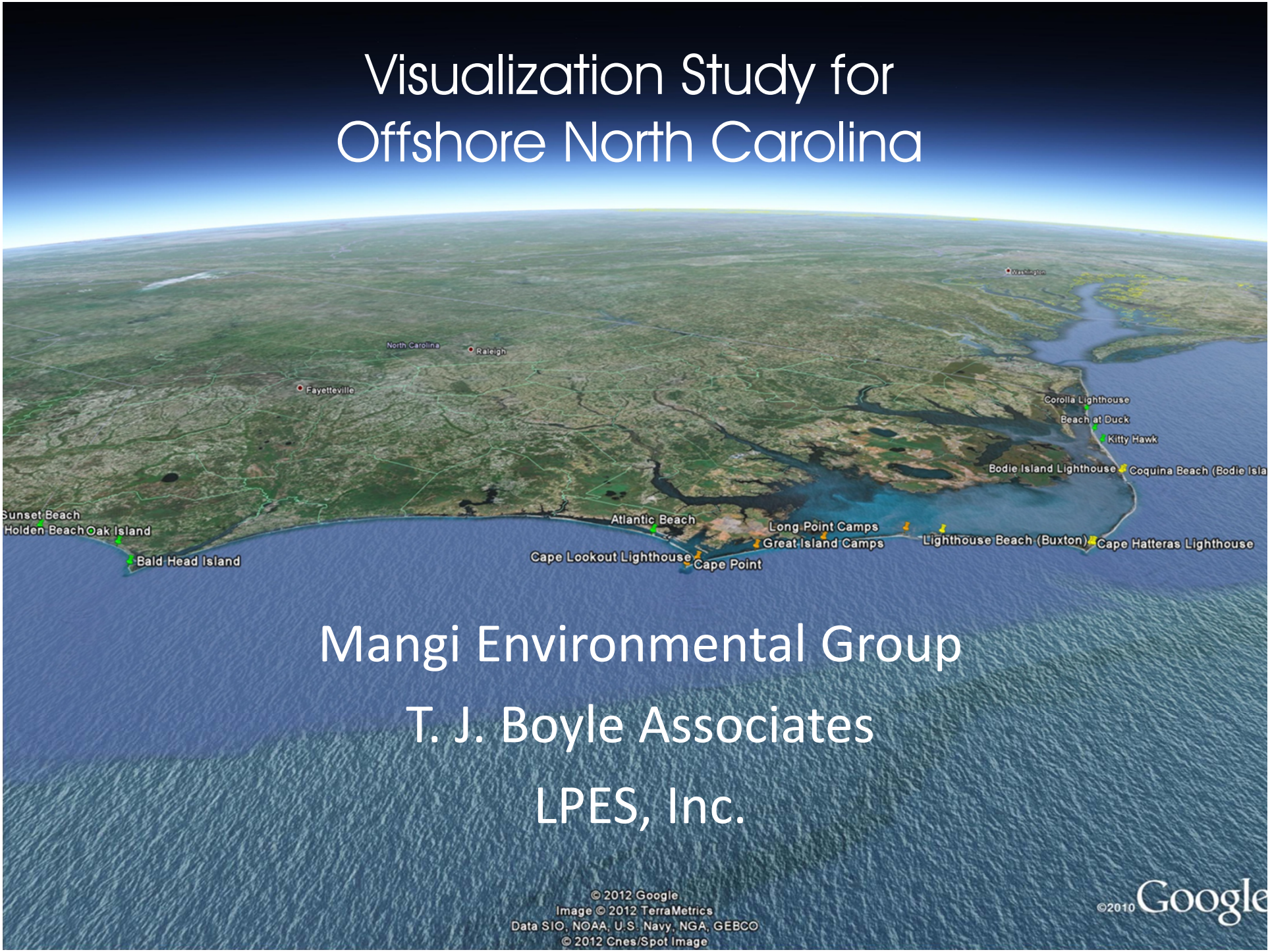
Visualization Study for Offshore North Carolina



Mangi Environmental Group

T. J. Boyle Associates

LPES, Inc.

Organization and Management Structure

- Mangi Team Project Manager: James F. Palmer
- Co-manager: Michael J. Buscher
- GIS and Visualization Specialist: Jeremy B. Owens
- Meteorological Expert: Timothy Lavallee

1) Study Purpose

- Utilize Project Data Provided by BOEM, Including Turbine Types, Number, and Layout
- Photographic Documentation of Specific Locations and Conditions Along the North Carolina Outer Banks
- Deliverables:
  - Create Wireframe Simulations
  - Create Photo-Realistic Simulations
  - Create Panoramic Wireframes
  - Create Panoramic Simulations
  - Create Animated Simulation Videos
  - Document and Analyze Existing Meteorological Data
  - Attend BOEM/NPS Meetings
  - Attend Public Outreach Meetings - ongoing

2) Guiding Principles

- Represent the highest contrast situations per the RFP
  - Document conditions where the sky background color is opposite that of the turbines based on sun position, cloud coverage, and absence of moonlight (for night simulations)
- Maintain accuracy in detail and scale of simulated turbines
  - Utilize best practices for preparing simulations
  - Utilize best practices for displaying simulations
- Maintain an open process that can be replicated by others
  - Document field work and methodology
  - Limited manual editing
- Utilize standard professional software
  - WindPRO 2.8
  - Adobe Photoshop
  - Kolor Autopano Pro
  - ArcView (GIS Software)

3) Process Used to Create Visualizations

A. Determine Minimum Photograph Resolution Based on Human Visual Acuity

B. Site Investigation and Photographic Documentation

C. Prepare Visualizations
   1. Single-Frame Simulations
   2. Panoramic Simulations
   3. Animated Videos

D. Correct Printing, Displaying and Viewing of Visualizations

A. Photograph Resolution

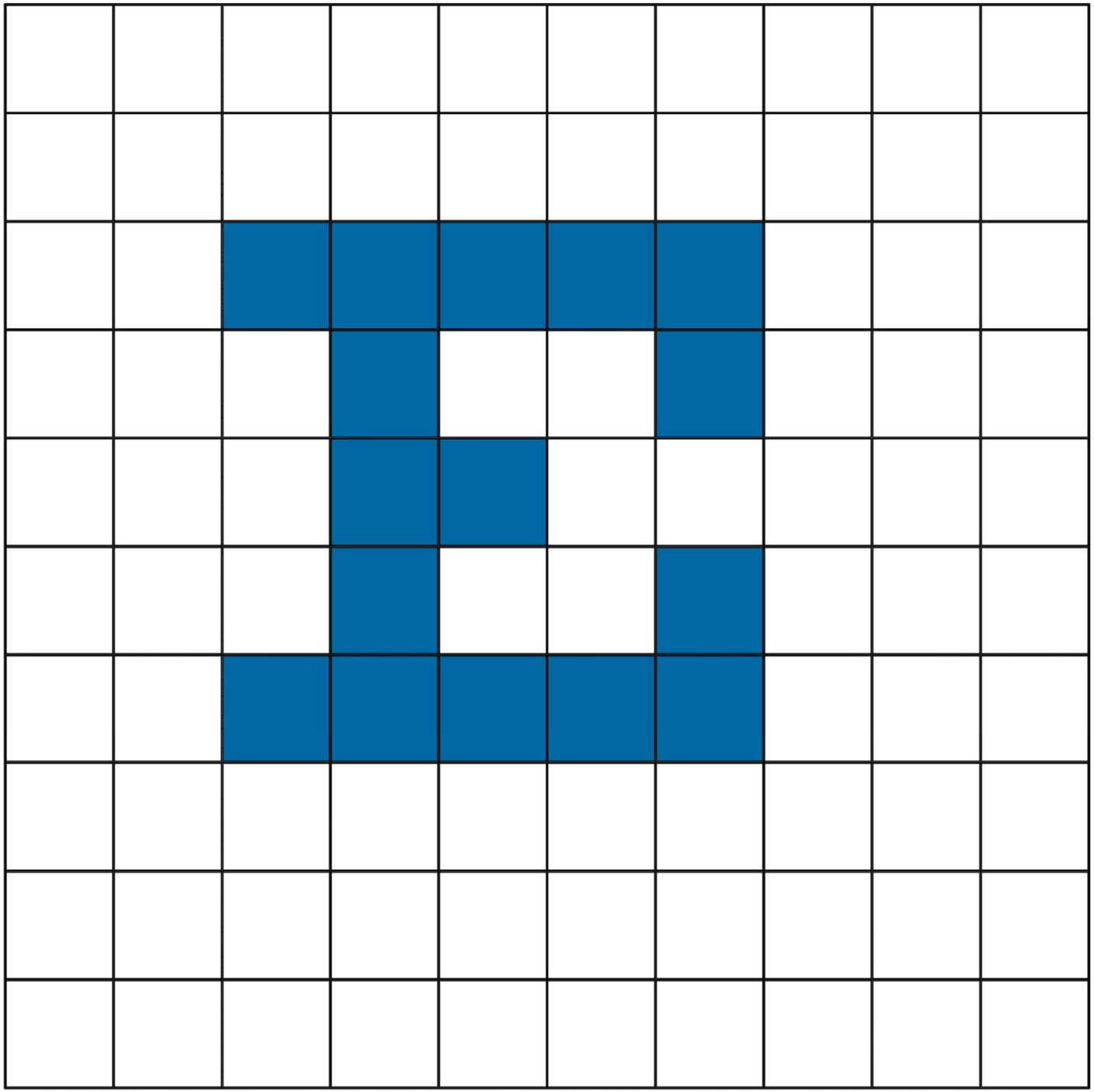
The RFQ requires use of the "highest resolution necessary to accurately represent offshore conditions up to 20 miles."

- Detection Acuity

  Detection requires only the perception of the presence or absence of stimuli. It is possible to distinguish "something" when it subtends approximately 0.5 arcminutes (1/120 of one degree), yet not be able to recognize it.

- Recognition Acuity

  The ability to see an object clearly enough to name it. The lower limit of normal visual acuity is often defined as the ability to recognize characters on a Snellen Eye Chart when they subtend 5 arcminutes (1/20 of one degree) from a distance of 20 feet. This is also known as 20/20 or "normal" vision.



A. Photograph Resolution (cont.)

- Recognition and Detection Acuity for Normal Vision

  The nacelle and tower of individual turbines may be recognizable at the distance specified in the RFQ scenarios, but it may be difficult to detect the individual turbine blades.

  - The maximum cord length (width) of the Siemens SWT-3.6-107 blade is 4.2 meters. This subtends 0.5 arcminutes at 15.59 nautical miles; beyond this distance, this blade is unlikely to be detected by someone with 20/20 vision
  - The maximum cord length (width) of the Vestas V164-7.0 blade is 5.4 meters, which subtends 0.5 arcminutes at 20.04 nautical miles; beyond this distance, this blade is unlikely to be detected by someone with 20/20 vision

A. Photograph Resolution (cont.)

Recognition and Detection Conclusions:

- Although the turbine blades will be very distant, a person with "normal vision" will likely be able to discern the widest portion of individual blades of the Vestas turbine from 20.04 nautical miles away

- The pixel resolution of the photographs needs to be such that one pixel subtends no more than 0.5 arcminutes in order to depict the blades at a distance of 20 nautical miles with the same amount of detail as seen by 20/20 vision

A. Photograph Resolution (cont.)

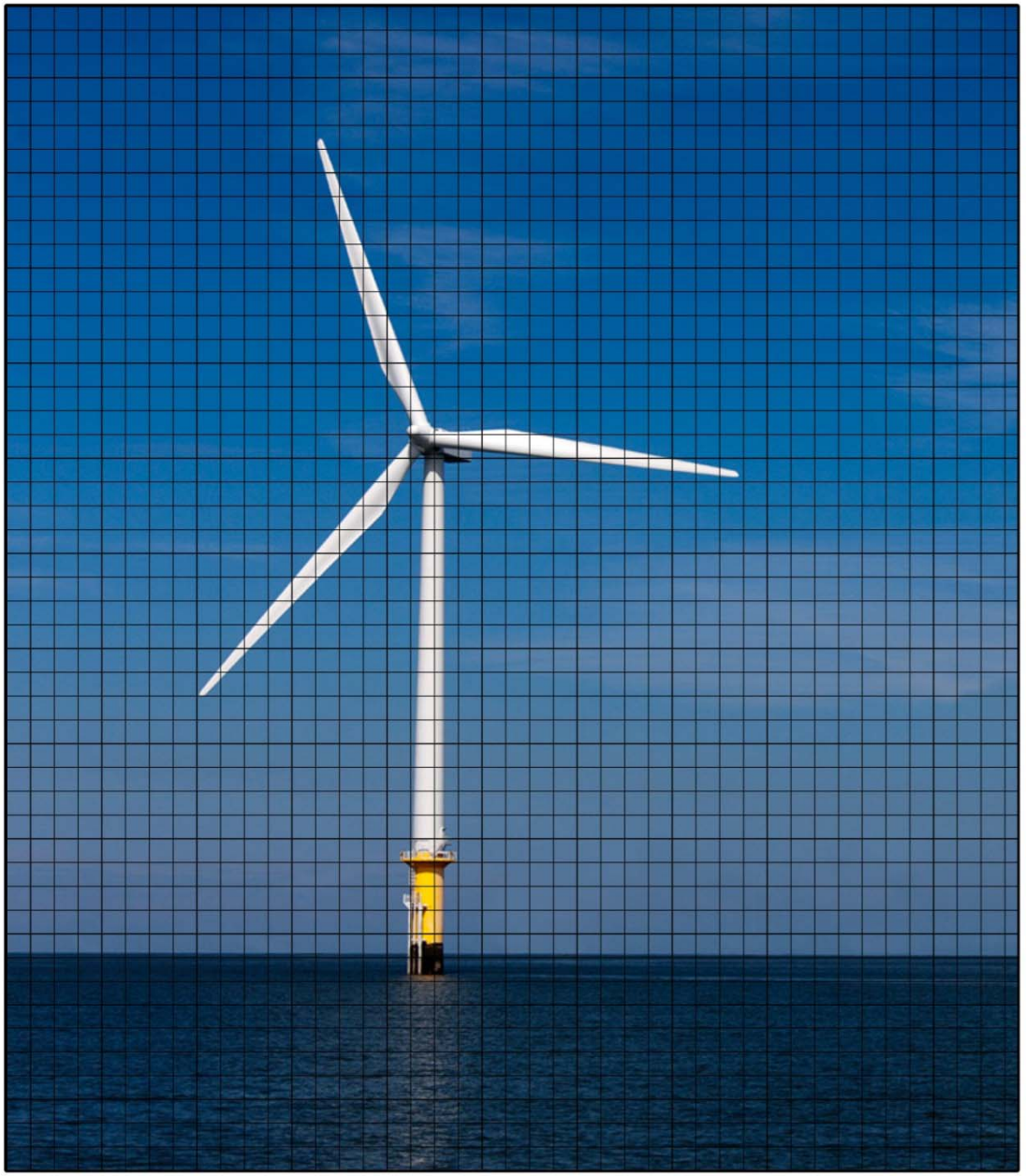
- Camera Resolution

  Nikon D7000 16.2 MP DSLR Camera / Nikkor AF-S DX 35mm fixed lens

  - A +/-50mm lens on a 35mm camera is an industry standard for preparing single-frame photographic simulations
  - The Nikkor 35mm fixed lens mounted on the Nikon D7000 produces an equivalent to a 52.5mm lens on a 35mm camera
  - Nikkor DX 35mm lens captures a horizontal angle of 37.3° and vertical angle of 25.3°, or 2,238-by-1,518 arcminutes
  - The Nikon D7000 highest resolution image is 4,928-by-3,264 pixels
  - Each pixel subtends 0.45 arcminutes, which is less than the maximum of 0.5 arcminutes. Therefore, the camera and lens system is adequate for accurately representing detail at a 20 nautical mile distance

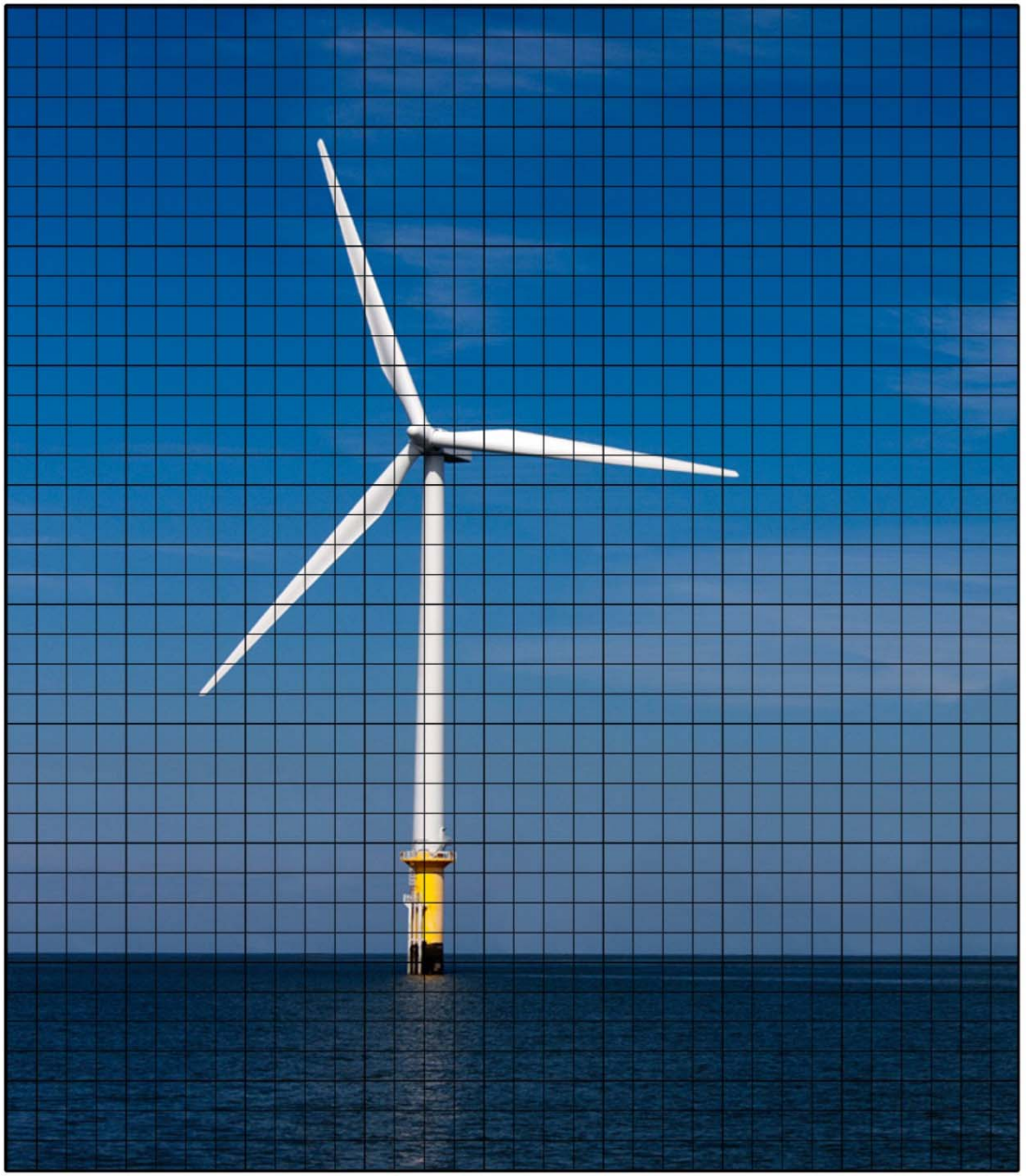
10
Nautical Miles

■ = 2.43m^2



15
Nautical Miles

■ = 3.65m^2



20
Nautical Miles

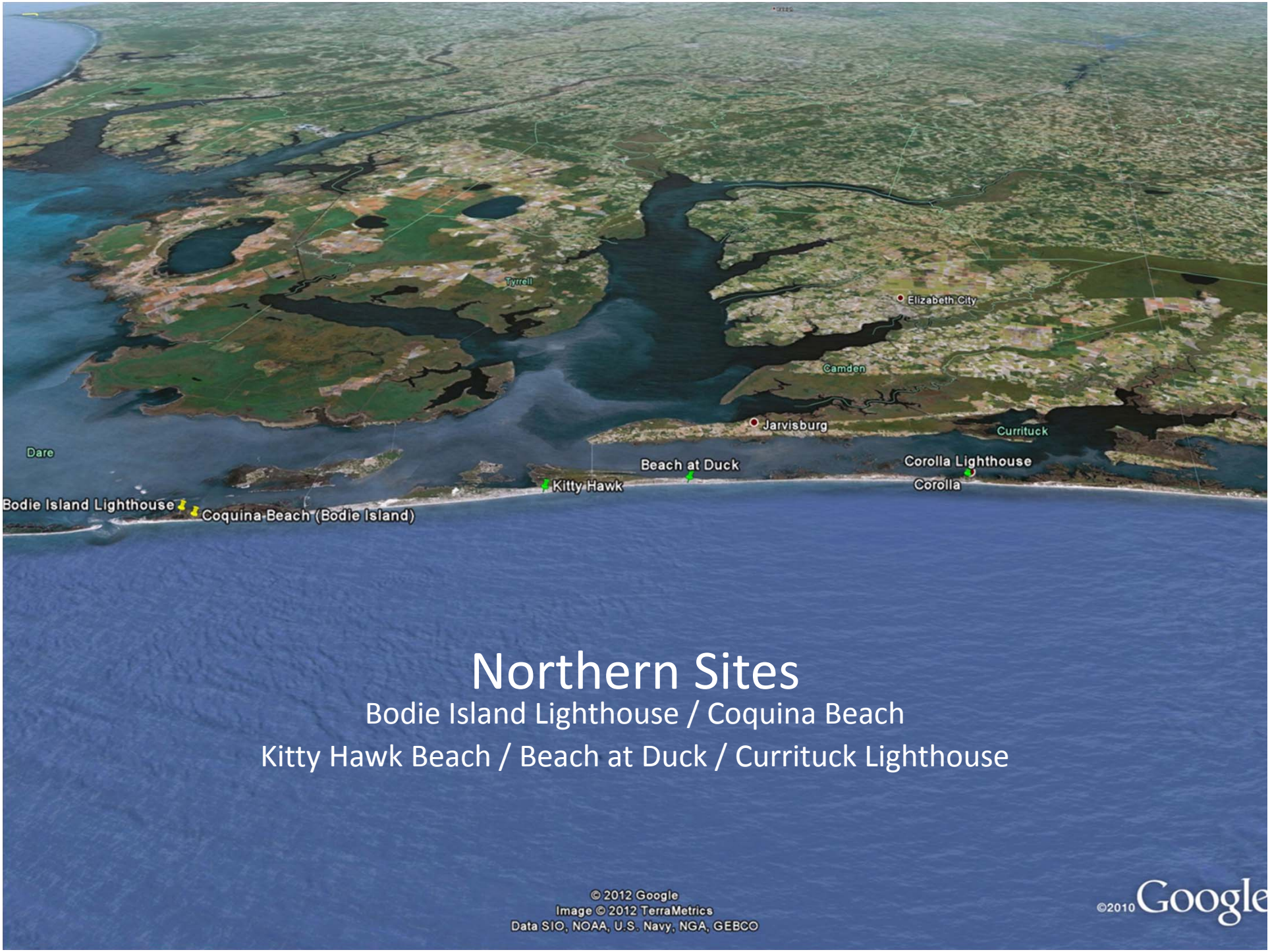
■ = 4.82m^2

B. Site Investigation and Documentation

Photograph Locations and Lighting Conditions

Location	Early Morning	Late Afternoon	Starlit Night	Foggy Night
Coquina Beach (Bodie Island)	X	X		
Bodie Island Lighthouse	X	X		
Lighthouse Beach (Buxton)	X	X		
Cape Hatteras Lighthouse	X	X / +	X / +	X / +
Ocracoke Beach (Ocracoke Island)	X	X / +	X / +	X / +
Portsmouth Life Saving Sta. Tower	X	X		
Long Point Camps	X	X / +	X / +	X / +
Great Island Camps	X	X	X	X
Cape Lookout Lighthouse	X	X / +	+	+
Cape Point	X	X	X	X
Holden Beach		X	X	
Bald Head Island		X		
Beach at Duck		X		
Kitty Hawk		X		
Corolla Lighthouse		X		
Atlantic Beach		X		
Sunset Beach		X		
Oak Island		X		

Note: X = simulations and + = animation



Northern Sites

Bodie Island Lighthouse / Coquina Beach

Kitty Hawk Beach / Beach at Duck / Currituck Lighthouse

North Central Sites

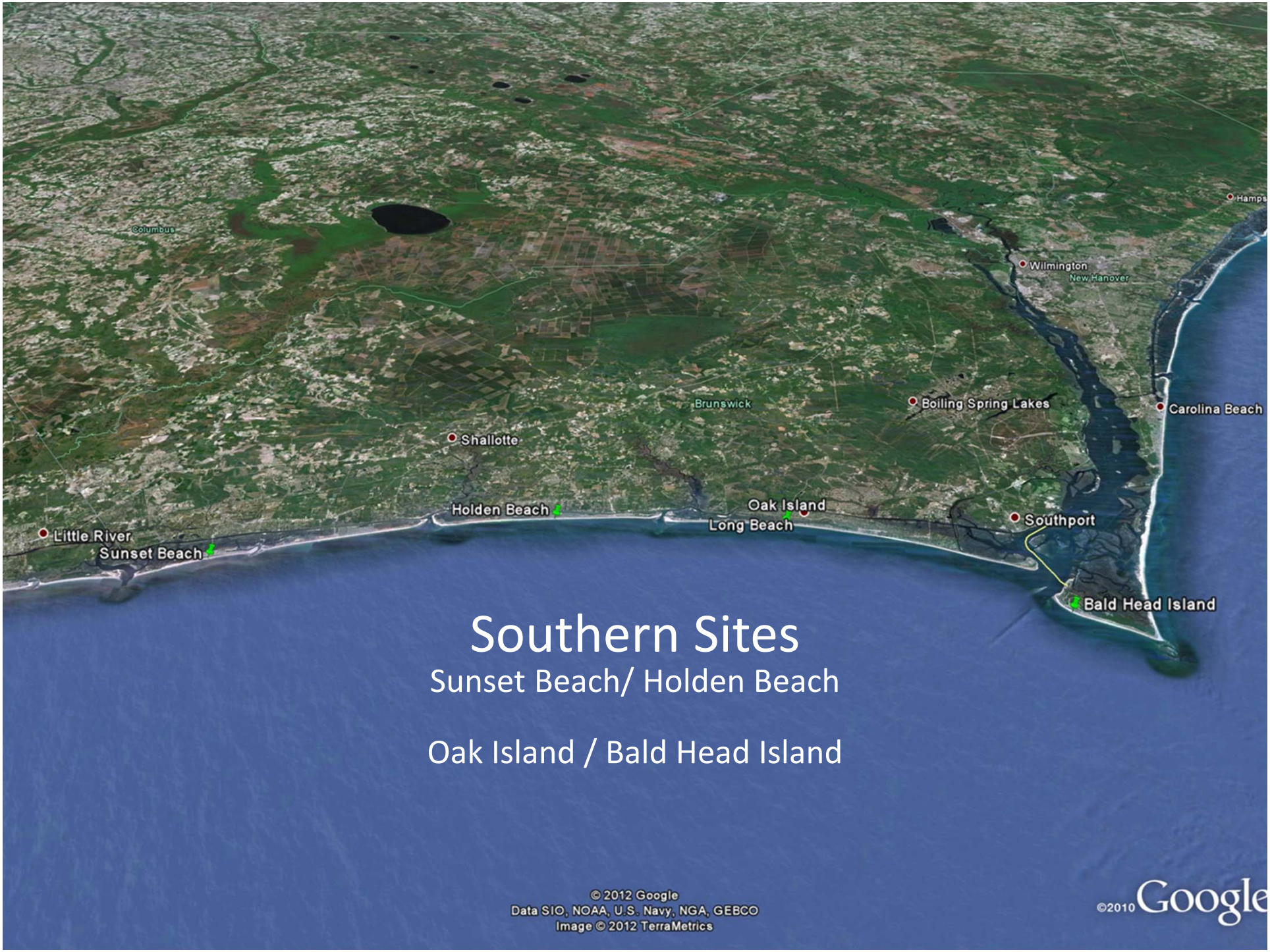
Portsmouth Life Saving Tower / Ocracoke Beach

Cape Hatteras Lighthouse / Lighthouse Beach

South Central Sites

Atlantic Beach / Cape Point / Great Island Camps

Long Point Camps / Portsmouth



Southern Sites

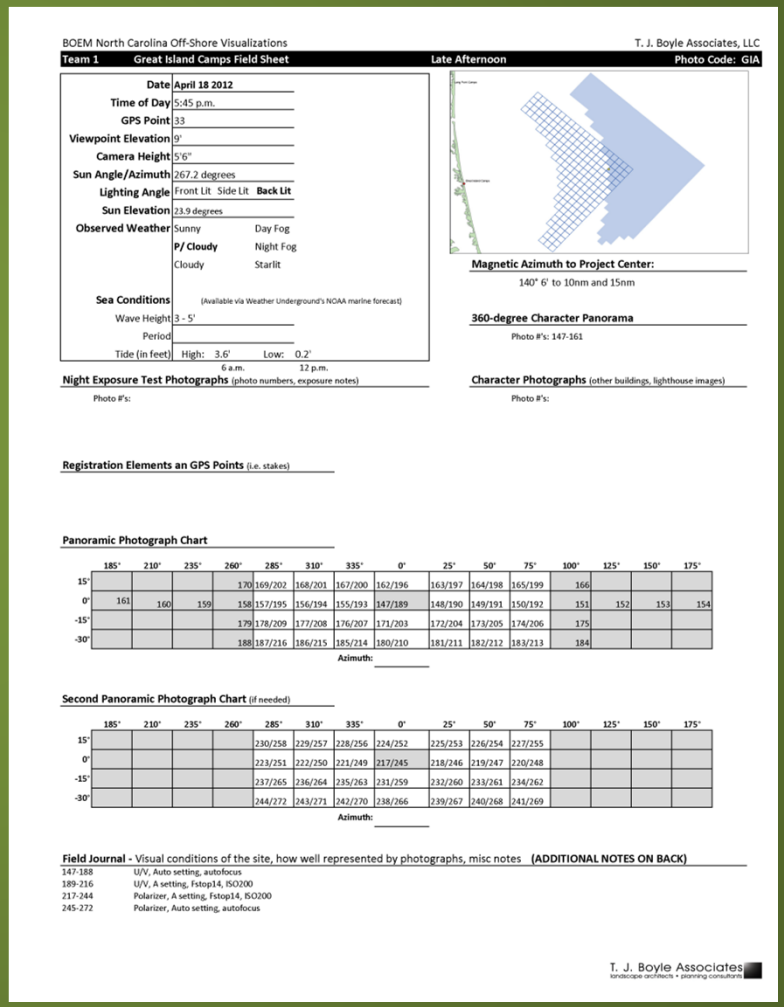
Sunset Beach/ Holden Beach

Oak Island / Bald Head Island

B. Site Investigation and Documentation (cont.)

Fieldwork Checklist

- Custom fieldwork checklist created for every viewpoint location
- Systematic photography and record keeping
- Utilized GPS units, aerial imagery and maps, and azimuths to the project locations provided by BOEM
- Determine and record viewpoint location and elevation with GPS
- Record observed sun angle, weather, sea condition, and site condition



BOEM North Carolina Off-Shore Visualizations — T. J. Boyle Associates, LLC

Team 1 — **Great Island Camps Field Sheet** — **Late Afternoon** — **Photo Code: GIA**

Date	April 18 2012
Time of Day	5:45 p.m.
GPS Point	33
Viewpoint Elevation	9'
Camera Height	5'6"
Sun Angle/Azimuth	267.2 degrees
Lighting Angle	Front Lit Side Lit **Back Lit**
Sun Elevation	23.9 degrees
Observed Weather	Sunny / **P/ Cloudy** / Cloudy / Day Fog / Night Fog / Starlit
Sea Conditions	(Available via Weather Underground's NOAA marine forecast)
Wave Height	3 - 5'
Period	
Tide (in feet)	High: 3.6' (6 a.m.) Low: 0.2' (12 p.m.)

Magnetic Azimuth to Project Center: 140° 6' to 10nm and 15nm

360-degree Character Panorama Photo #'s: 147-161

Night Exposure Test Photographs (photo numbers, exposure notes) Photo #'s:

Character Photographs (other buildings, lighthouse images) Photo #'s:

Registration Elements an GPS Points (i.e. stakes)

Panoramic Photograph Chart

	185°	210°	235°	260°	285°	310°	335°	0°	25°	50°	75°	100°	125°	150°	175°
15°				170	169/202	168/201	167/200	162/196	163/197	164/198	165/199	166			
0°	161	160	159	158	157/195	156/194	155/193	147/189	148/190	149/191	150/192	151	152	153	154
-15°				179	178/209	177/208	176/207	171/203	172/204	173/205	174/206	175			
-30°				188	187/216	186/215	185/214	180/210	181/211	182/212	183/213	184			

Azimuth:

Second Panoramic Photograph Chart (if needed)

	185°	210°	235°	260°	285°	310°	335°	0°	25°	50°	75°	100°	125°	150°	175°
15°					230/258	229/257	228/256	224/252	225/253	226/254	227/255				
0°					223/251	222/250	221/249	217/245	218/246	219/247	220/248				
-15°					237/265	236/264	235/263	231/259	232/260	233/261	234/262				
-30°					244/272	243/271	242/270	238/266	239/267	240/268	241/269				

Azimuth:

Field Journal - Visual conditions of the site, how well represented by photographs, misc notes **(ADDITIONAL NOTES ON BACK)**

147-188 U/V, Auto setting, autofocus
189-216 U/V, A setting, Fstop14, ISO200
217-244 Polarizer, A setting, Fstop14, ISO200
245-272 Polarizer, Auto setting, autofocus

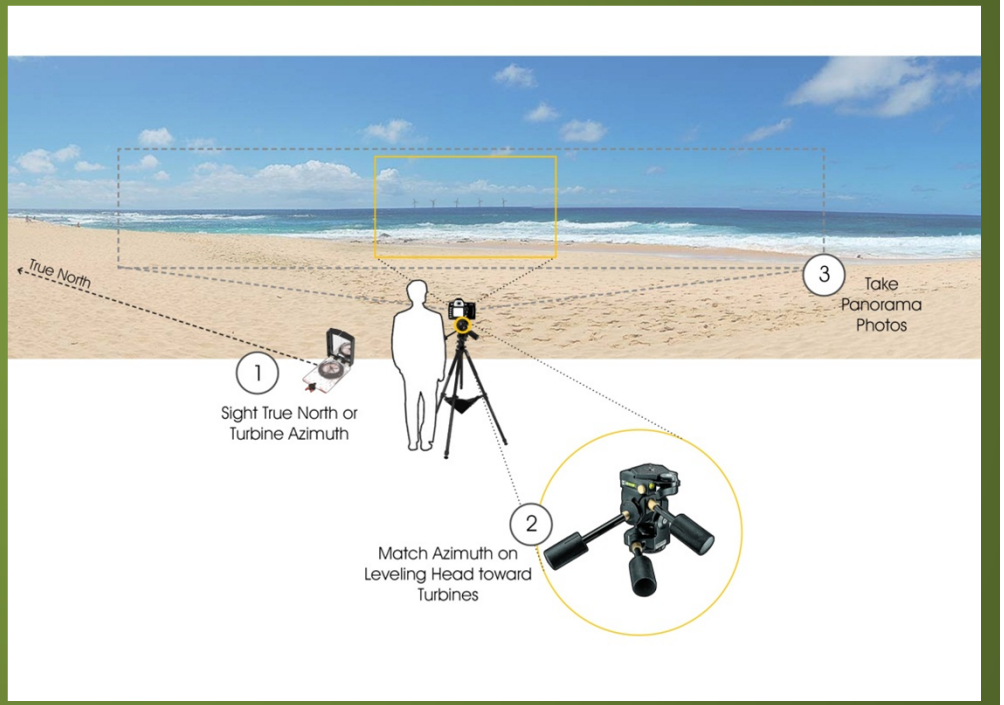
T. J. Boyle Associates — landscape architects + planning consultants

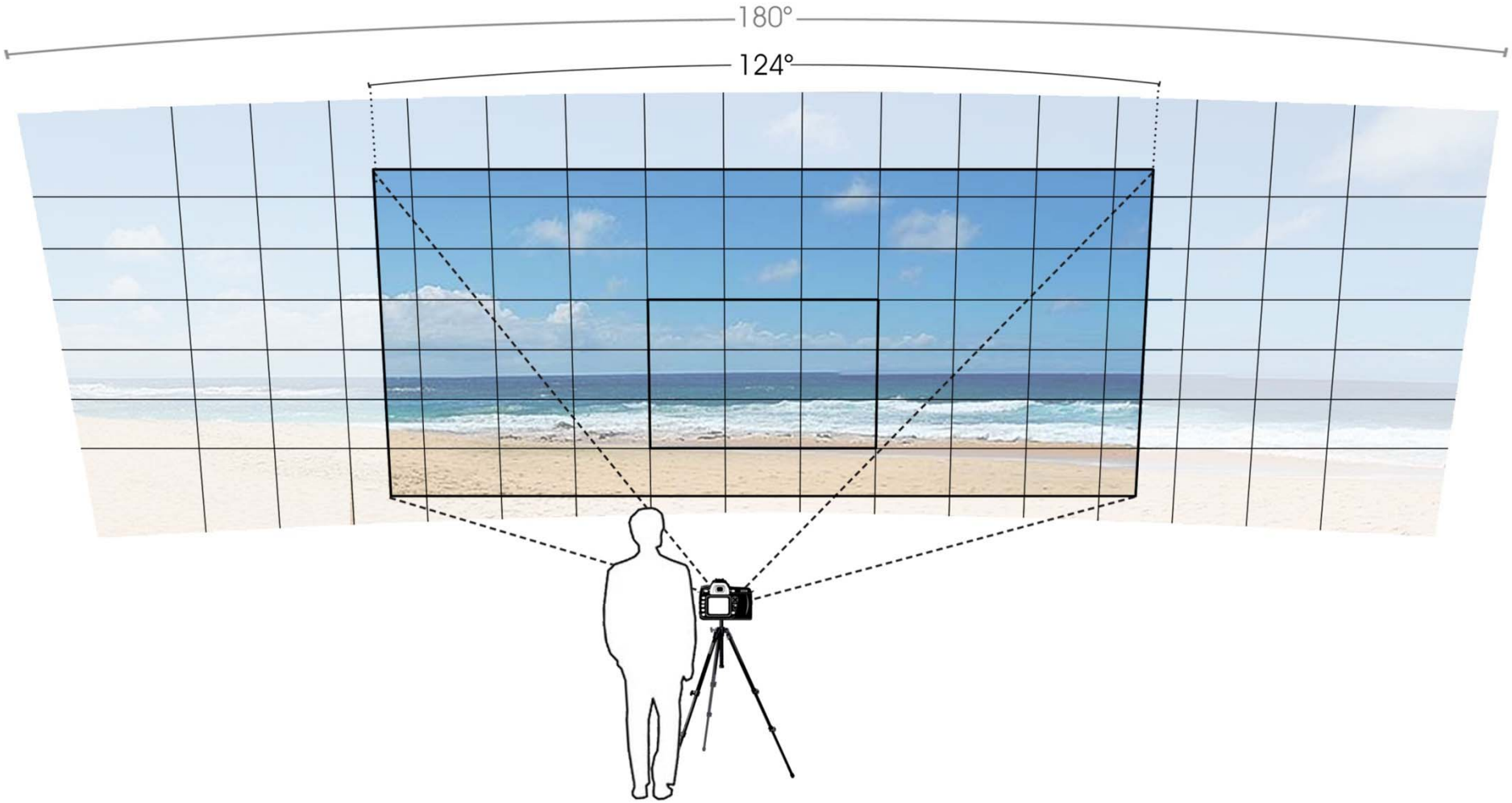
Visualization Study for Offshore North Carolina

B. Site Investigation and Documentation (cont.)

Fieldwork Checklist

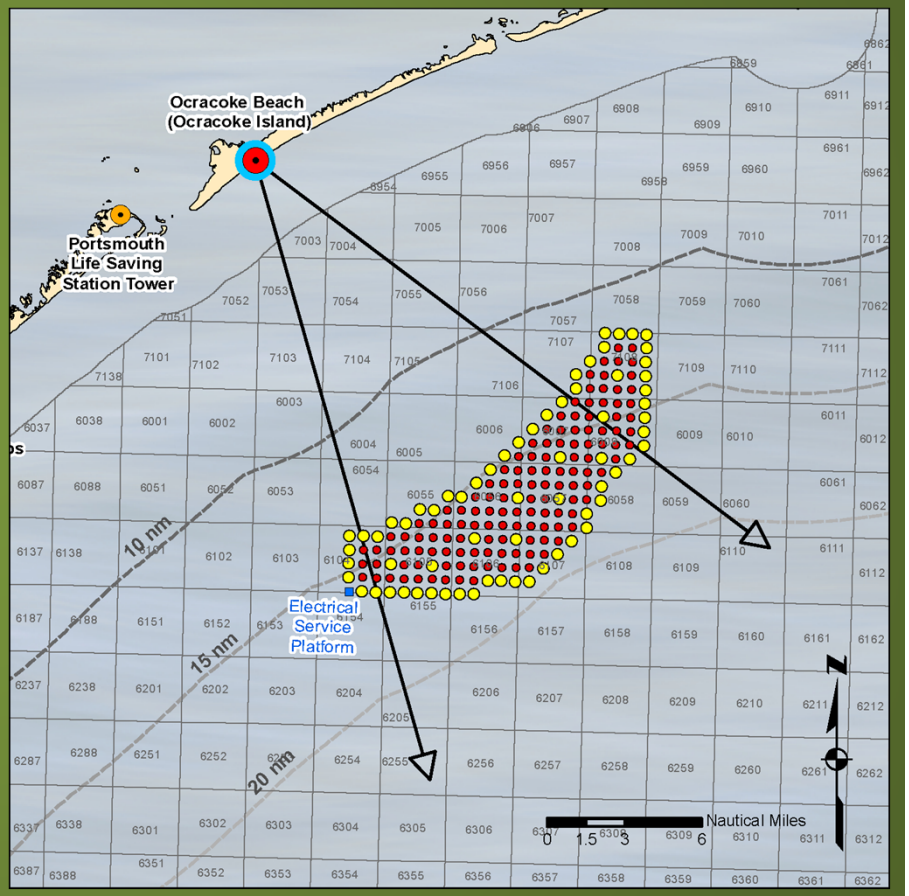
- Set-up tripod, leveling pan head and camera to the standard height (approx. 5 feet)
- Mount compass on camera hot-shoe and adjust compass bearing
- Take photographs at azimuth and bearing as described on fieldwork checklist, recording photo numbers
- Transfer photographs to laptop computer and check for correct exposure, focus, etc.
- Re-photograph and check as necessary



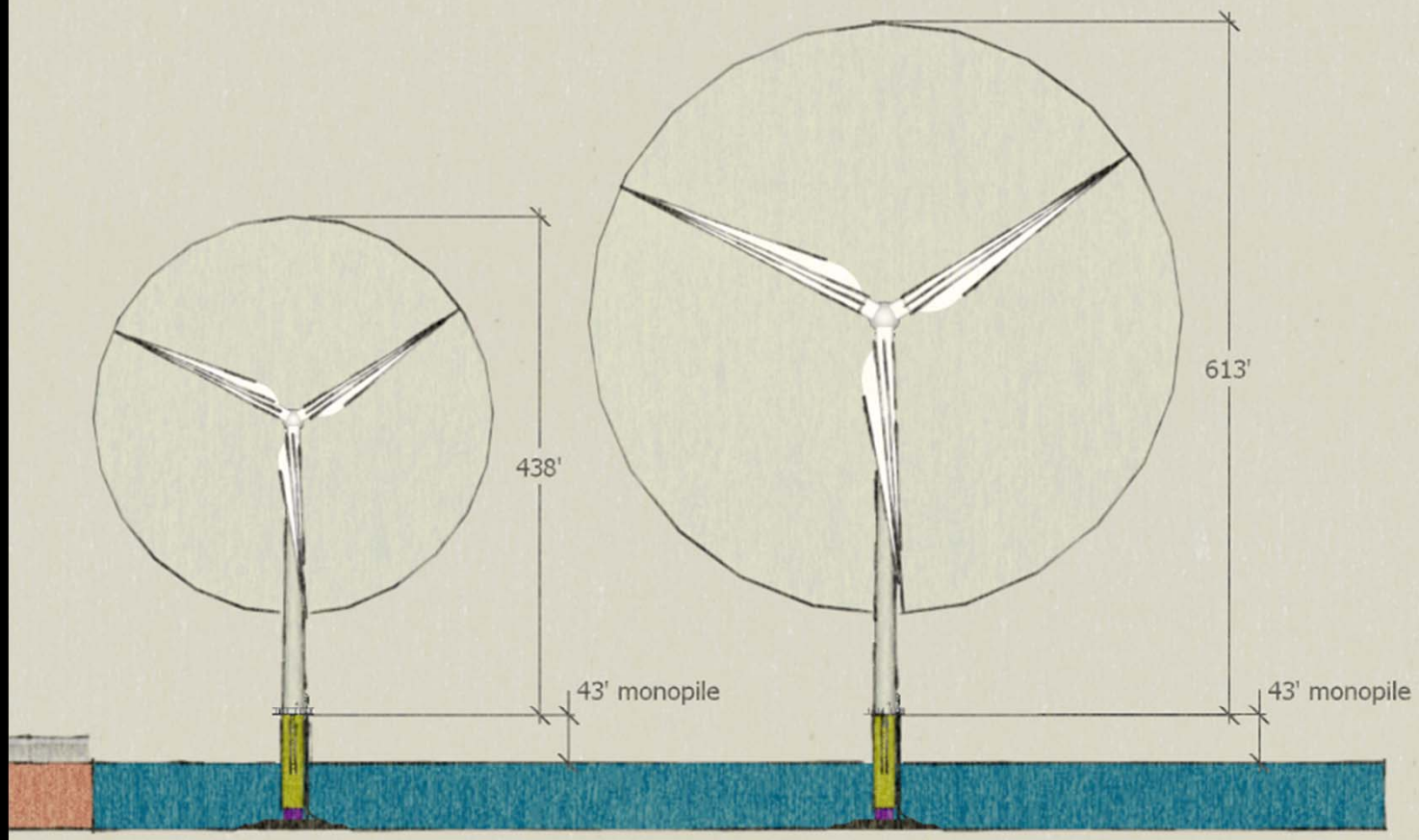

180°
124°

C. Prepare Visualizations:
1. Single-Frame Simulations

- Utilize turbine locations provided by BOEM for three distances at each site (10nm, 15nm and 20nm)
- Model two types of turbines at each distance (Siemens 3.6 MW and Vestas 7.0 MW)
- Utilize tools within WindPRO to create a geo-referenced digital version of each site/condition
- Import original photographs and align with the computer model using field data, camera and lens information, and other elements in the view that were located using GPS, compass or aerial photos
- Utilize WindPRO to create wireframes, simulations
- Utilize WindPRO and Autopano Pro to create panoramas
- Utilize WindPRO and Adobe Photoshop CS6 to create animations



Visualization Study for Offshore North Carolina



Siemens SWT-3.6-107 **Vestas V164-7.0 MW**

C. Prepare Visualizations (cont.):

1. Single-Frame Simulations

- Set WindPRO atmospheric conditions to correspond to the photographic lighting conditions
- 200 turbines per project distance
- Three distances (10nm, 15nm, and 20nm)

39 lighting conditions
x 3 distances
x 2 turbine types
234 simulations

18 locations
x 200 turbines
x 3 distances
x 2 turbine types
21,600 individual turbines modeled

C. Prepare Visualizations (cont.):

1. Single-Frame Simulations

Nighttime Simulations

- Performed nighttime photographic reconnaissance of FAA L-864 aviation warning lights both on the Outer Banks (Hatteras Rescue 21 tower) and on turbines in New Hampshire (Lempster Wind Power Project)
- Used the photographed lights from the field recon as the light symbol within WindPRO
- Nautical Navigation Hazard Lights are intended to be visible from 2 to 5 nautical miles

Visualization Study for Offshore North Carolina

2 LUMINOUS RANGE FOR NIGHT TIME

The required value for illuminance is $E_t = 2 \times 10^{-7}$ lx

$I = 0.686\ D^2\ (0.05)^{-D/V}$ where I is in candela, and D & V are numerical values in M

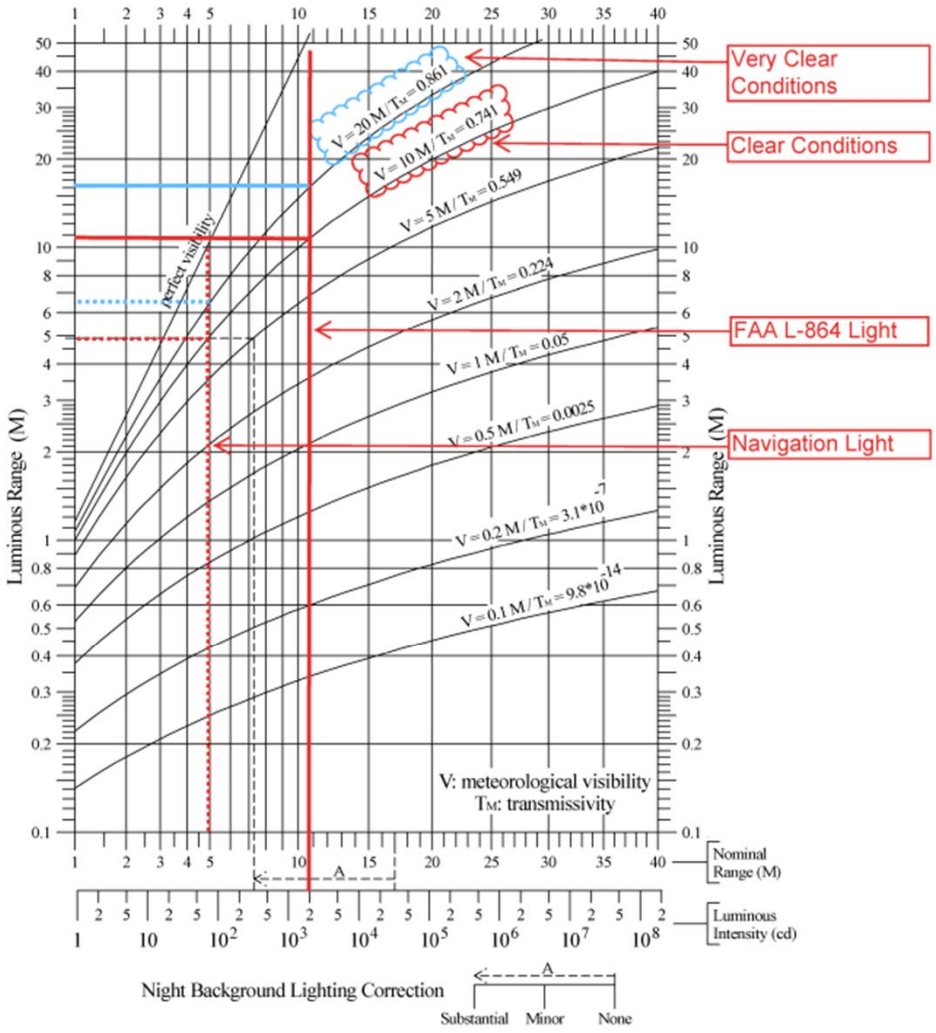


Figure 2 Luminous Range diagram – night time

C. Prepare Visualizations (cont.):

1. Single-Frame Simulations

- Determined that one weather condition described in the RFP, the Nighttime Foggy condition, would result in no visibility of turbines or lights based on NOAA definition:

> "Fog: Water that has condensed close to ground level, producing a cloud of very small droplets that reduces visibility to less than one km (three thousand and three hundred feet)."

- Coordinated with BOEM and the NPS to switch to a "misty night" condition, which would mimic light dispersion and attenuation due to the presence of moisture around the turbines. It is unknown if such a situation will occur, or what meteorological conditions would be needed to create such a "misty night". However, the settings used to create the mist effect are documented. The "misty night" condition is for illustrative purposes only.

Long Point Camps Afternoon – Vestas 10nm Wireframe

Long Point Camps Afternoon – Vestas 10nm Simulation

Long Point Camps Starlit Night – Vestas 10nm Simulation

Long Point Camps Misty Night – Siemens 10nm Simulation

D. Correct Printing, Displaying and Viewing of Visualizations:

1. Single-Frame Simulations

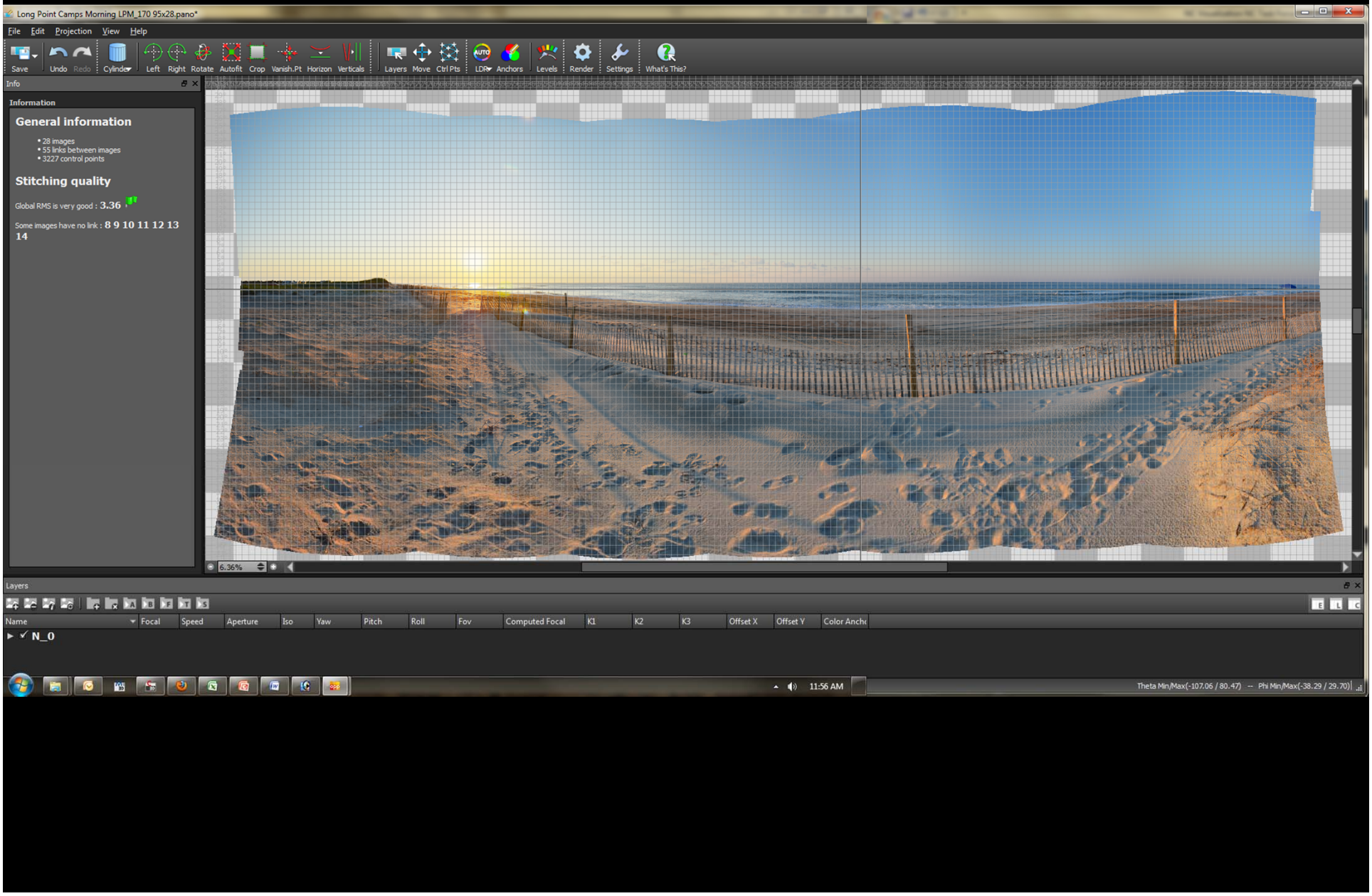
- When printed at 1200 dpi or higher on a color printer and quality 11”x17” paper at actual size, the single-frame simulations will be in proper perspective and resolution when viewed at 23.5” from the eye

- When viewed on a monitor, use the highest screen resolution possible and view at a distance of approximately twice the image height

C. Prepare Visualizations:
2. Panoramic Simulations

- RFP states that the panoramas should encompass 124 degrees horizontal field of view (‘full primary human field of view’) and should show 55 degrees vertical field of view
- Autopano Pro software used to align, stitch, and crop the panoramas to the desired field of view
- A cylindrical projection was set within Autopano Pro – this is the industry standard and most practical approach for viewing and printing panoramas
- Panoramas then imported into WindPRO for simulating turbines

Kolor Autopano Pro Software – Cylindrical Projection



Long Point Camps Afternoon – Vestas 10nm Panorama Wireframe

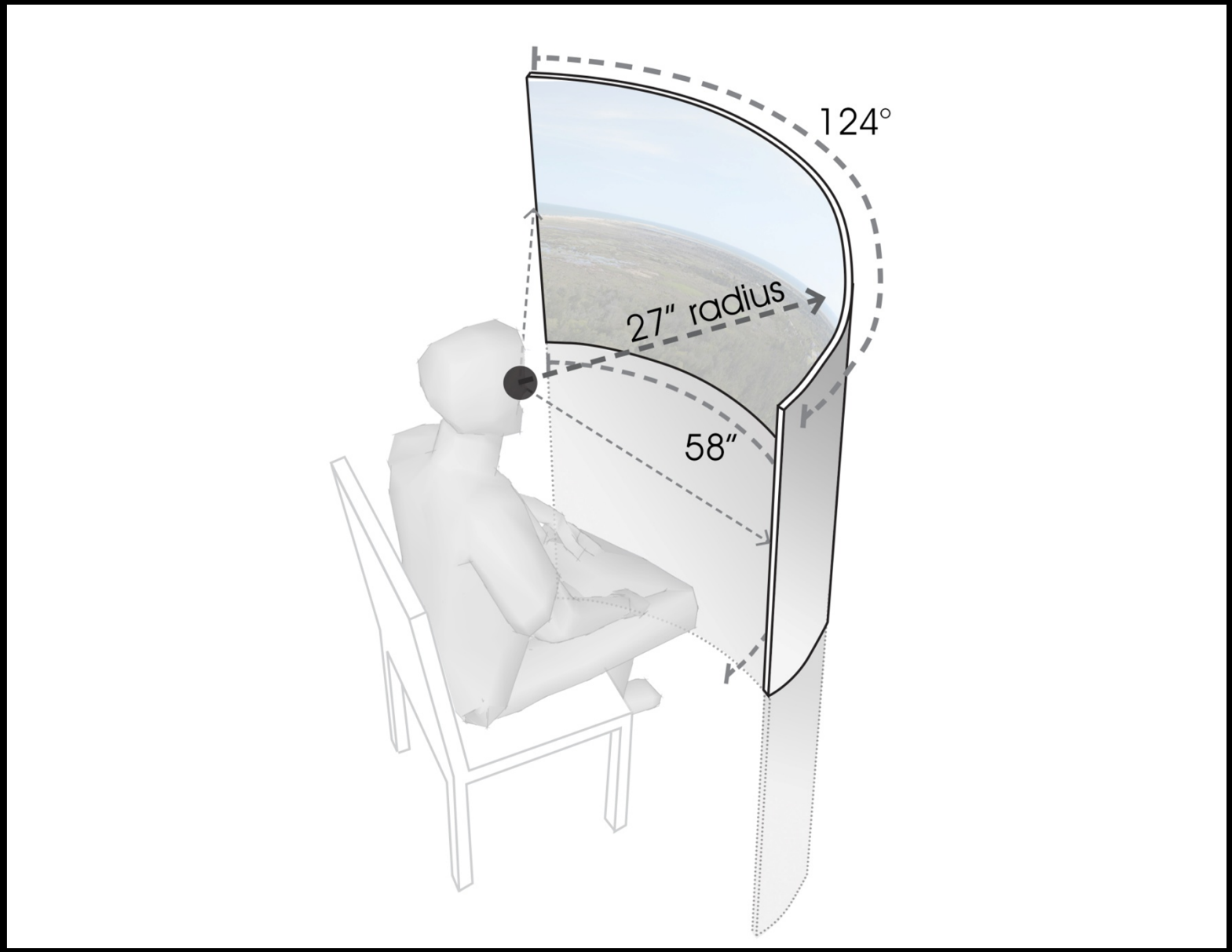
Long Point Camps Afternoon – Vestas 10nm Panorama Simulation

D. Correct Printing, Displaying and Viewing of Visualizations:

2. Panoramic Simulations

- When printed at 600 dpi or higher on a color plotter and quality 30”x60” paper at actual size, the panoramic simulations will be in proper perspective and resolution when viewed in a curved cylindrical projection at a radius of 27” from the eye
- When viewing flat on a wall, stare straight ahead at the image and move side to side rather than turning your head, maintaining a distance of 27” from the eye
- Cylindrical projections are not entirely accurate when viewed flat on a wall, and can only the central 6-10 degrees of vision is considered accurate

Properly Viewing a Panorama



C. Prepare Visualizations:

2. Animated Videos

- Animated simulations showing turbine blade movement and warning lights
- Prepared for four (4) locations and three (3) light conditions each
- Total of twelve (12) conditions, each with Projects at 10nm and 20 nm, and with each type of turbine for a total of forty eight (48) animated videos

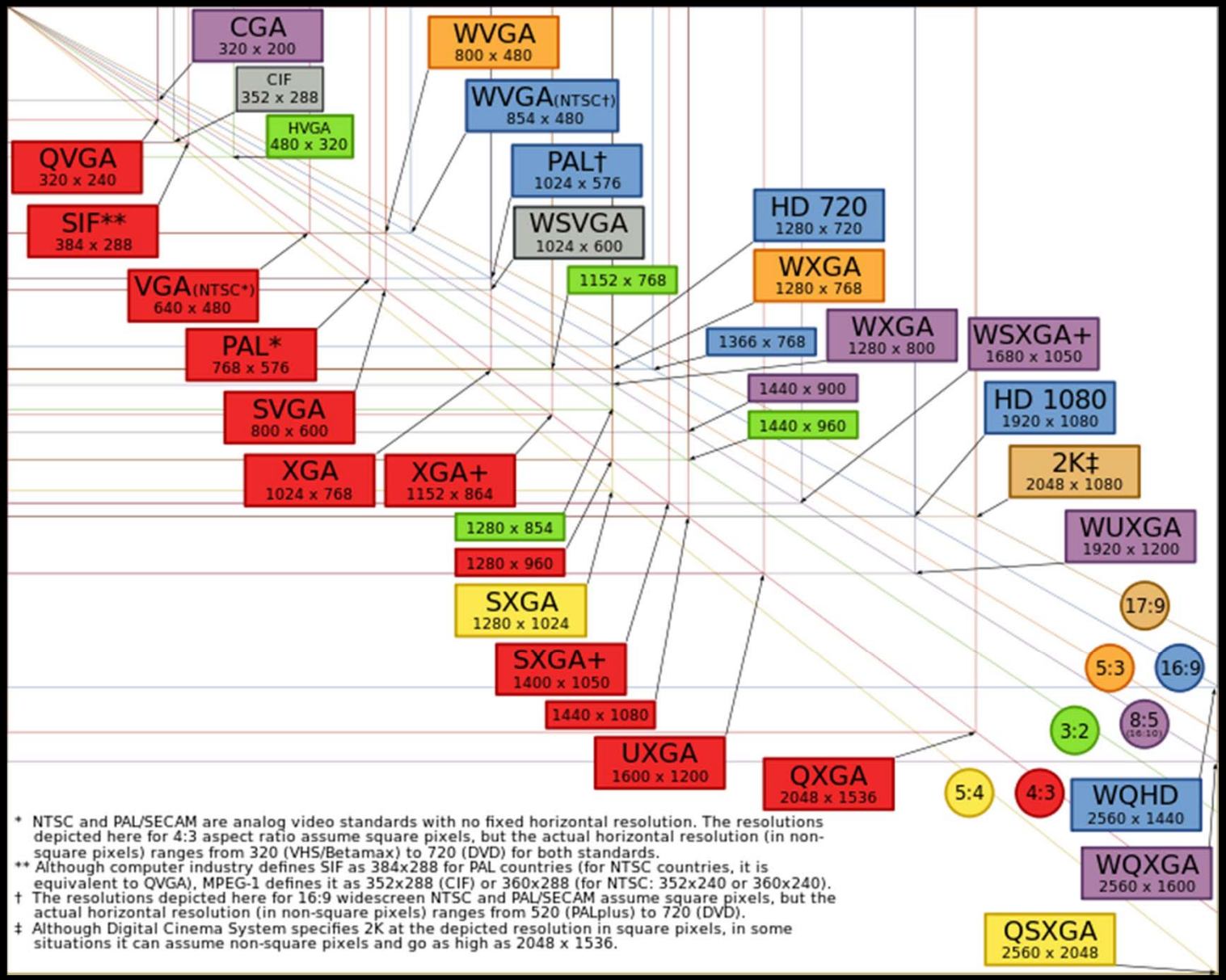
D. Correct Printing, Displaying and Viewing of Visualizations:

3. Animated Videos

Display Resolution

- Nikkor DX 35mm lens has a “normal” horizontal angle of 37.3°, vertical angle of 25.3°,or 2,238-by-1,518 minutes.
- The RFQ specifies that the animations are to have at least 720p resolution. The standard 720p format is 1280-by-720 pixels (720 pixels tall). Each pixel in 720p format would represent about 2 arcminutes on a side, which is 25% of the resolution necessary to meet the detection acuity threshold of 0.5 arcminutes.
- The standard 1080p format is 1920-by-1080 pixels (1080 pixels tall). Each pixel in 720p format would represent 1.41 arcminutes on a side, which is 35% of the resolution necessary to meet the detection acuity threshold of 0.5 arcminutes
- Since 1080p meets the resolution criteria in the RFP, and is the current standard for display devices and video editing software, a resolution of 1080p is used for the animations.

Standard Display Resolution Technology (from Wikipedia)



Long Point Camps Afternoon – Vestas 10nm Animation

VISUALIZATION STUDY FOR
OFFSHORE NORTH CAROLINA

ANIMATION

010 Long Point Camps
Late Afternoon
Vestas V164-7.0 MW
10 nm

T. J. Boyle Associates
landscape architects • planning consultants

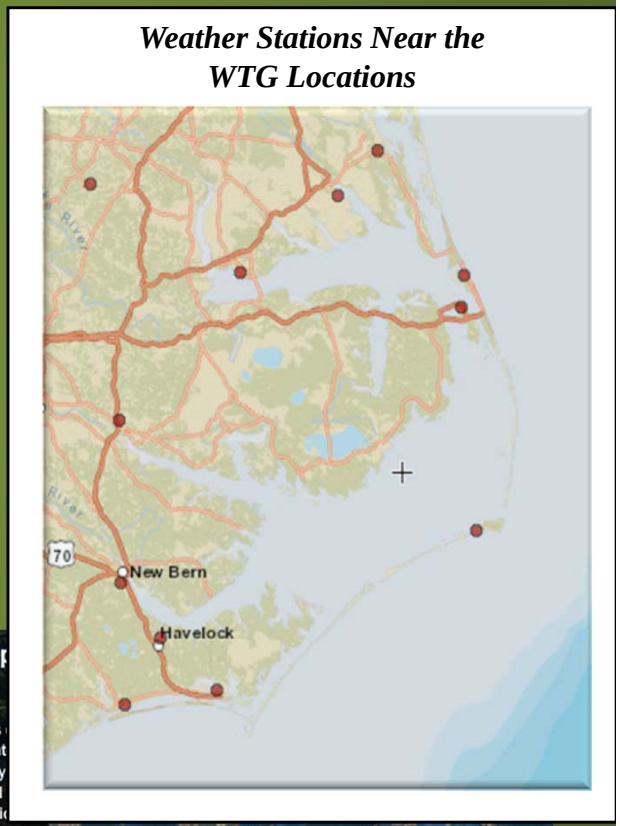
4) Document and Analyze Meteorological Conditions

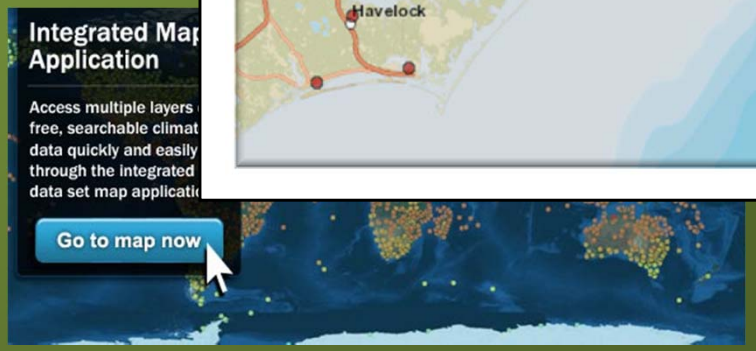
NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)

Data Collection:

Gather historical information of the meteorological conditions at the identified study areas to determine average visibility and weather conditions

- NOAA Weather Data including visibility, precipitation, wind speed and direction, cloud conditions
- Ten years of hourly meteorological data
- Data was obtained for seven weather stations along the North Carolina coastline

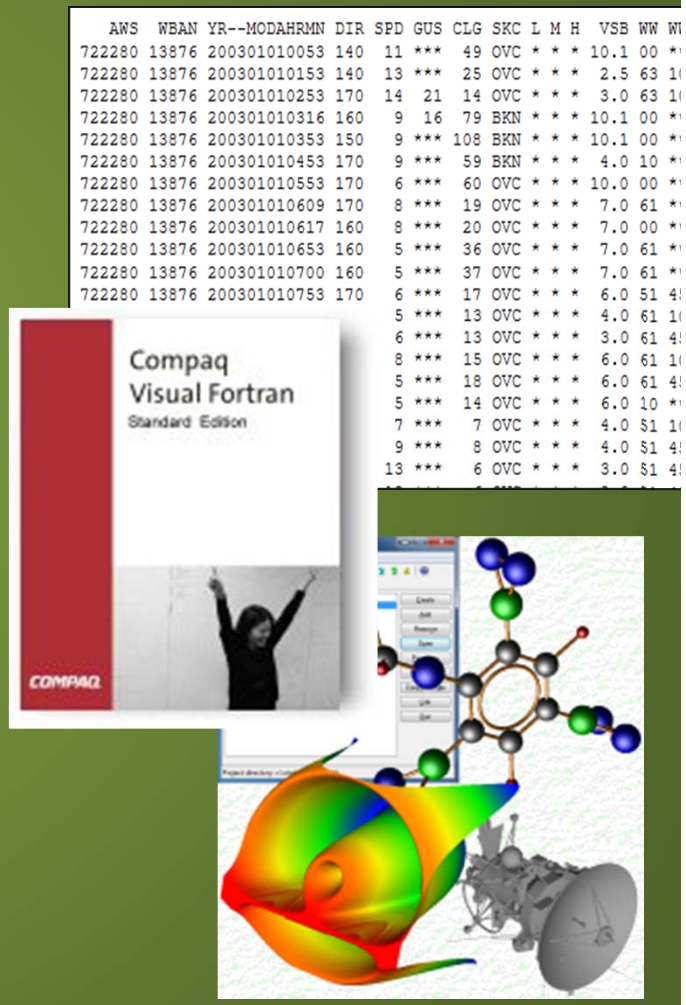




4) Document and Analyze Meteorological Conditions (cont.)

Data Processing

- A database was developed using Digital Visual Fortran to input the meteorological data and calculate the metrics of interest including:
  - The average number of days that there is visibility to 10 nm, 15 nm and 20 nm
  - The average visibility to 10 nm, 15 nm and 20 nm in each season
  - The average number of days that are sunny
  - The average number of days that are sunny in each of the four seasons
  - The average percent of each day that is sunny, cloudy and foggy
  - The average number of days that are foggy/cloudy for at least 50% of the day
  - The typical wind rose plot for each month



Visualization Study for Offshore North Carolina

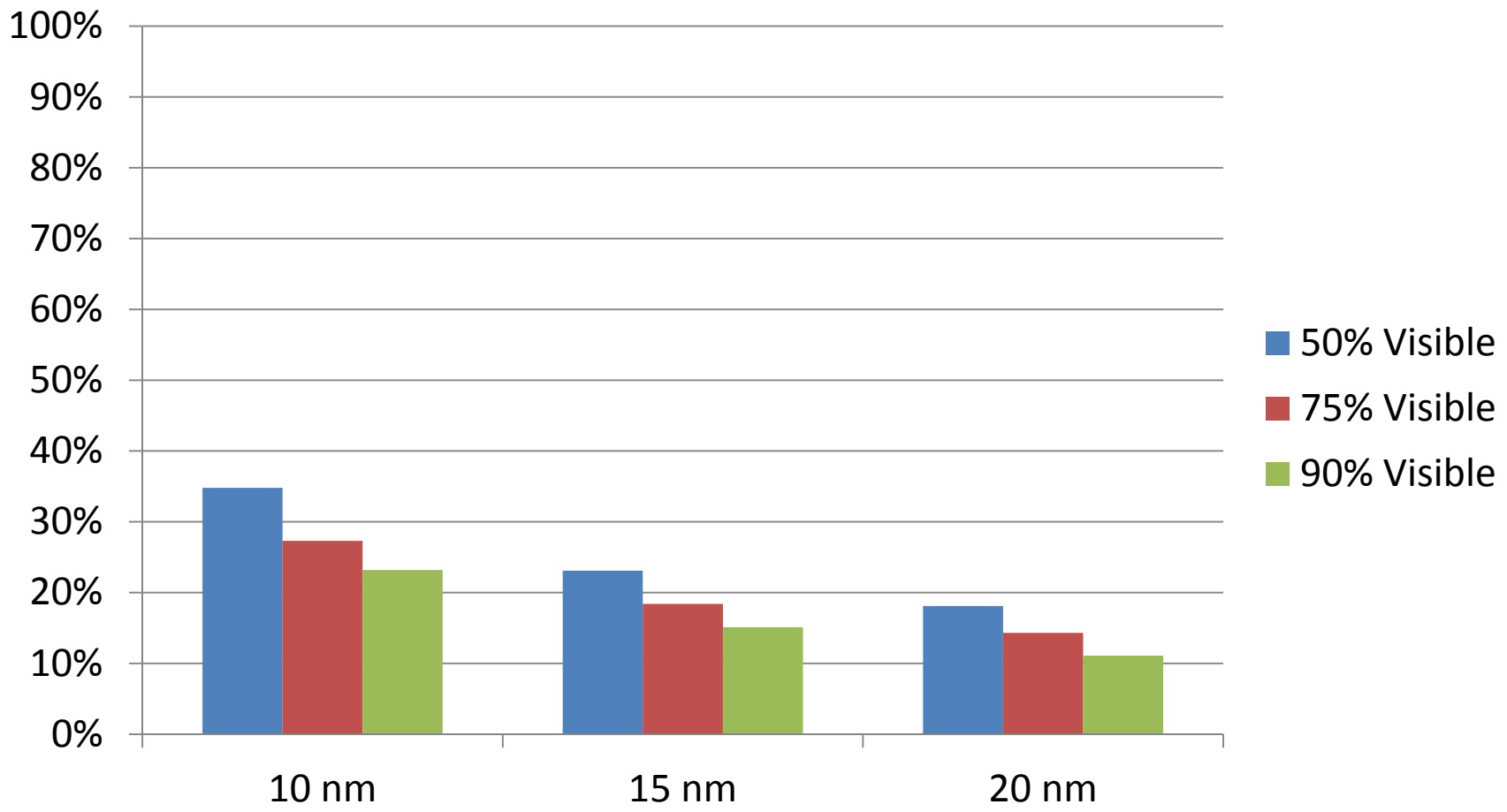
4) Document and Analyze Meteorological Conditions (cont.)

Visibility Metrics

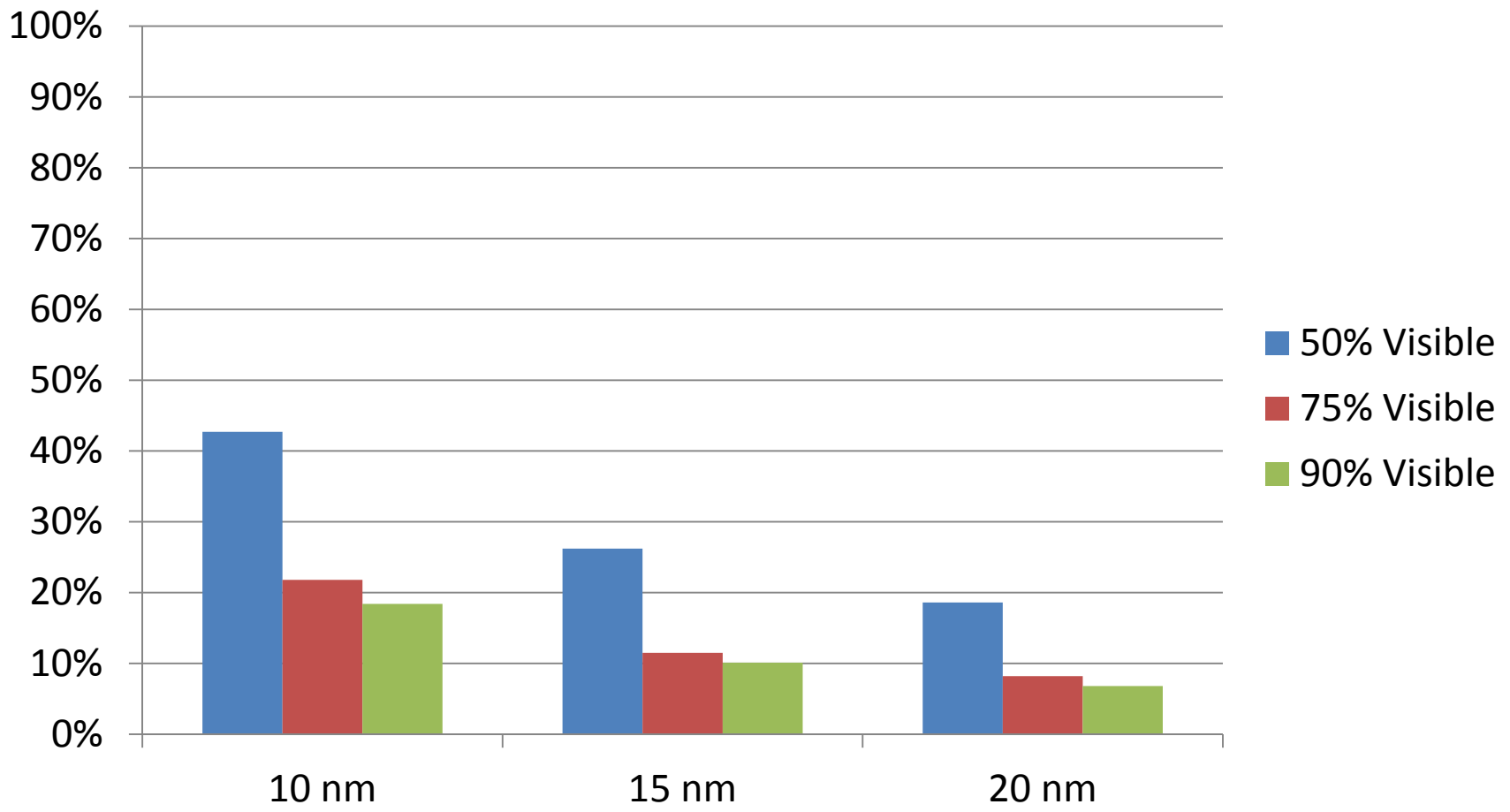
Visibility is a measure of the horizontal opacity of the atmosphere at the point of observation and is expressed in terms of the horizontal distance at which a person should be able to see and identify: in the daytime, a prominent dark object against the sky at the horizon; at night, a known, preferably unfocused, moderately intense light source (i.e. FAA L-864 aviation warning light)

- NOAA considers 10miles full visibility, normally reported on clear days
- Develop an algorithm based on data at adjacent weather stations to extend (i.e. extrapolate) the visibility information to 20 nm.
- Calculation of the visibility metrics was specifically designed to differentiate between the locations. However, variability across all 18 locations is low with a standard deviation of 2.9% for daytime and 6.1% for nighttime.

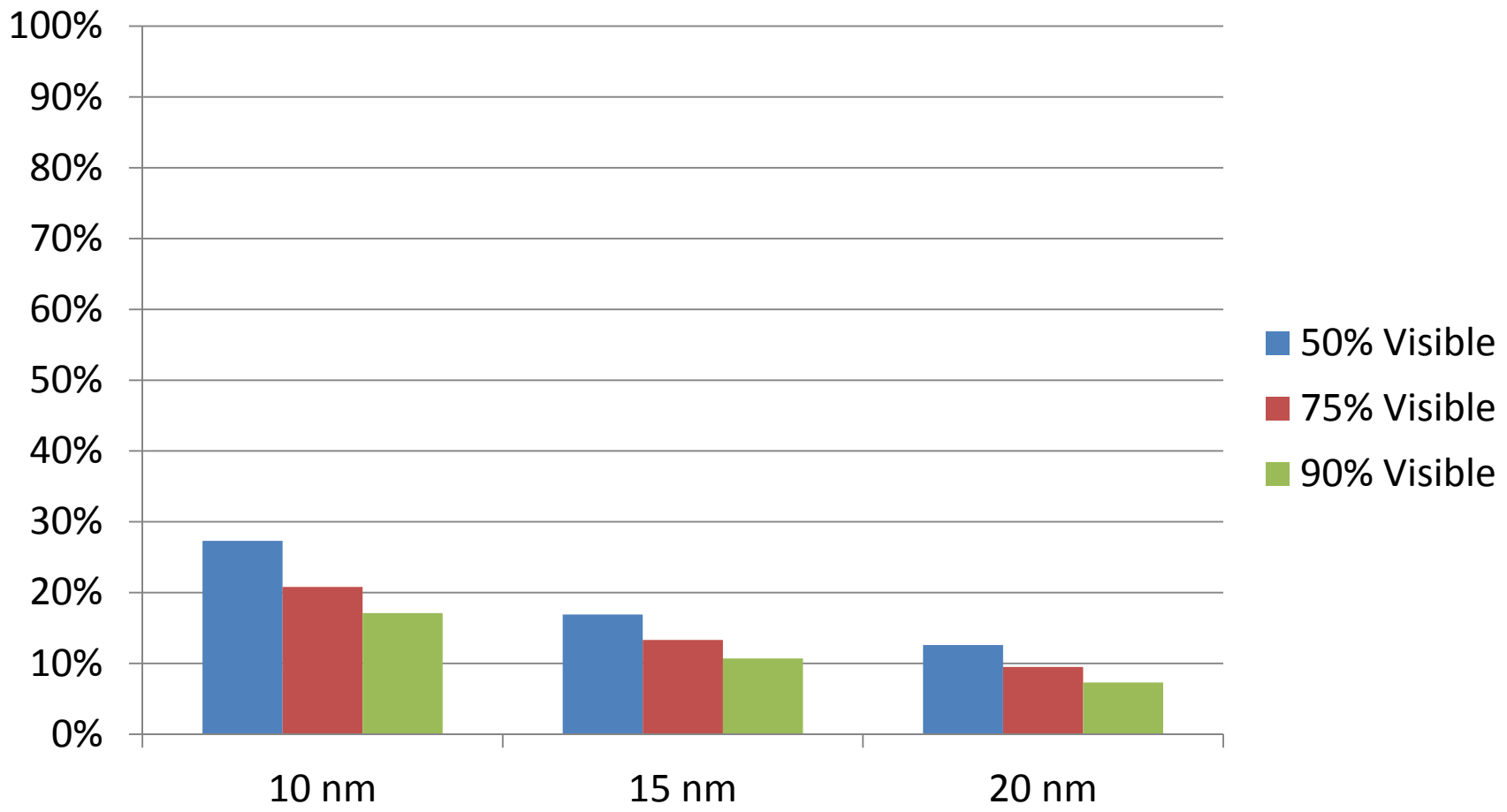
Percent of Days Annually with Visibility to 10 nm, 15 nm and 20 nm, 50%, 75% and 90% of the Day



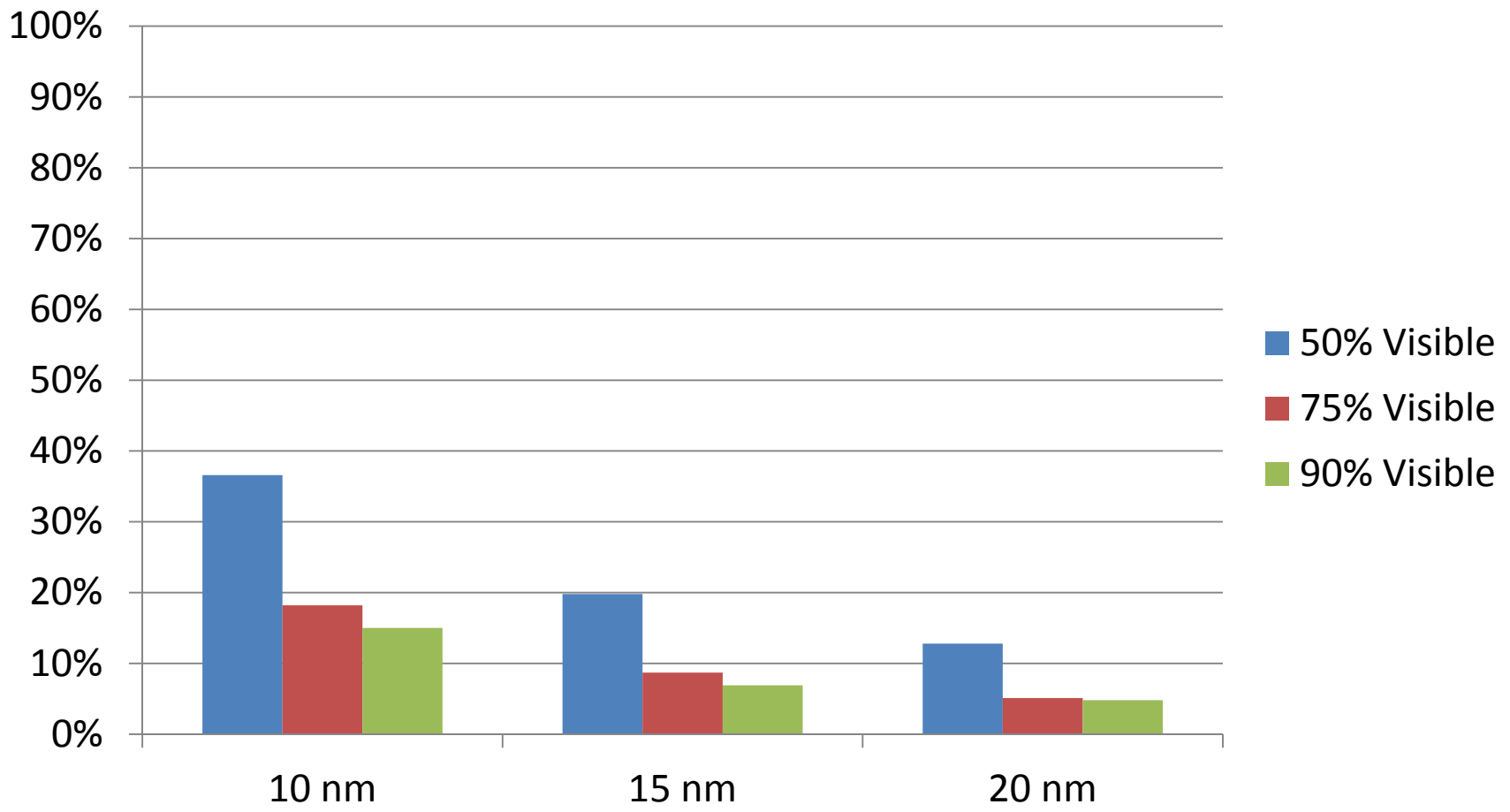
Percent of Nights Annually with Visibility to 10 nm, 15 nm and 20 nm, 50%, 75% and 90% of the Night



Percent of Summer Days with Visibility to 10 nm, 15 nm and 20 nm, 50%, 75% and 90% of the Day



Percent of Summer Nights with Visibility to 10 nm, 15 nm and 20 nm, 50%, 75% and 90% of the Night

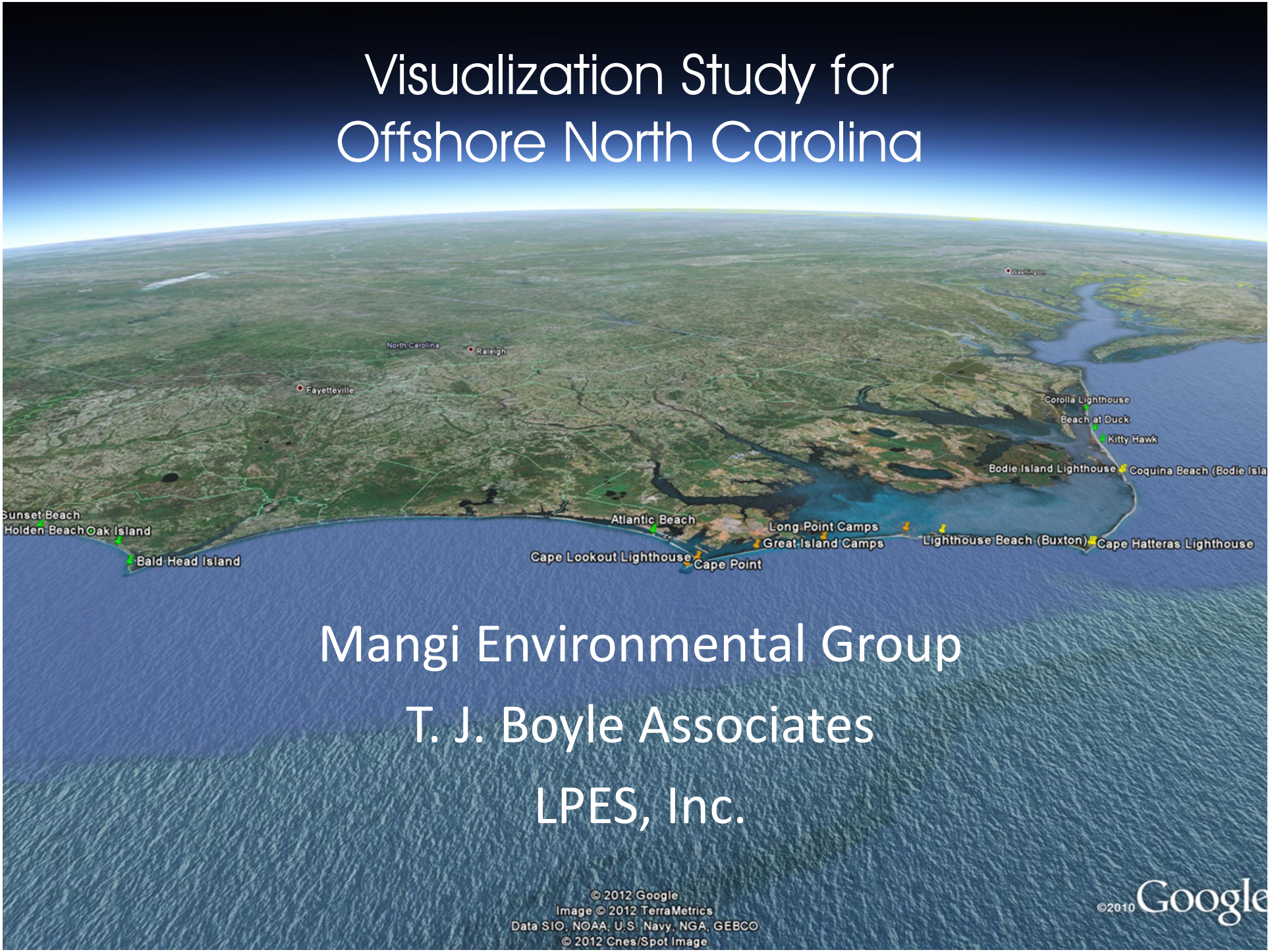


4) Document and Analyze Meteorological Conditions (cont.)

Conclusions:

- During the day there is visibility to 10 nm at least 50% of the day 34.8% of the time, or 127 days per year (this drops to 27.3% in the summer due to hazy conditions)
- In general, the sky is clear 67.8% of the time and cloudy the remaining 32.2% of the time during daytime hours
- It is rarely foggy (less than 1%)
- There is low variability across all 18 locations
- Visibility is only indirectly related to cloud cover as it pertains to haze or periods of precipitation
- Summers have less clouds with higher temperatures creating hazy viewsheds and limiting visibility during summer days the most
- Winter nights are the clearest

Visualization Study for Offshore North Carolina



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