B. Find a familiar constellation, preferably high in the sky. Then find the limiting magnitude chart for that constellation.

C. After looking at the chart and becoming familiar with the stars in the constellation, try to find the dimmest star you can see, or the star with the highest value of magnitude. It may take several minutes for your eyes to dark-adapt enough to see very faint stars and you may need to look at the chart several times, so use the red light. Be as patient as possible and take your time, it takes effort to see the faintest stars.

D. Once you have determined the magnitude of the dimmest visible stars, use the Bortle scale to find the Bortle Class of the sky.

E. Refer to the GPS and weather meter to complete the upper portion of the data sheet.

Step 6:
After the camera and telescope have finished taking the 104 all-sky images, you are ready to shut down.

A. In some instances the sky may be better for data acquisition after you have taken a first set. In this case, take another data set if it is possible. **Be sure to add another folder and change the path in the script!** If no repeat is necessary, power down the camera. Disconnect the telescope and camera from ACP before closing the ACP window. Verify that all images have been saved in their proper folders. Under "C:/images/raw" check to make sure all 104 images are there, and cut-and-paste them into the date folder with the 15 dark and bias frames. Shut down the laptop. If you have time, have fun viewing with the telescope.

Step 7:
Shut down and pack up. Here are a few things to consider while packing up the equipment.

A. Make sure to retract the focus knob completely into the optical tube, otherwise the telescope will not fit

into its case.

B. Be sure to put everything back in the pelican cases gently and appropriately. The pelican cases work well because of all the extra padding they offer to sensitive equipment. If things are shoved back in the cases and the foam is damaged, these cases are useless in protecting the equipment during transportation.

C. When coiling up cords, be careful not to kink them or coil them too tightly. Cords can break, especially if they become stiff from being exposed to cold temperatures.

2.1.5 Office Procedures – After Data Acquisition

The following must be done as soon as possible at the office after a night of data collection. These steps will make the start-up process easier when it is time to head back out into the field.

Step 1:

Clean and organize equipment.

While the equipment is in use, it is exposed to many elements, such as dust, frost, and rain. Usually, after a night of work the equipment is covered in a fine layer of dust, especially if there was any hint of a breeze. Use a vacuum cleaner to remove dust from the telescope and laptop computer. Use a can of compressed air and carefully clean items including the camera lens, 35mm lens, eyepieces, and laptop. Once everything is dusted off, check that it is in good condition and neatly arranged back in the pelican cases. On the laptop double-check that you have moved the light images from the raw folder to the date folder.

Step 2:

Charge batteries.

Charge both Kendrick batteries and both batteries for the laptop. The Kendrick batteries will be fully charged when the green light is displayed on the battery charger, which can be achieved overnight. To charge the laptop, make sure both batteries are inserted in the ports on the bottom of the laptop and plug it in. These batteries will only charge while the computer is powered up. Other work can be done with the computer while they are charging. Also, check the batteries on the GPS unit and weather meter; replace them if they are low. Batteries should be periodically charged (every two months) when not in use because they slowly discharge with time.

Step 3:

Burn 4 back-up copies of the new data on a CD.

Backing up is extremely important! Many factors that can contribute to losing data, including computer failure, the computer dropped in the field, or over-writing data by running a script. Don't make the mistake of losing a whole night of work by simply failing to follow through with this step. Bring one of the back-up copies home for safe storage in case there is an accident at the office. Send another to the Program Manager of the national NPS Night Sky Team. Keep the third at SEUG headquarters, and the fourth should go to the Northern Colorado Plateau Network.

2.1.6 Trouble-Shooting the Equipment

The following is a checklist of tactics to try when the equipment fails to function properly. The tactics were developed based on difficulties confronted while using this equipment over the past few months. The equipment is very sturdy and generally reliable. However, because of the large amount of equipment, when something breaks it can be extremely frustrating trying to pinpoint the source of the problem. Problems may arise due to a hardware problem, such as a loose cable or frayed cord, or corrupted software, such as a bad download or upgrade. Good luck!

Step 1:
Investigate Possible Hardware Problems.

If the telescope, camera, or computer is not responding properly:

Check the 12-Volt battery and make sure it has a full charge. Also check that the computer's battery is fully charged.

Run through the leveling and alignment process again. The tripod and telescope must be precisely level and the telescope should point as close to true north as possible.

Check for any loose or frayed cables and confirm that everything is plugged in properly and snuggly.

If the telescope loses its position while slewing:

Check to see that the counterweight was not forgotten.

Firmly tighten RA-lock and DEC-lock.

Step 2:
Investigate Possible Software Problems.

If ACP is not working:

From the toolbar in the ACP window go to *ACP>prefernces>observatory*. Make sure the proper latitude, longitude and elevation have been set for the site you are monitoring.

Under the *telescope* option on the toolbar select *set-up* to make sure the proper telescope and properties have been selected. Under properties make sure that COM 1 is selected. Complete this procedure for the camera set-up options as well.

Under the *ACP>prefernces>telescope* tab, make sure the tilt-up limit is set to 90 degrees and the minimum elevation is set at 0 degrees.

Make sure the computer's clock has been set to the clock on the hand-held GPS unit. The telescope clock must also be set to this time. The telescope and computer clock must match for ACP to function properly.

Check that you have the latest version or upgrades installed for the ASCOM driver, MaxIm DL, and ACP software. As you are installing the upgrade or download make sure the proper file size is saved to the computer. In many cases when there has been a software problem it has been a result of a truncated upgrade.

If the script fails while running in ACP:

Look at the *console output* window and scroll up until you find the line that gives the source of the failure. In some cases it is s simple fix, like connecting the telescope or camera. In other cases it might take some investigation, and it could lead back to bad software or bad communication between the telescope and ACP.

If the FLI MaxCam is not working:

Check to see that FLIGrab and FLIUpdate have been installed on your computer. These files should be located under the C drive in a folder labeled Finger Lakes.

If the telescope is not aligning properly:

There are many steps you can take to correct this error. These steps should probably be routinely followed once a year to correct for any slippage that may occur during transportation of the instrument. After each step is completed, power-down the telescope and let it sit for five minutes. Place the telescope in the Alt/AZ home position, then power-up the telescope again and let it sit for five more minutes. You can find all software and instructions on the Meade webpage (listed below).

The first thing to do is to download the newest firmware or upgrade to the Autostar Handbox. Make sure you download the upgrade to the hard drive on your computer and it is the proper size, before you install on the handbox.

Reset the handbox.

Train the home position.

Train drives.

Calibrate sensors.

If the telescope will not point somewhere it is asked and you know it is in the sky you should check the slew limits on the handbox. Go to *Set-up>telescope>Mnt. upper limit & Mnt. lower limit*. They should be set for +90 and –90 respectively.

Step 3:

Get Help.

If you have completed steps 1 and 2, looked over the equipment, and have not been able to find the source of the malfunction, it is time to seek help. The list below are good places to start. All individuals and WebPages listed have been very helpful.

Meade Tech Support: 800-626-3233 or 949-451-1450
www.meade.com, Click on the tech support link on the left of the screen.

The following is an entire webpage devoted to problems with Meade LX200 telescopes. Chances are that someone else out there has had the same problem as you and you may be able to find a post on how to fix the problem. http://www.meadelx200gps.com/tips.html

Robert B. Denny at ACP: 480-396-9700, support@dc3.com

Finger Lakes: www.fli-cam.com/support.htm, 585-624-3760

Dan Duriscoe, NPS Night Sky Team: dan_duriscoe@nps.gov

Chad Moore, NPS Night Sky Team: chad_moore@nps.gov

2.2 DEFINITION OF A COMPLETE BASELINE DATA SET

One of the primary goals of this program is to acquire a representative baseline data set for each of the park units of the Southeast Utah Group. These units include Arches National Park, Canyonlands National Park, Natural Bridges National Monument, and Hovenweep National Monument.

Currently, the definition of a complete baseline data set is an evolving one. To assess what constitutes a true baseline data set, more data must be acquired from a larger range of parks and regions and during different seasons in order to determine precision and number of datasets required. The proposed working protocol is now aiming for a minimum of 5 data sets to be collected from each park, with a goal of 10 data sets as the ideal number. They should be collected in varying weeks throughout the year with the objective that as many data sets as possible are collected in a period with the clearest night sky. In the Four Corners region of the United States this would typically be the winter season, which is defined as November through March. This suggested protocol is based on extinction data taken from the NPS Air Quality Division, which has shown the extinction values are lowest in winter. The NPS Night Sky Team has defined the standard condition as the 20th percentile of extinction values (cleaner than four out of five days). However, collecting data when the opportunity arises is important because there are many natural factors that can interfere with data acquisition anytime during the year, which can include weather conditions, smoke, dust, humidity, and air glow.

2.3 DATA ANALYSIS

Once a complete data set is gathered the light images must be calibrated before they can be processed in ArcView or ArcGIS. This is performed in the **Maxim DL** software. Ten bias frames and five dark frames are acquired on each night just before the light frames are taken. The median of the bias frames must be subtracted from the light frames. A master flat field image must be collected for the camera, lens and filter combination; the flat frame then will be divided into the light frames. Dan Duriscoe has completed a script that will make the image calibration a very simple and quick process that can be completed immediately after collecting the light, dark, and bias frames. A master flat frame has yet to be acquired for any of the camera/lens systems thus far.

After calibrating the light frames they are ready to be stitched together to form a panorama and a polar all-sky image of the site. In the past, the images have been stitched together using ArcView software. However, Dan is currently in the process of writing scripts to run this analysis in ArcGIS software, which we believe will be the preferred software in the future. Currently, Dan is the only individual familiar with this process. Once the images are complete a relative color scheme is assigned to the changing brightness values throughout the picture. The color scheme illustrates the increase in sky brightness in areas of the sky where near and distant cities are located. If sky conditions are fairly dark at a site, on a particular night, certain natural events will also show up on the finished images, like the Milky Way, Zodiacal Light, or auroral glow.

These images are the first of their kind, which means they are baseline photos that represent conditions in 2003 (not pristine), which will be compared to future photos. The NPS Night Sky Team is looking forward to pioneering the data analysis process in the near future. It is our hope to obtain sky brightness values in magnitude. This will allow us to quantitatively define how bright light sources are and compare them to other objects of known brightness. For example, the amount of light measured from Las Vegas as seen from Death Valley is lighting up the sky to the average brightness of Jupiter. We also hope to document how these sources of light change over the altitude of the sky, which would say that the light of Las Vegas extends 15 degrees upward into the sky. Finally, we wish to share this initial information with the public to demonstrate the affect our human-caused light has on the rapidly disappearing dark sky above.

2.4 DATA MANAGEMENT

It is important to safeguard monitoring data associated with this project. With the initiation of the Northern Colorado Plateau Network Inventory and Monitoring Program in 2000, protocols are being established for coordinated and ongoing network-wide management of inventory and monitoring-related data. All Night Sky monitoring data will be incorporated into the network data management framework, which will help ensure the long-term security, compatibility, and accessibility of the data.

All raw data will be copied onto at least four sets of CDs. One set will be stored at the private residence of Angie Richman or Charles Schelz. Another set will be stored in the biologist office at SEUG headquarters and eventually archived with the SEUG curator. The third set will be sent to the national Night Sky Monitoring team. The final set will be given to the Northern Colorado Plateau Network Inventory and Monitoring Program.

3. RESULTS

Night sky in Arches National Park.

3.1 Sites Where Baseline Data has been Collected

Nineteen data sets have thus far been collected in park units of the Southeast Utah Group: six in Arches National Park, five in Canyonlands National Park, four in Hovenweep National Monument, and four in Natural Bridges National Monument (see **TABLE 2**). The current protocol calls for a minimum of five data sets from each park, with the majority of data being collected in a period of time with the greatest clarity. The time of greatest clarity for the Four Corners area of the southwestern United States is typically the winter season.

TABLE 2. Data Sets Collected for Southeast Utah Group as of December 31, 2003

Location	Date	Camera	Exp. Time	LM	Bortle Class
Arches NP, Balanced Rock, Lat: 38 42 10.1, Long: -109 34 00.3					
1.	Oct 13 2001	Apogee	10 sec	X	X
2.	June 3 2003	Apogee	8 sec	X	X
3.	Aug 26 2003	MaxCam	8 sec	6.9	2
4.	Sept 3 2003 (2sets)	MaxCam	12 sec	6.8 – 6.9	2
5.	Sept 29 2003	MaxCam	12 sec	6.8	3/2
6.	Dec 18 2003	MaxCam	10 sec	6.7	3
Canyonlands NP, Buck Canyon					
1.	Oct 10 2001	Apogee	15 sec	X	X
Canyonlands NP, Grandview Point, Lat: 38 18 37.5, Long: -109 51 29.7					
2.	Oct 13 2001	Apogee	15 sec	X	X
3.	June 1 2003	Apogee	8 sec	X	X
4.	Aug 29 2003 (2 sets)	MaxCam	8 sec	7.0	2
5.	Nov 18 2003	MaxCam	10 sec	6.9	2

TABLE 2 (cont.). Data Collected for Southeast Utah Group as of December 31, 2003

Location	Date	Camera	Exp. Time	LM	Bortle Class
Hovenweep NM, Mound near VC, Lat: 37 23 17.9, Long: -109 04 34.2					
1.	June 5 2003 (2 sets)	Apogee	8 sec	X	X
Hovenweep NM, Field Site, Lat: 37 23 19.1, Long: -109 06 45.9					
2.	Sept 23 2003 (2 sets)	MaxCam	8 sec	6.7	3
3.	Oct 28 2003	MaxCam	8 sec	6.7	3
4.	Dec 17 2003	MaxCam	8 sec	6.9	3
Natural Bridges NM, Loop Road, Lat: 37 36 31.3, Long: -109 59 11.5					
1.	June 4 2003	Apogee	8 sec	X	X
Natural Bridges NM, Solar Building Roof, Lat: 37 36 34, Long: -109 58 44					
2.	Sept 25 2003	MaxCam	12 sec	7.1	2
3.	Nov 17 2003 (2 sets)	MaxCam	10 sec	7.1	2/3
4.	Dec 16 2003	MaxCam	10 sec	6.5	3

NOTE: Data sets collected on the same night are counted as one data set.

3.2 DISCUSSION OF PRELIMINARY RESULTS

The primary objective of our work has been to acquire baseline data on the sky quality in each of the four units of the Southeast Utah Group. Despite the arduous nature of this work, finicky equipment, and constant upgrades we have been fairly successful in accomplishing our objective. All data sets were obtained with a Meade LX200 GPS telescope, FLI MaxCam CCD camera (Apogee camera used sometimes), a Nikon 35mm lens set at f/2, and a green "Bessel V" filter. Images were obtained using SkyMap Pro, MaxIm DL, and ACP3 software. Visual observations in the form of general weather data, limiting magnitude estimates and Bortle Sky Class measurements were also gathered for each night of data collection **(see APPENDIX 1 for visual observation methods)**. Light, dark, bias, and flat field images will be calibrated in MaxIm DL. Then using ArcGIS software they will be mosaiced into panoramic and all-sky polar views. A master flat image must still be acquired to fully calibrate and process the images.

Sky brightness values in magnitudes per square arc-second have been calculated based upon an instrument constant of 16.42. This instrument constant was arrived at after analysis of previous data sets and was corrected with an offset of –0.24 magnitudes. The offset was determined from side-by-side comparisons with Lowell observatory's photoelectric photometer mounted on the 16-inch telescope on Mars Hill in Flagstaff, Arizona. Preliminary results from these monitoring efforts indicate that the sky brightness near the zenith at Canyonlands (21.8) and Natural Bridges (21.7) locations were near the theoretical natural (unpolluted) level of 21.9 magnitudes per square arc second in V-band. The sky at Arches and Hovenweep, unfortunately, are slightly degraded at 21.4 magnitudes/square arc-second. Analyzing the images of the sky closer to the horizon revealed some sources of light pollution from distant cities and towns that are significantly affecting the sky quality at

Hovenweep and Arches, and to a lesser degree at Canyonlands and Natural Bridges.

The night sky is a resource in the Southeast Utah Group of parks, and the skies here are some of the darkest in the National Park Service systemwide. This resource should be addressed in management plans and promoted through interpretation efforts. Those who visit these parks are in a unique position to see the night sky in its original pristine state. Many dark sky opportunities are fading or encumbered by light pollution in other parks. Tragically in our present day, only about one percent of parks within the system are free of light pollution

TABLE 3. Sky Brightness in Magnitudes Per Square Arc-Second in V-Band

PARK	THEORETICAL CLEAR LEVEL	MEASURED SKY BRIGHTNESS LEVEL	% LOSS*
Arches National Park	21.9	21.4	50
Canyonlands National Park	21.9	21.8	10
Hovenweep National Monument	21.9	21.4	50
Natural Bridges National Monument	21.9	21.7	20

*** Percent loss is the difference between theoretical and measured light levels. Each 0.1 mag. change roughly corresponds to a 10% difference.**

Arches National Park, Balanced Rock

This site is generally quite dark, except for the glow coming from the town of Moab, Utah, 10 miles to the south and the glow of Grand Junction, Colorado, 75 miles to the northeast. Unfortunately, the glow from Moab washes out the Scorpius Milky Way and extends15 degrees altitude and encompassing roughly 15 degrees of azimuth. Despite the large impact from these two major light sources, the sky above Arches is typically a 6.8/ 6.9 limiting magnitude and a Bortle Class 3.

Canyonlands National Park, Grandview Point

The view of the sky from Grandview Point is essentially unobstructed and nearly pristine. The most significant light sources that can be seen from Grandview Point at night appear to be the towns of Blanding and Monticello, Utah, to the south, the town of Moab, Utah, to the east and the town of Green River, Utah, to the north. There are a few secondary light sources that can also be seen, including the junction at La Sal and the traffic lights from I-70, Highway 191, and the recreational roads in the Needles District of Canyonlands. However, all of the light sources are far enough away from Grandview Point that a limiting magnitude of 7.1 and a Bortle Class of 2 are usually recorded at this site. These numbers indicate that this is one of the finest night sky sites in the National Parks

Natural Bridges National Monument, Solar Building

The visual appearance of the sky from this location is stunning; Natural Bridges has the darkest sky of all four parks. While this is undoubtedly partly due to the location's topographic position, surrounded on three sides by mountains and plateaus so that the horizon is not clear, there are no primary sources of light pollution to affect this sky. The only light sources are secondary light sources, which are the Cortez, Colorado, and Shiprock, New Mexico, area to the Southeast and the town of Kayenta, Arizona, to the Southwest. It was assumed before data was collected at Natural Bridges that the town of Blanding, Utah would have an impact on the sky, but from the

solar building the light from Blanding is mostly blocked by the Bear's Ears, a prominent feature of the eastern horizon. Actually the most significant light source to be seen from the top of the solar building are the housing, maintenance yard, and visitor center lights within Natural Bridges. Car headlights traveling on Highway 95 and into the park show up in some images.

However, these light sources do not have a large impact on the sky. The appearance to the naked eye of the Scorpius Milky Way easily fit Bortle's description for Class 2 with intricate detail resembling veined marble, and the sky is quite dark to within 15 degrees of the horizon in all directions. With these conditions a limiting magnitude of 7.1/7.2 and a Bortle Class of 2 or 1 are reliably measured at Natural Bridges. This is a very dark and pristine sky worthy of aggressive protection.

Hovenweep National Monument, Square Tower Unit

Hovenweep has the most impacted sky of all four parks; twelve light domes can be seen consistently around the horizon. There are quite a few primary sources of light pollution affecting this sky, including the towns of Monticello, Blanding, Bluff, Aneth and Montezuma Creek in Utah, Shiprock through Farmington in New Mexico, and Cortez and Dove Creek in Colorado. The secondary light sources are coming from neighboring smaller reservations towns including Red Mesa, Arizona, Towaoc, Colorado, and White Mesa, Utah, and from the individual yard lights on private residences. With these conditions a limiting magnitude of 6.6/6.7 and a Bortle Class of 3 or 4 is generally measured at Hovenweep.

3.3 MONITORING SITES, RESULTS, AND DESCRIPTIONS

3.3.1. ARCHES NATIONAL PARK BALANCED ROCK

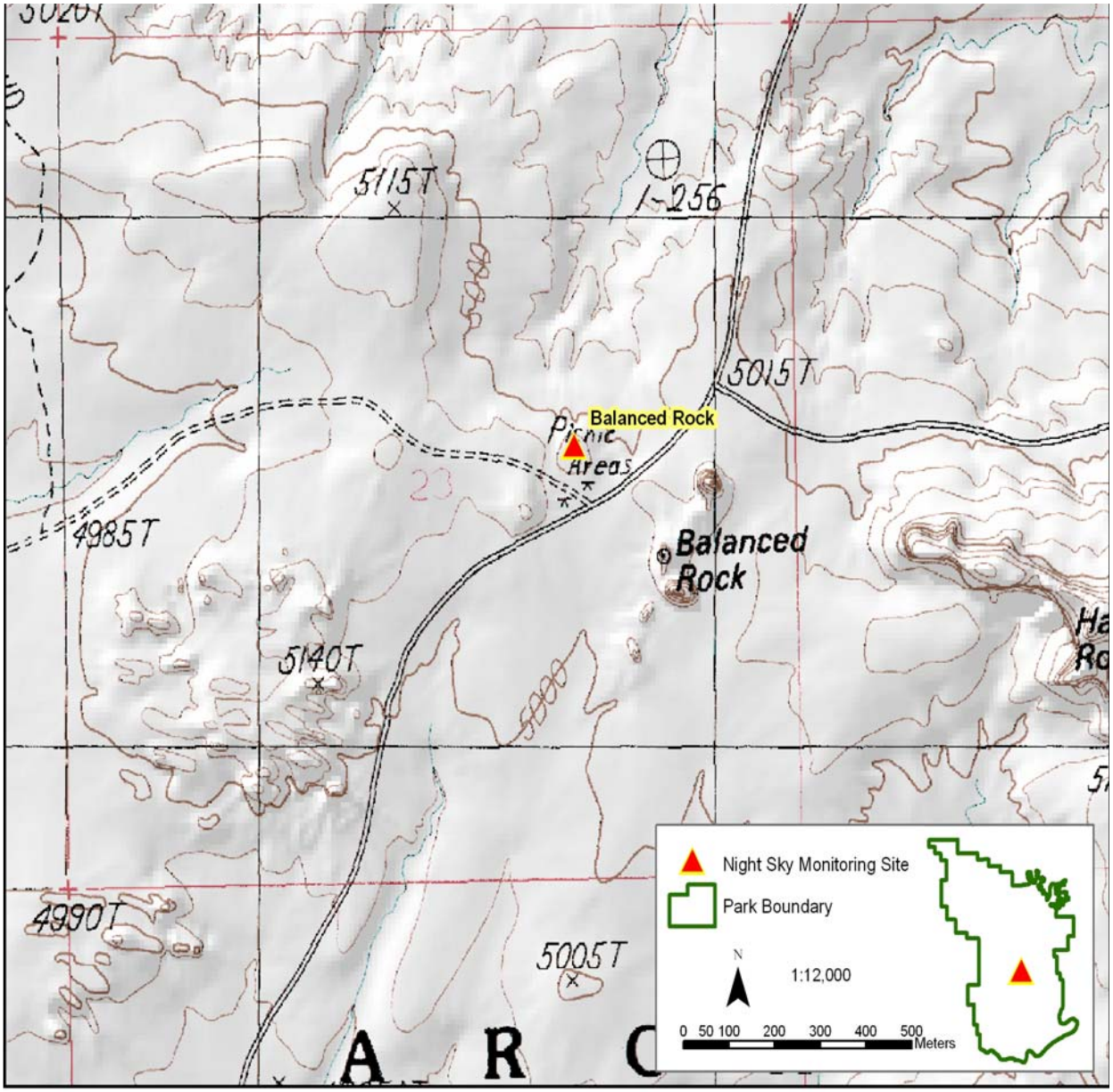
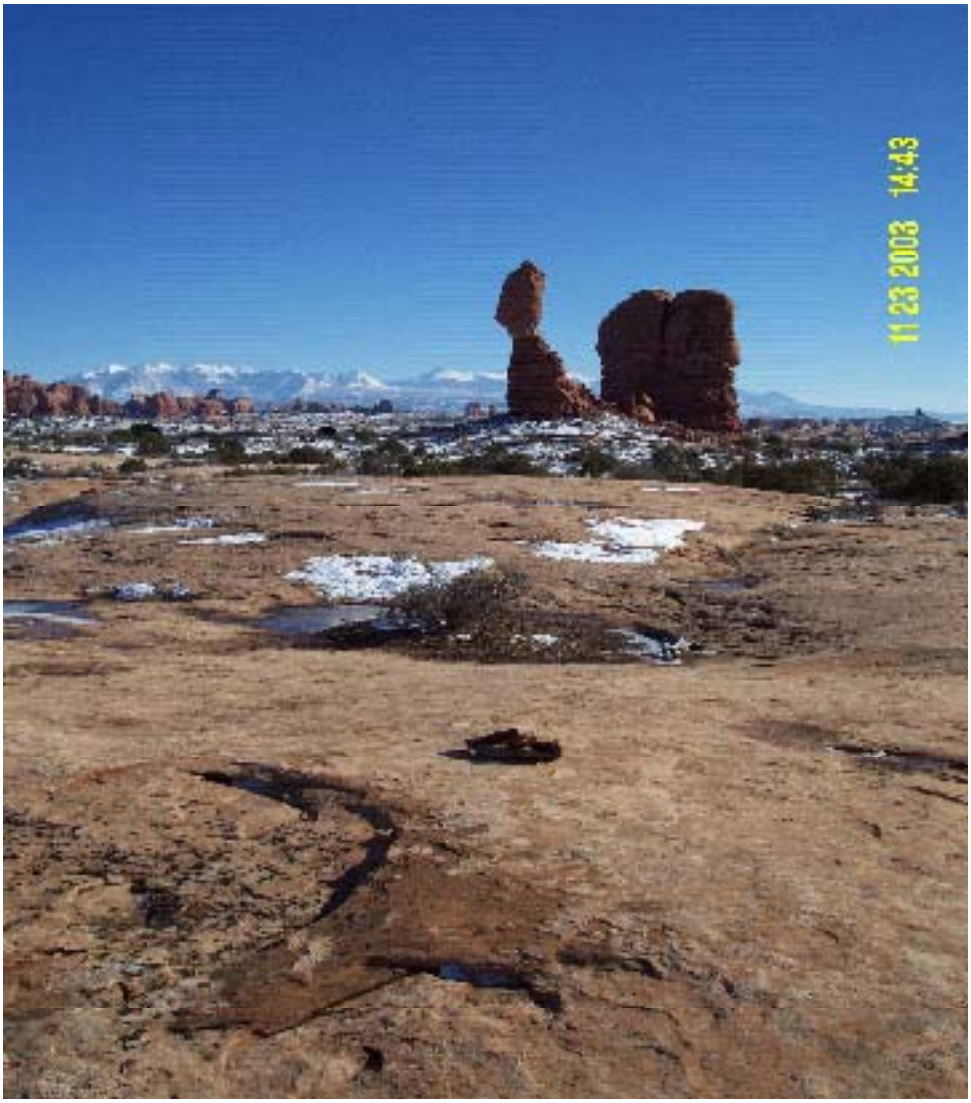


FIGURE 11. Location of Night Sky Monitoring Point at Balanced Rock in Arches National Park.

LOCATION: Balanced Rock Monitoring Site	
UTM N (Zone: 12S)	4284769.5
UTM E (Zone: 12S)	624635.4
Latitude	38° 42’ 10.1” N
Longitude	109° 34’ 00.3” W
Elevation	5044’



Rock cairn marking instrument location at Balanced Rock Site in Arches National Park.

Location:

From the entrance station at Arches National Park drive 8.8 miles into the park, to the Balanced Rock area. Make a left turn onto the Willow Springs dirt road, which is directly across from the first entrance to the Balanced Rock parking lot. This dirt road was once the main entrance to the park. Drive west on the dirt road about .25 mile to a picnic area on the right. Make a U-turn and drive back towards the main road. Notice a few small pullouts on the left or north side of the road. Park the vehicle at the last of these pullouts, located approximately 30 meters from the paved portion of the road (see photo below). Walk out and identify the site before carrying all the heavy equipment out. To find the site, walk north from the car approximately 10 feet across soil to a slickrock outcrop. Walk northeast over the slickrock for a couple hundred feet toward the highest point on the horizon. There is a small rock cairn on top of the highest point, where the tripod should be set-up. The above picture of Balanced Rock is facing southeast and shows the rock cairn in the forground.

Parking area for unloading equipment at Balance Rock Site in Arches National Park.

Results:

Figures 12 and **13** are the resulting images obtained from one data set taken at the Balanced Rock site in Arches National Park (Duriscoe and Duriscoe 2002). A color scheme has been assigned to display the increase in sky brightness over the entire sky. The legend for the color scheme can be found to the right in each image. The color relating to the darkest possible sky is deep purple while the brightest possible sky is white.

By looking at the all-sky images the primary light sources affecting this park can be identified as well as some of the secondary sources. After the data is collected the azimuth of each light source is obtained and confirmed on a map. There are two different types of light sources that can be seen in these images, the first being artificial human caused lighting and the second being natural lighting from the sky. The most significant light sources that can be seen from Balanced Rock at night are the town of Moab, Utah, approximately 8 miles to the south and the city of Grand Junction, Colorado, approximately 80 miles to the northeast.

In this particular data set there appears to be a lot of moisture in the air. Moisture will make close light sources brighter and it will drown out far-away light sources. That is one of the reasons, besides distance, that Moab looks so bright and Grand Junction is barely detectable. There are many natural factors that can interfere with collecting data, like humidity, smoke, dust or even scattered light from the Milky Way, zodiacal light, or air glow. To help compensate for the natural interference it is important to obtain more than one data set from each park in varying weeks.

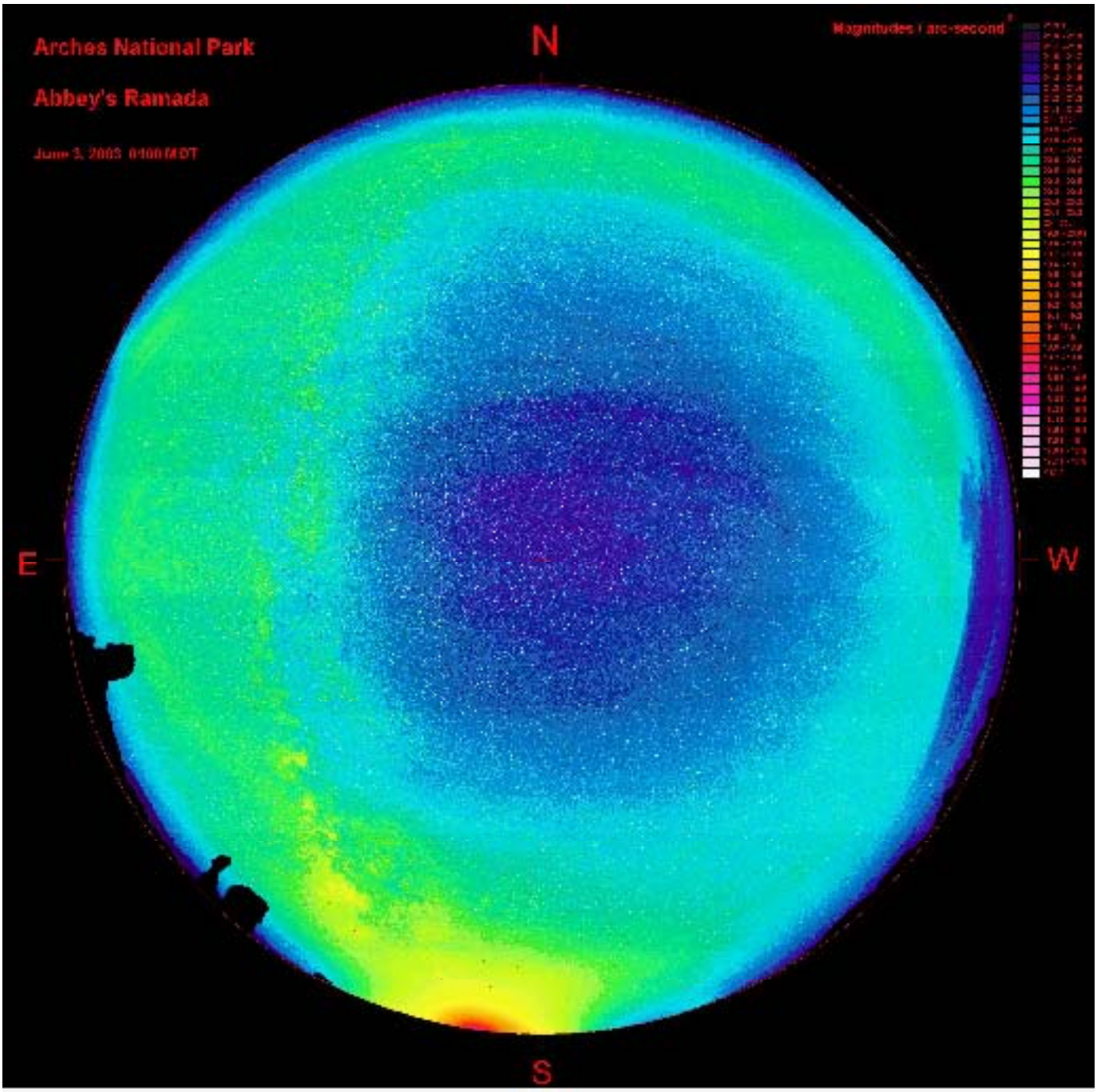


FIGURE 12. Polar projection all-sky mosaic of sky brightness images collected at the Balanced Rock site in Arches National Park (Durisco and Durisco 2002).

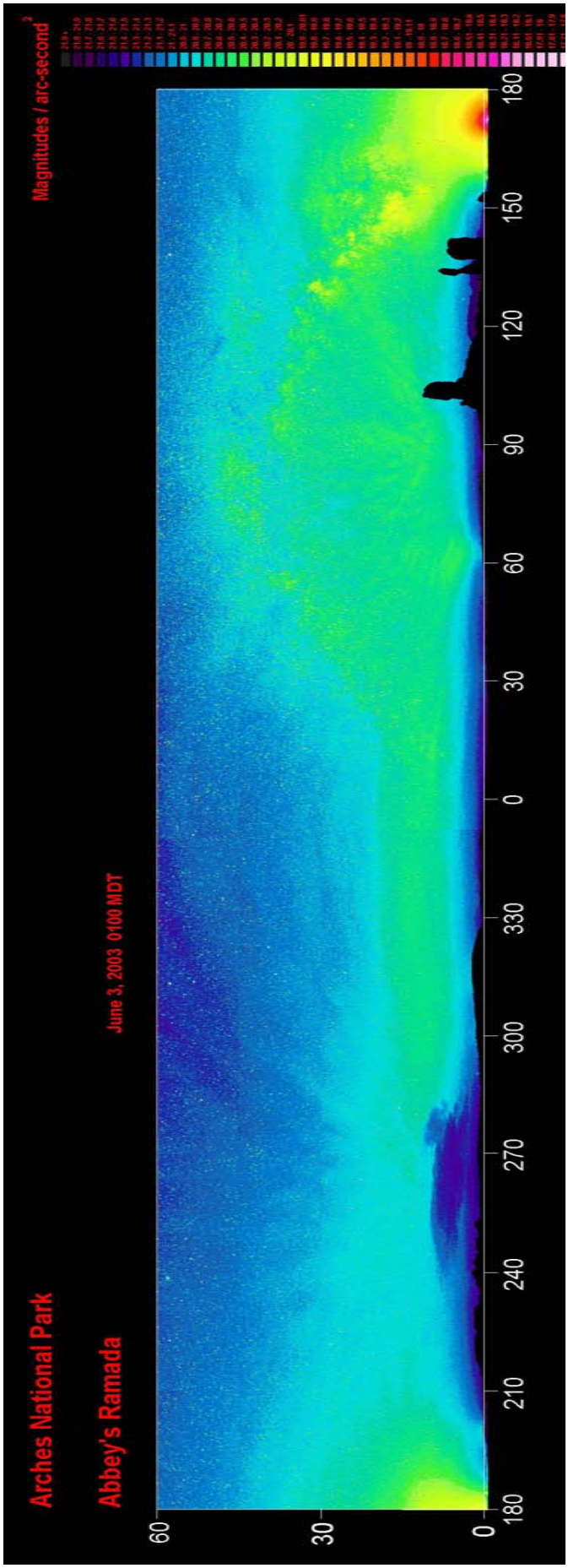


FIGURE 13. Panoramic mosaic of sky brightness images collected at the Balanced Rock site in Arches National Park (Duriscoe and Duriscoe 2002).

3.3.2 CANYONLANDS NATIONAL PARK GRANDVIEW POINT

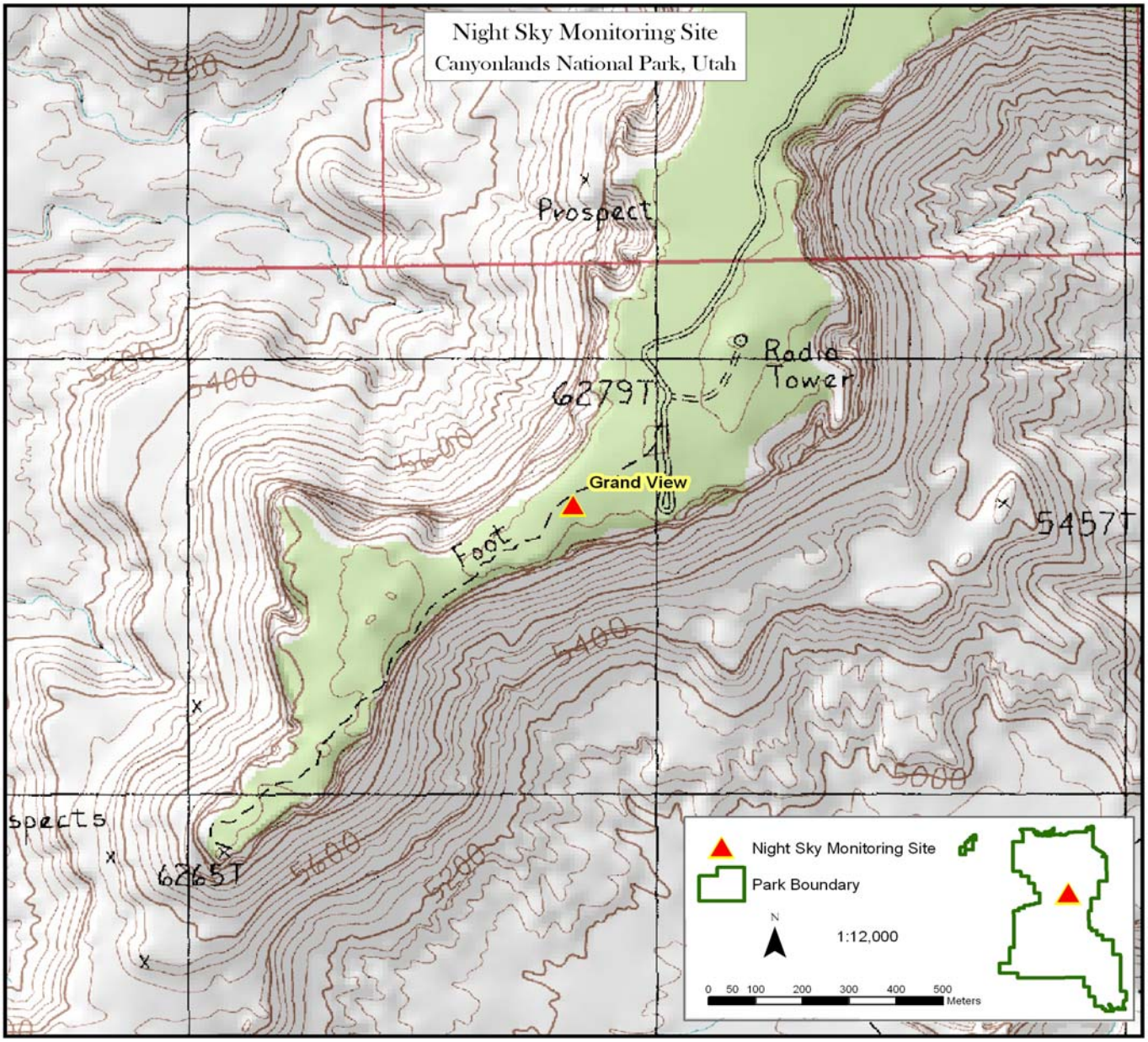


FIGURE 14. Location of Night Sky Monitoring Point at Grandview Point in Canyonlands National Park.

LOCATION: Balanced Rock Monitoring Site	
UTM N (Zone: 12S)	4284769.5
UTM E (Zone: 12S)	624635.4
Latitude	38° 42’ 10.1” N
Longitude	109° 34’ 00.3” W
Elevation	5044’

View of Grandview Point Site in Canyonlands National Park.

Location:
From the entrance station at the Island-in-the-Sky District of Canyonlands National Park, drive 12 miles to the Grandview Point parking lot. Park the vehicle near the restrooms. Walk toward the restrooms. Just before reaching them, look on the right for a low barrier made from branches indicating that this is not the trail. Step over the barrier and onto the slickrock. Avoid stepping on cryptobiotic soil crusts. Walk across the slickrock for a short distance in a southwest direction. At the end of this slickrock section, turn left (south), and then walk toward the highest point on the horizon. From the highest point, locate a USGS section marker cemented into the rock. The tripod should be set-up directly above this marker.

Location of Grandview Point Site in relation to parking area in Island-in-the-Sky District of Canyonlands National Park.

Marker (USGS Benchmark) where telescope is set-up at Grandview Point Site in Canyonlands National Park.

Results:

Figures 15 and **16** figures are the resulting images obtained from one data set taken at the Grandview Point site in the Island-in-the-Sky District of Canyonlands National Park (Duriscoe and Duriscoe, 2002). A color scheme has been assigned to display the increase in sky brightness over the entire sky. The legend for the color scheme can be found to the right in each image. The color relating to the darkest possible sky is deep purple, and the color relating to the brightest possible sky is white.

By looking at the all-sky images the primary light sources affecting this park can be identified as well as some of the secondary sources. After the data is collected the azimuth of each light source is obtained and confirmed on a map. There are two different types of light sources that can be seen in these images, the first being artificial human-caused lighting and the second being natural lighting from the sky. The most significant light sources that can be seen from Grandview Point at night appear to be the towns of Blanding and Monticello, Utah, to the southeast, the town of Moab, Utah, to the northeast and the town of Green River, Utah, to the northwest. There are a few secondary light sources that can also be seen, including the junction at La Sal and lights from vehicles on I-70, Highway 191, and the recreational roads in the Needles District of Canyonlands. However, all of the light sources are far enough away from Grandview Point that a limiting magnitude of 7.1 and a Bortle Class of 2 are usually recorded at this site. This is a very dark and pristine sky worthy of aggressive protection.

The green band that appears around the horizon could be interpreted as moisture or an unusually bright airglow night. These are natural sources of light and not interpreted as human-made light pollution. Because all the light sources are some distance from Grandview Point, they are probably dimmed down by the moisture in the air. However, final interpretations await the calculation of the extinction coefficient, proposed to be completed in 2004.

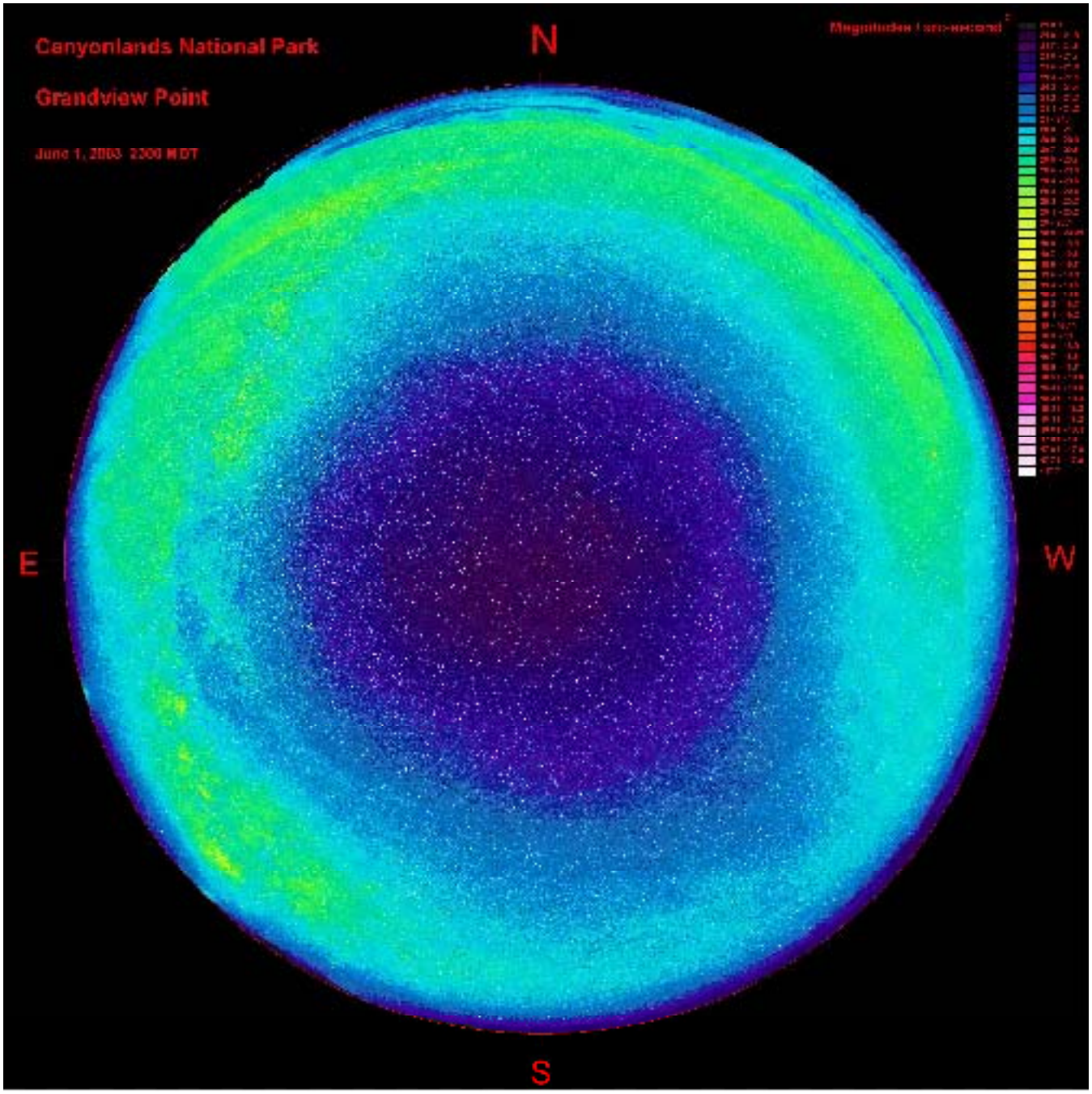


FIGURE 15. Polar projection all-sky mosaic of sky brightness images collected at Grandview Point in the Island-in-the-Sky District of Canyonlands National Park (Duriscoe and Duriscoe 2002).

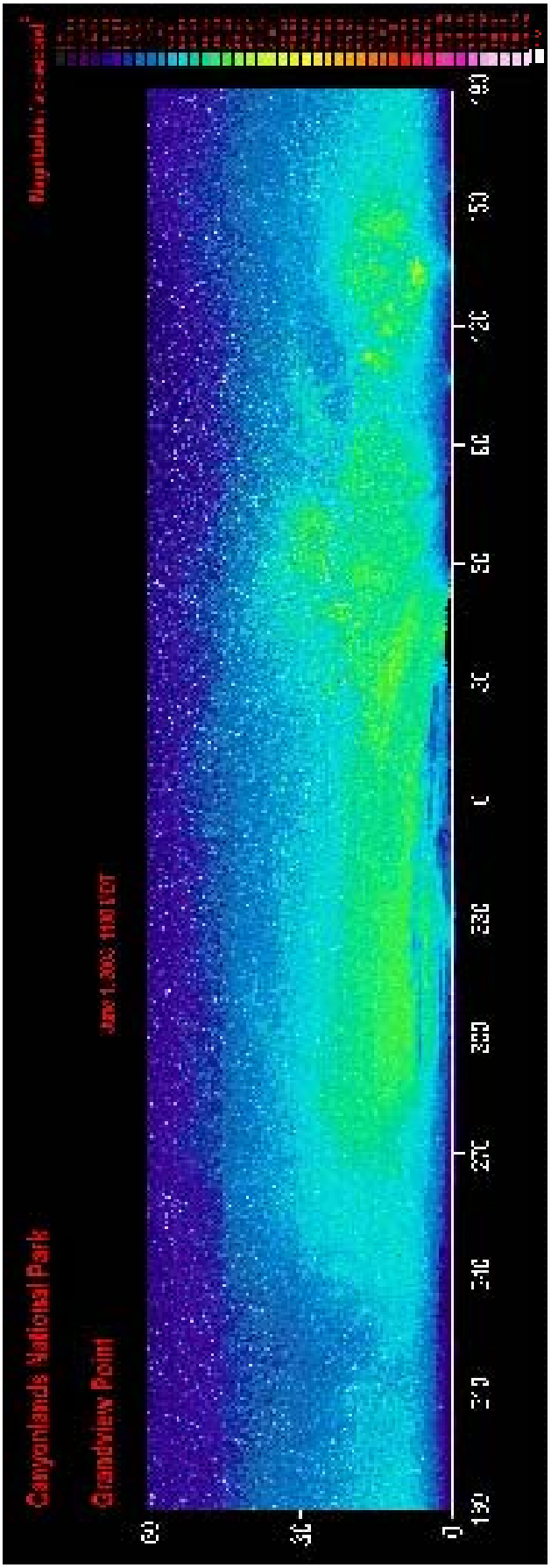


FIGURE 16. Panoramic mosaic of sky brightness images collected at Grandview Point in the Island-in-the-Sky District of Canyonlands National Park (Duriscoe and Duriscoe 2002).

3.3.3 NATURAL BRIDGES NATIONAL MONUMENT MAINTENANCE AREA

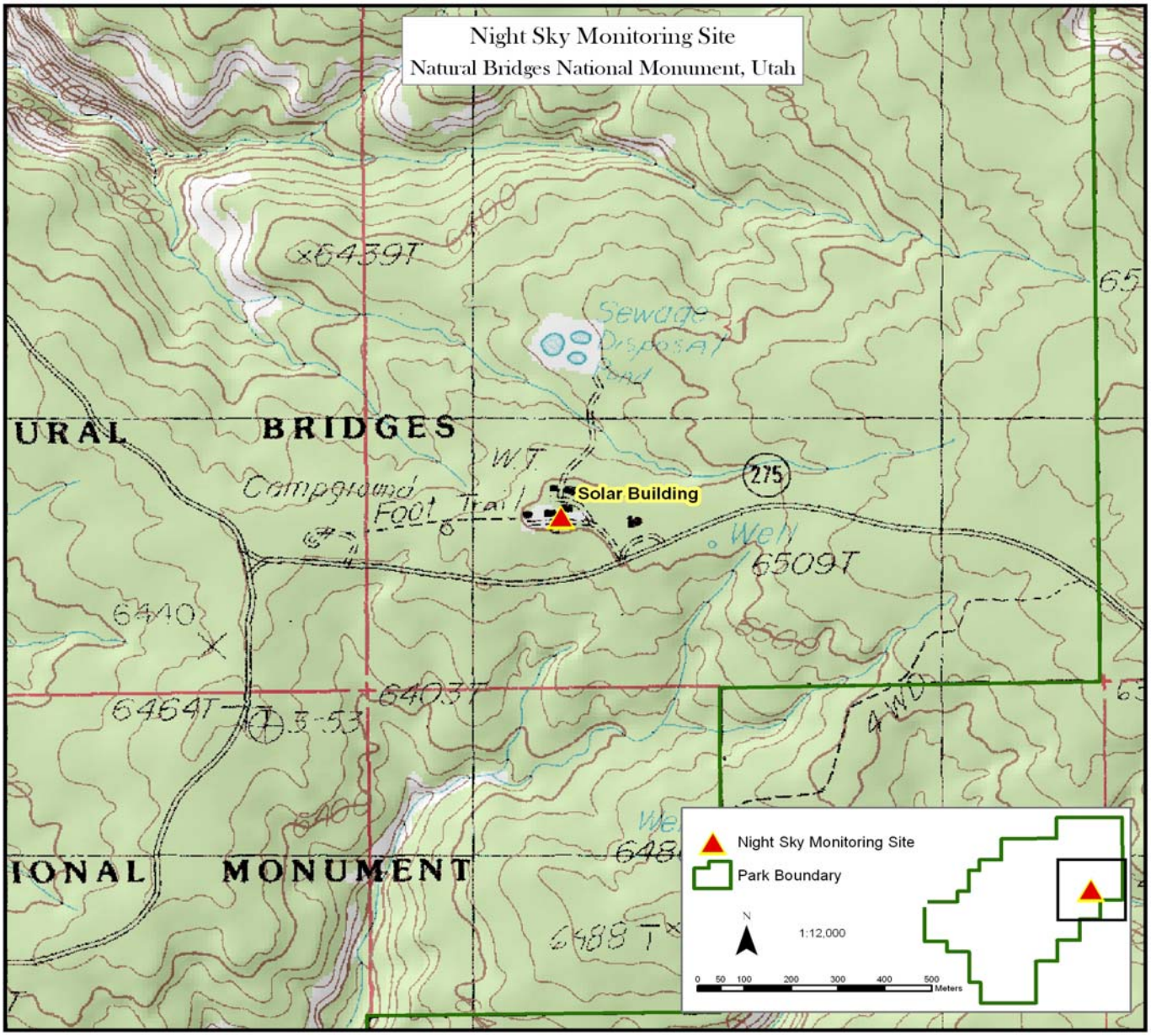


FIGURE 17. Location of Night Sky Monitoring Point on top of the Solar Building in the Maintenance area of Natural Bridges National Monument.

LOCATION: Natural Bridges Monitoring Site	
UTM N (Zone: 12S)	4162973.5
UTM E (Zone: 12S)	590125.4
Latitude	37° 36’ 33.5” N
Longitude	109° 58’ 44.3” W
Elevation	6482’

View of Solar Building Site in Natural Bridges National Monument.

Location:

Drive through the visitor center parking lot at Natural Bridges National Monument, and turn right into the residential area. Do not turn into the housing area, but continue forward into the maintenance yard. Park the vehicle to the west of the second building on the left, where it is easiest to back in the vehicle. Find the ladder that leads to the roof of the building housing solar equipment (see above photo). Climb the ladder onto the roof and you will see an X, which is spray-painted red in the place where the tripod should be erected. Be careful to stay on the boardwalk while the data is being collected, as walking on the roof could jiggle the equipment. Two people are needed to lift the equipment to and from the roof of the building. The solar building is the preferred place to collect data, however, a secondary site has been chosen for times when conditions are too hazardous to climb onto the roof. The secondary site is located to the west of the road triangle-shaped island at the beginning of the Monument's loop drive.

Equipment set-up at Solar Building Site in Natural Bridges National Monument.

Results:

Figures 18 and **19** are the resulting images obtained from one data set taken near the beginning of the loop road at Natural Bridges National Monument (Duriscoe and Duriscoe 2002). This was the first and only data set to be taken at this location. Later data sets where acquired from the top of the solar building in the maintenance yard.

Natural Bridges has the darkest sky of all four parks. There are no primary sources of light pollution to affect this sky. The only light sources are secondary light sources, which are the Cortez, Colorado, and Shiprock, New Mexico, area to the southeast and the town of Kayenta, Arizona, to the southwest. These two light domes do not have a large impact on the sky. It was assumed before data was collected at Natural Bridges that the town of Blanding, Utah, would have an impact but from the solar building the light from Blanding is mostly blocked out by the Bear's Ears, a prominent feature of the eastern horizon. Actually the most significant light sources to be seen from the top of the solar building are the housing, maintenance yard, and visitor center lights within Natural Bridges. Car headlights traveling on Highway 95 and into the park appear in some images. The park staff at Natural Bridges has been very cooperative in turning off all lights around these buildings and they have been sensitive to driving in and out of the park while data is being collected. With these conditions a limiting magnitude of 7.1/7.2 and a Bortle Class of 2 or 1 are reliably measured at Natural Bridges. This is a very dark and pristine sky worthy of aggressive protection.

In the images below you can see a light blue band that stretches around the horizon. This is airglow. The dark bands are smoke from a nearby forest fire. Notice that across the left side of the image is another light blue band which is the light from the Milky Way.

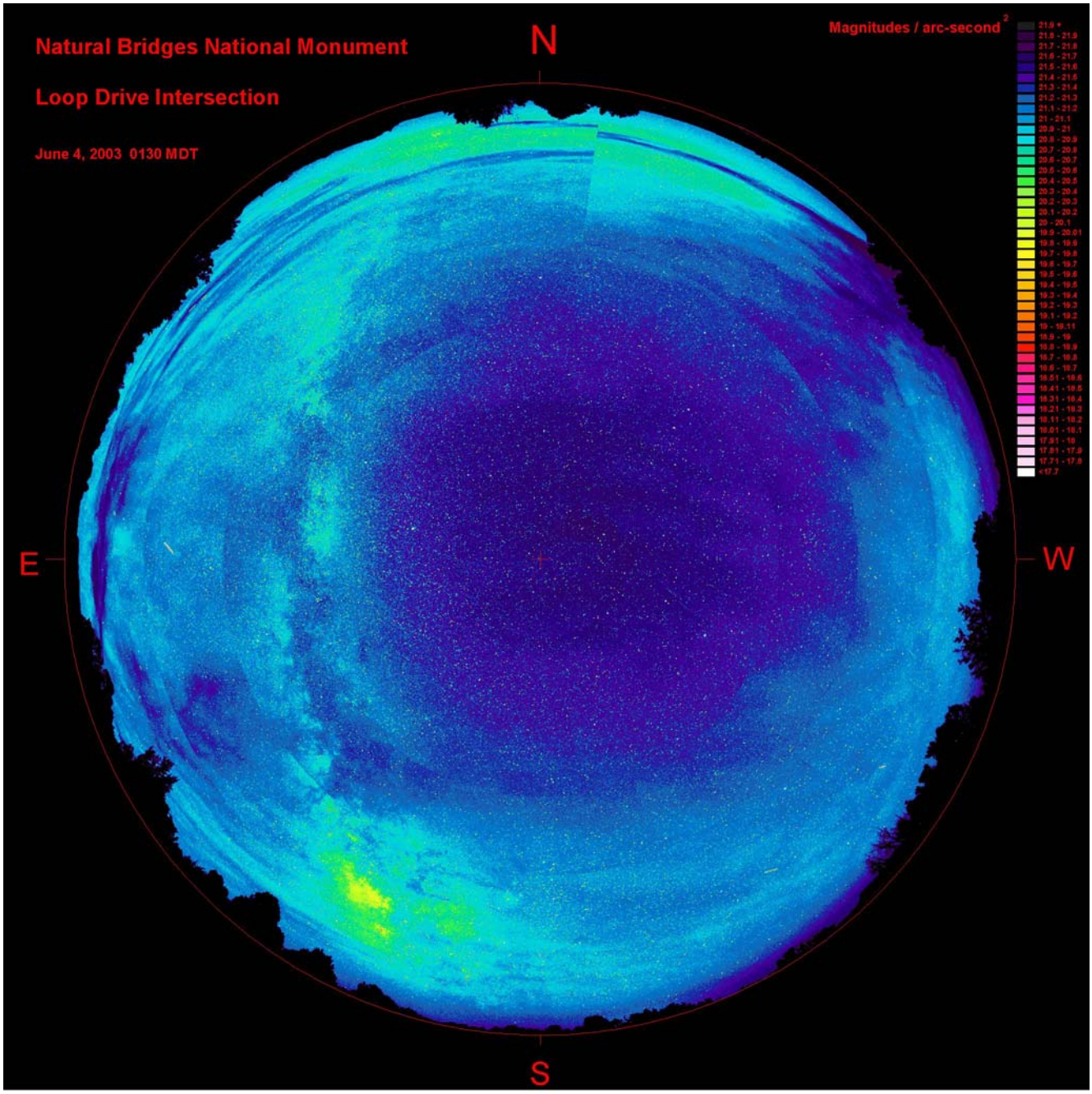


FIGURE 18. Polar projection all-sky mosaic of sky brightness images collected at Natural Bridges National Monument (Durisco and Durisco 2002).

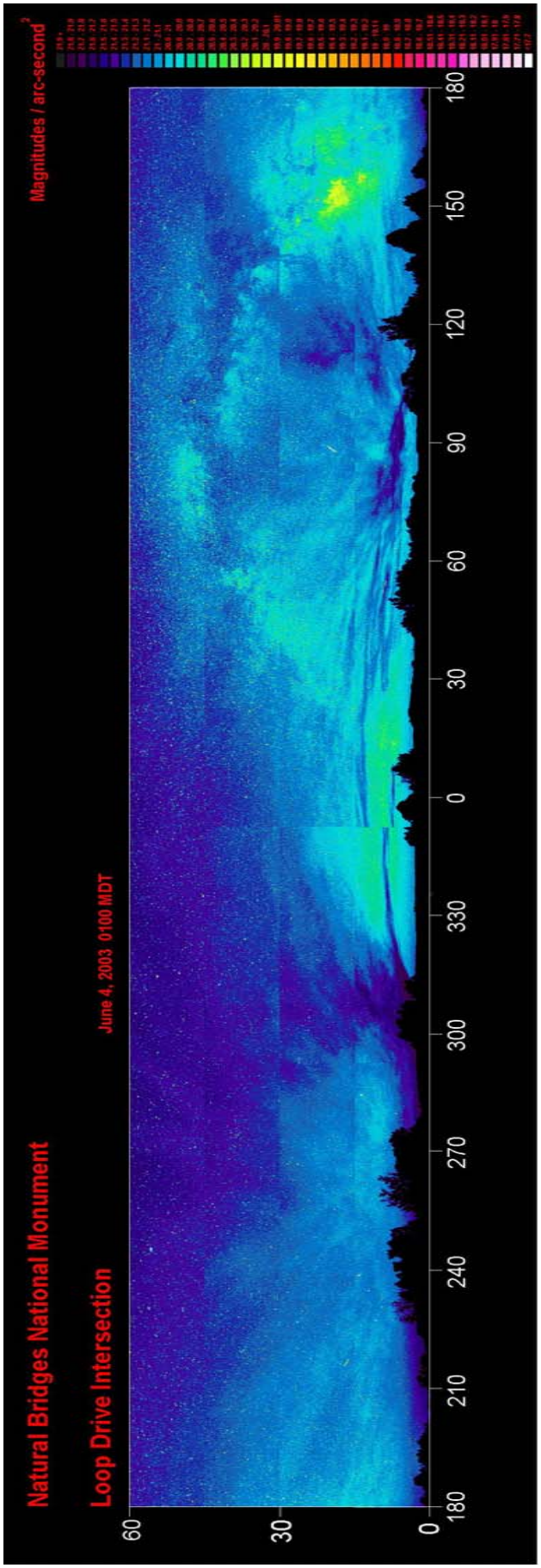


FIGURE 19. Panoramic mosaic of sky brightness images collected at Natural Bridges National Monument (Duriscoe and Duriscoe 2002).

3.3.4. HOVENWEEP NATIONAL MONUMENT SQUARE TOWER UNIT

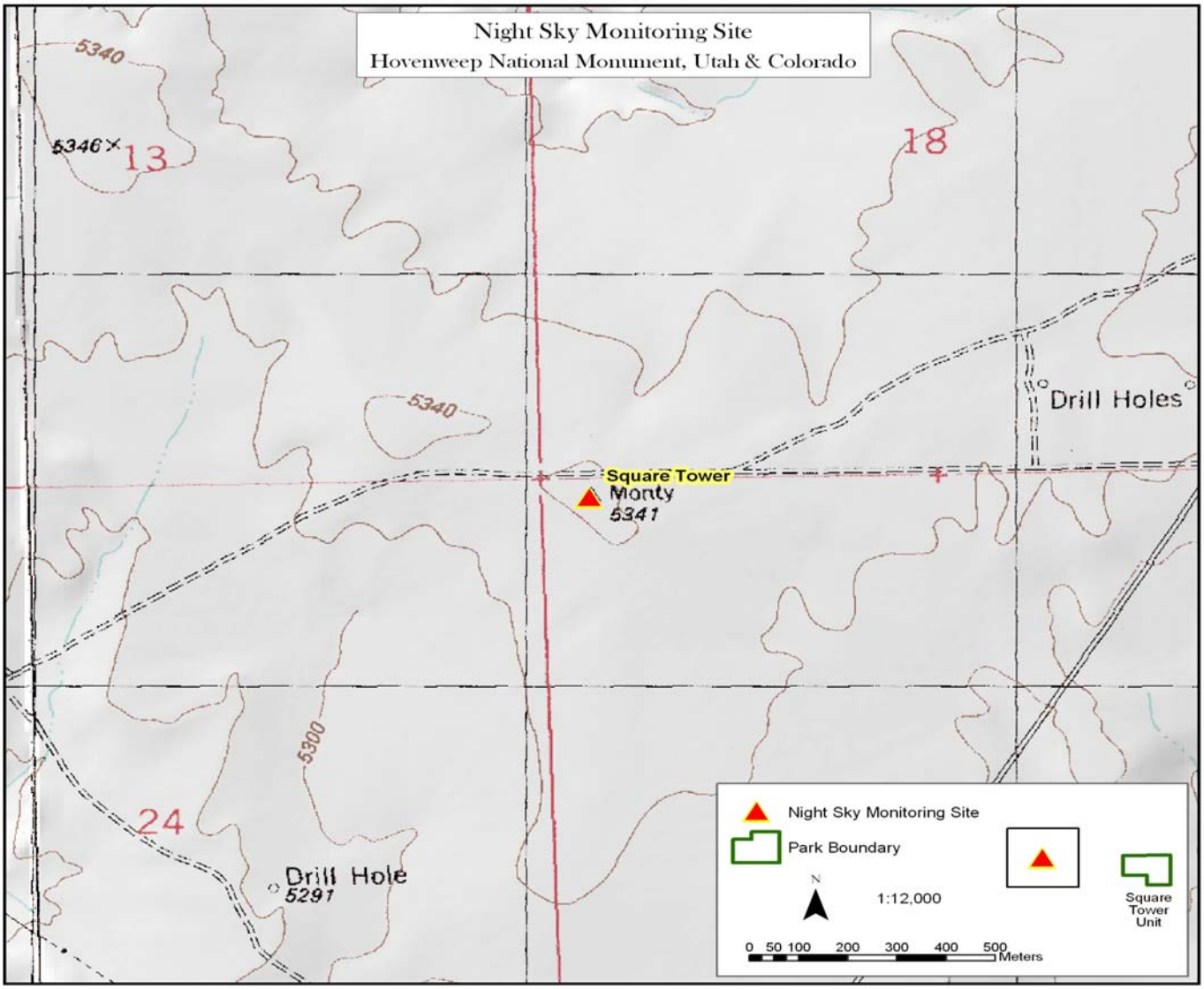
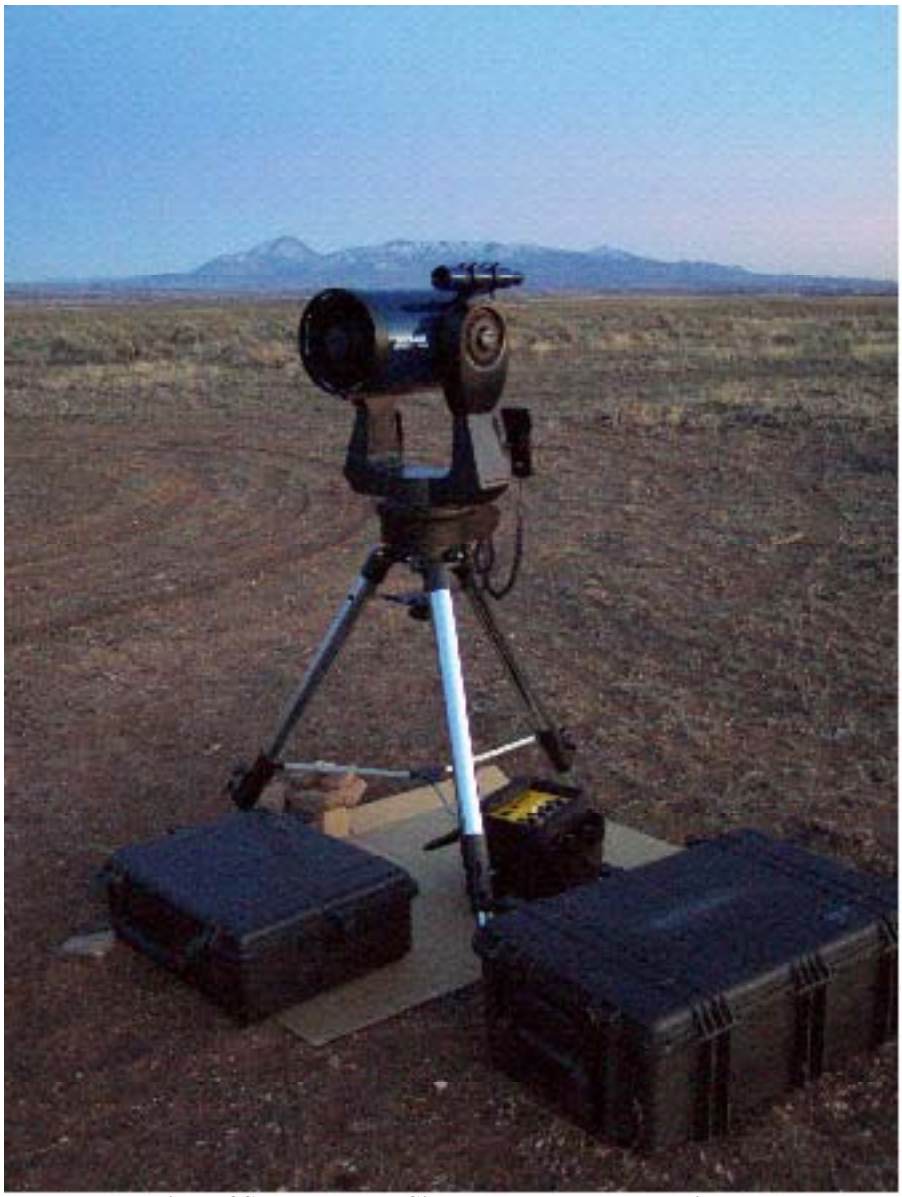


FIGURE 20: Location of Night Sky Monitoring Point near the Square Tower Unit of Hovenweep National Monument. Actual site is not within Monument boundary.

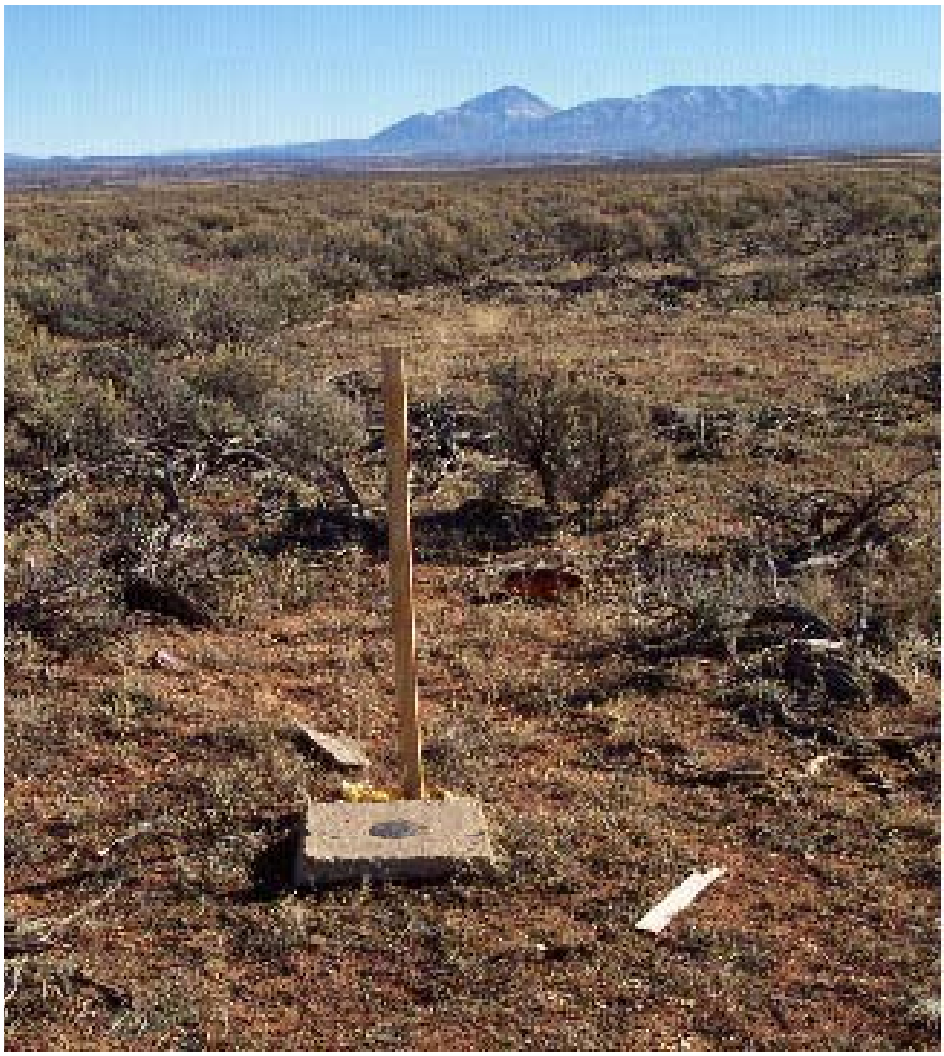
LOCATION: Square Tower Monitoring Site	
UTM N (Zone: 12S)	4139655.2
UTM E (Zone: 12S)	667091.5
Latitude	37° 23’ 19.1” N
Longitude	109° 06’ 45.9” W
Elevation	5270’



View of Square Tower Site near Hovenweep National Monument.

Location:

Drive to the Visitor Center in the Square Tower Unit at Hovenweep NM, then turn around and drive back out to the stop sign, which is 4/10th of a mile. Make a left turn, which will put you back out onto the main road driving west. Drive 9/10th of a mile at which time you will cross over a cattle guard and shortly after the road will turn sharply to the left. At the point where the road turns left a dirt road continues in the west direction. Drive onto the dirt road and follow it for 9/10th of a mile. During the mile the road is at a gradual incline, look toward the horizon for the highest place on the road, this is where you will turn again. Once at this point turn left onto a less obvious dirt road, there is a steep bump just as you turn off onto this road. Follow this road for about 100 feet or until you come to a turn around point. Park the vehicle. You will have driven a total of 2.2 miles from the visitor center. There is a USGS section marker placed in cement to the east of the turn around. There is a piece of rebar which looks like an archaeological site stake to the west of the turn around. After finding the rebar, walk south about 10 feet, there you will find a small rock cairn with an old rusted tin can. The tripod should be set-up directly above this marker. Once you have unloaded the equipment, move the vehicle back out to the main dirt road so it will not interfere with the data.



USGS section marker found at Square Tower Unit site

Results:

Figures 21 and **22** are the resulting images obtained from one data set taken near the visitor center at the Square Tower Unit in Hovenweep National Monument (Duriscoe and Duriscoe 2002). This was the first and only data set to be taken at this location. Later data sets where acquired from the site described above, which is 2.2 miles from the visitor center, outside the boundaries of the Monument.

Hovenweep has the most impacted night sky of all four parks; twelve light domes can be seen consistently around the horizon. There are quite a few primary sources of light pollution that are affecting this sky. They are the towns of Monticello, Blanding, Bluff, Aneth and Montezuma Creek in Utah, Shiprock through Farmington in New Mexico, and Cortez and Dove Creek in Colorado. The secondary light sources are coming from neighboring reservation smaller towns, including Red Mesa, Arizona, Towaoc, Colorad,o and White Mesa, Utah, and from the individual yard lights on private residences. With these conditions a limiting magnitude of 6.6/6.7 and a Bortle Class of 3 or 4 is generally measured at Hovenweep.

In the images below you can see a greenish band that stretches around the horizon. This band may represent airglow or clouds. You can also see a greenish band through the middle of the images that represents the light from the Milky Way. You can see all twelve light domes around the horizon.

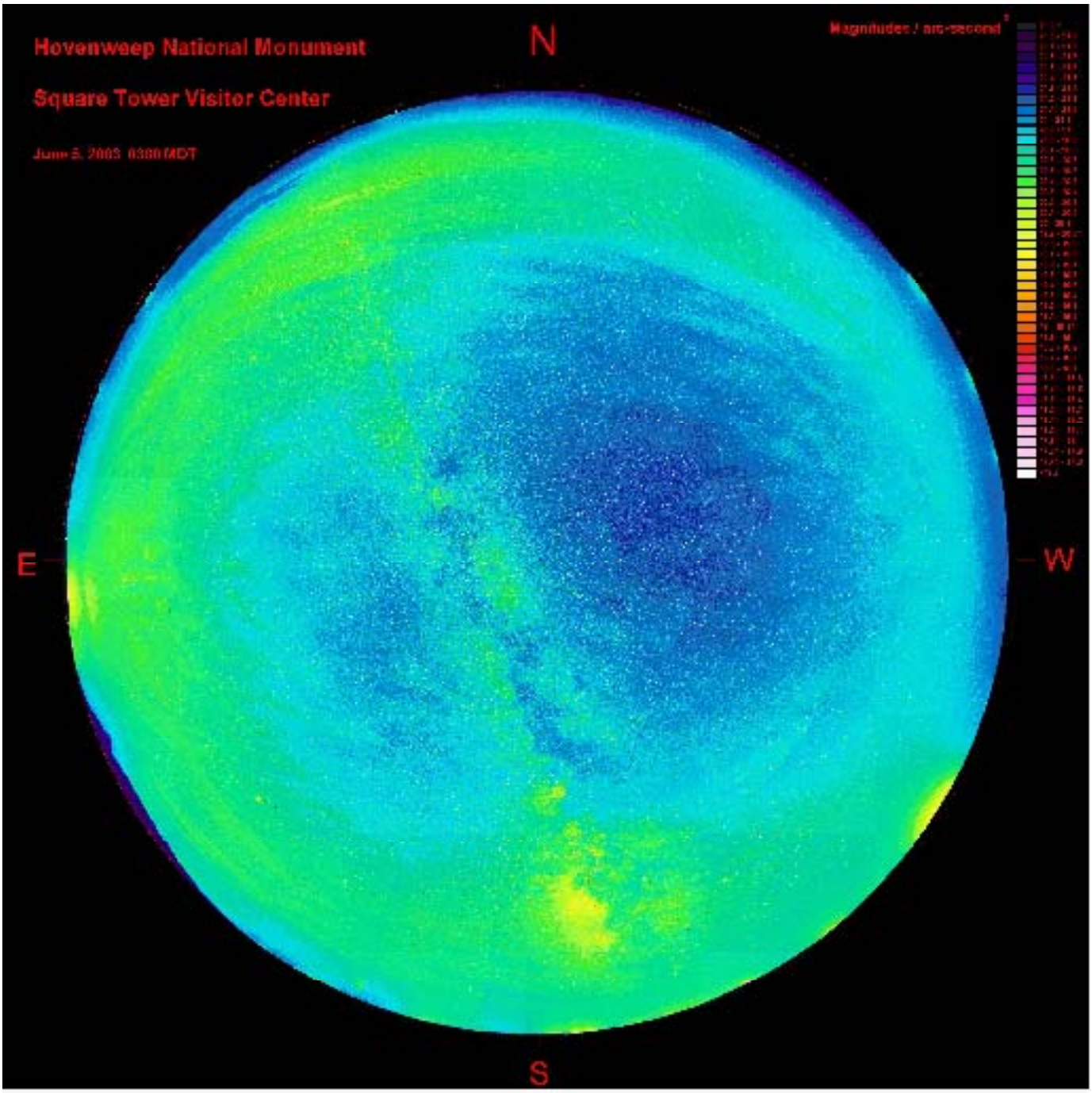


FIGURE 21. Polar projection all-sky mosaic of sky brightness images collected at the Square Tower Unit of Hovenweep National Monument (Duriscoe and Duriscoe 2002).

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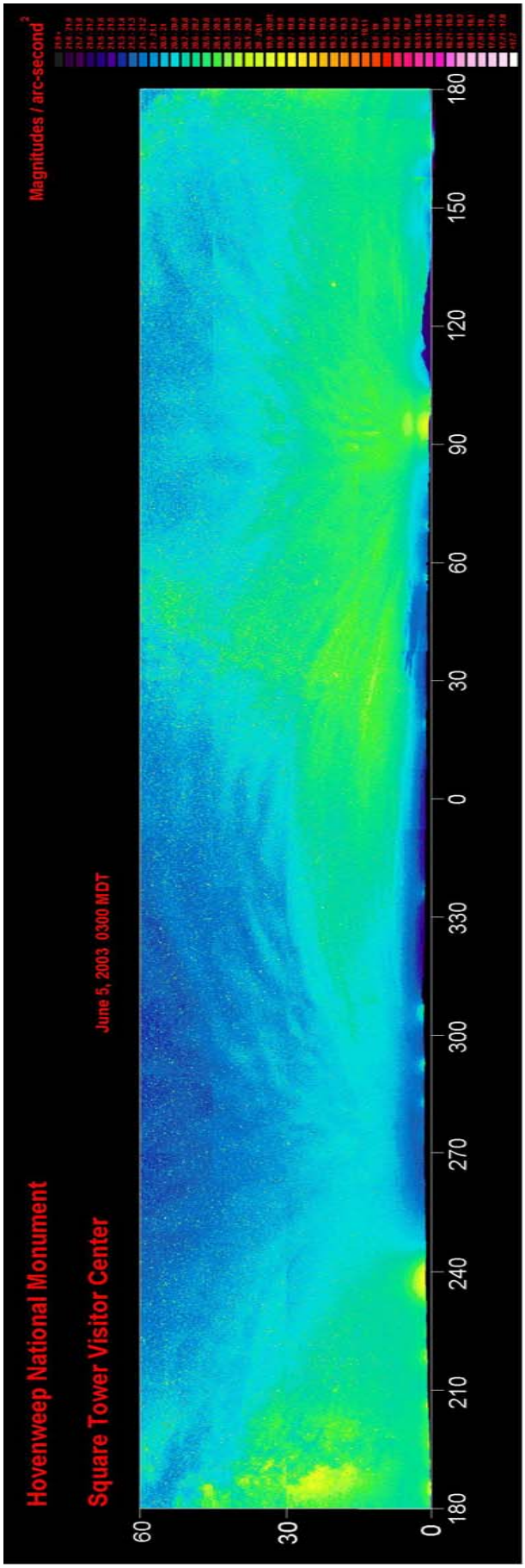

FIGURE 22. Panoramic mosaic of sky brightness images collected at the Square Tower Unit of Hovenweep National Monument (Duriscoe and Duriscoe 2002).

4. DISCUSSION

Nineteen night sky data sets have thus far been collected in park units of the Southeast Utah Group (see **TABLE 1,** page 34), including six data sets in Arches National Park, five data sets in Canyonlands National Park, four data sets in Hovenweep National Monument, and four data sets in Natural Bridges National Monument. The current protocol calls for a minimum of five data sets from each park with the majority of data being collected during the time of year with the greatest sky clarity, which is generally winter in our area.

All images from Duriscoe and Duriscoe (2002) are preliminary only, as the collected data cannot be accurately processed until there is a definitive flat field image for calibration. This calibration is expected to be completed in 2004, after which all images will be reprocessed.

After looking at the data collected so far, it appears that the night skies above the park units of the SEUG are of **national significance,** although further analysis and camparson must be done. Visitors to these parks have the rare opportunity to see the night sky the way human beings have viewed it for thousands of years. It can inspire us and connect us with a pre-industrial time. These values illustrate a basis for dark night sky preservation, protection, and restoration. Now that we have acquired this valuable data it is a good time to get others involved, from the community, Universities or Scientific Institutions, to help collect a wider range of data and educate on the importance of proper night lighting.

The methodology is evolving, and constantly being updated and improved. Because of this factor, the work that has been conducted thus far for the night sky monitoring program at the SEUG has been very frustrating and rewarding at the same time. We have worked closely with the National Night Sky Team to develop our work plan and activities. This program as a whole is still in the development phase, which has brought a variety of upgrades and changes along the way, including everything from new versions of software to new equipment preferences and designs. Not all of the equipment we are using was designed for the heavy use we have demanded. Many hours were spent in the office adjusting and tweaking the equipment to ensure its accuracy in the field.

However, with this in mind, the data we have collected is informative and extremely valuable. Before night sky data was collected in the SEUG in 2001, park managers did not know the condition of this resource. Now we have established preliminary data at each of the four park units. This data identifies light pollution sources for each park and quantifies their impact on the sky. We now know the condition of the night skies in these four parks and how they relate to each other. And there is still much more that can be accomplished with this data.

The Night Sky Program at the parks of the Southeast Utah Group is firmly established with the completion of the field work and this plan. We now have baseline data sets that represent the condition of the night sky in 2001 thru 2003. With continued support for this project we expect to continue data collection in 2004.

5. RECOMMENDATIONS

An immediate goal is to complete the minimum of five data sets from each park with the majority of data being collected during the winter season. A longer-term goal is to complete ten data sets per site.

TABLE 4. Data Sets Needed for Complete Baseline Data Sets at the SEUG

PARK	SEASON	SETS NEEDED (minimum/ideal)
Arches National Park	Fall-Winter	0/4
Canyonlands National Park	Fall-Winter	0/5
Hovenweep National Monument	Fall-Winter	1/6
Natural Bridges National Monument	Fall-Winter	1/6

Once a definitive flat for calibration is obtained, all images will be reprocessed and evaluated for extinction coefficient on a night-by-night basis.

Another primary goal is to acquire baseline measurements from other parks across the Colorado Plateau. This data will establish the parks' climate and extinction characteristics, which will be similar in neighboring parks. By keeping these variables constant we can compare the sky brightness of each park, and then visualize where the night skies of the Southeast Utah Group fit into the spectrum. We can experiment with data, possibly collecting 20 data sets from a certain park in a relatively short period of time to specifically monitor the affects that weather conditions can have on sky brightness values. We can compare parks with brighter night skies to those with darker night skies. We can compare parks that have the same light sources; this will demonstrate how light pollution permeates over distance and how it affects each park based on distance. For example, the town of Grand Junction, Colorado, is just outside the park boundary of Colorado National Monument so the affect it will have on the Monument's night skies is much larger than the affect it will have on Arches National Park some 80 miles away. We can predict that if the town of Moab, Utah, were to grow and eventually generate as much light as Grand Junction currently does, the sky above Arches would look similar to the current night sky above Colorado National Monument. We can even acquire the growth rate data from the Moab Chamber of Commerce or other sources and estimate how soon this might happen. Similar comparisons and predictions could be made for Mesa Verde National Park, Hovenweep National Monument, and Natural Bridges National Monument, which share Cortez, Colorado, as a light source. Each park is at a different distance from Cortez, so we can see the affect the town's lights have over various distances and how other towns could potentially affect the night sky at different parks.

These and other Night Sky Monitoring Program goals are itemized below.

1. Continue collecting night sky data at the four park units of the Southeast Utah Group until a solid data baseline is established (see METHODS, page 37 and TABLE 4, page 66).

2. Plan to collect future data sets in the SEUG as often as possible in conjunction with the NPS National Night Sky Monitoring Team, at least every 5 years or when nearby development or light pollution changes appear to be occurring within or outside of the SEUG parks.

3. Fully calibrate FLI MaxCam to a known standard so a master flat field image can be acquired. Once a definitive flat for calibration is obtained, all images will be reprocessed and evaluated for extinction coefficient on a night-by-night basis.

4. Support the collection of baseline data in parks of the surrounding region in order to establish regional light pollution influences. Collect data at Capitol Reef National Park, Colorado National Monument, and Mesa Verde National Park.

5. Refine the equipment and protocols. Strive to simplify as much as possible, in order to decrease equipment weight and shorten set-up time.

6. Coordinate and communicate analyses and results with other night sky monitoring efforts, especially with the NPS National Night Sky Monitoring Team.

7. Work with local communities and assist in education and the resolution of night sky pollution problems. Develop Phase 2 of the Night Sky Management Plan which will develop educational materials for park visitors, local municipalities, and the general public.

8. Develop a Light Pollution Management Plan for the parks of the Southeast Utah Group (Phase 3) and involve management in a commitment to the preservation of dark skies.

9. Firmly establish the night sky as a natural and cultural resource in park management plans and develop a night sky initiative for the SEUG.

6. LITERATURE

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APPENDIX 1

Data Sheet

Visual Limiting Magnitude Sampling

Sampling Conditions

Observer: Angie Richman	Eyes 20/20: (Y) N glasses contacts		Age: 25
Date: Sept. 03, 2003	Time Sampling Began: 2:30am		TimeZone: MDT
Location: balanced Rock - Arches	Lat/Long: 38°42'10.1" -109°34'00.4"		Elevation: 5015 ft
Weather: Slightly breezy, high clouds			
Humidity: 28 %	Temp: 70° °C (F)	Dew Present (circle): Yes (No)	
Transparency Estimate (circle):	Clear, top 25%	(50-75%)	25-50% Poor, lower 25%
Stability Estimate (circle):	Steady at 30°	Steady at 45°	(Steady at Zenith) Unsteady
Wind Speed: calm 1-3 (4-7) 8-12 13-18 19+		Direction: North	
Bortle Sky Class: Class 1 2 (3) 4 5 6 7 8 9			
Other Data Collected:			

Observors should be well rested. Sampling should be made 30 minutes after exposure to bright light and 5 minutes after exposure to dim lights. One star count should be as close to the zenith as possible. Observations should begin after astronomical twilight.

				Star Count Method		Map Method
Area	Azimuth	Altitude	Time	# of Stars	Limit Mag	Faintest Star Mag
7	340	50	3:00am			6.8-6.9

Limiting magnitude table for star counts is on the back side of this data sheet. Consult detailed maps of survey areas for map method.