TO: All Interested Parties
FROM: Jessica Schultz, Radar Focal Point, National Weather Service (NWS)
SUBJECT: Lowering the Minimum Scan Angle of the Weather Surveillance Radars - Model 1988 Doppler (WSR-88Ds) serving Greer, SC; Columbia, SC; and Raleigh, NC
DATE: February 5, 2019

In accordance with provisions of the National Environmental Policy Act of 1969, the National Weather Service (NWS) prepared a Draft Environmental Assessment (EA) analyzing the potential environmental effects of lowering the minimum scan angle of the KGSP, KCAE, and KRAX WSR-88Ds serving the Greer, SC; Columbia, SC; and Raleigh, NC areas, respectively. The Draft Environmental Assessment is available for public review and comment. The Draft EA may be obtained at:

https://www.roc.noaa.gov/WSR88D/SafetyandEnv/EAReports.aspx

The National Weather Service (NWS) owns and operates the three existing WSR-88Ds. The KGSP WSR-88D is located at Greenville-Spartanburg International Airport in Greer, Spartanburg County, SC. The KCAE WSR-88D is located at Columbia Metropolitan Airport in West Columbia, Lexington County, SC. The KRAX WSR-88D is designated KRAX is located at the North Carolina State University (NCSU) agricultural research facility in Clayton, Johnston County, NC. The KGSP, KCAE, and KRAX WSR-88Ds were commissioned in 1995 and 1996, and have all been in continuous operation since being commissioned. The radars are three of the 159 WSR-88Ds in the nationwide network.

The three WSR-88Ds transmit a narrow focused main beam with a width of 1 degree. In normal operation, the WSR-88D antenna rotates horizontally to cover all directions (i.e. azimuths). The radar antenna also varies the scan angle at which it points with respect to the horizon. Currently, all three WSR-88Ds operate at a minimum of scan angle of +0.5 degrees (deg) above the horizon. NWS proposes to reduce the minimum scan angle of the KGSP and KRAX WSR-88Ds from the current minimum of +0.5 deg to +0.2 deg (i.e. 0.3 deg lower than existing) to provide enhanced coverage of the lower portions of the atmosphere. The minimum scan angle of the KCAE WSR-88D would be reduced to +0.4 deg (i.e. 0.1 deg lower than existing). No construction activities or physical modification of the KGSP, KCAE, or KRAX WSR-88Ds would be required to implement the proposed action; the only change would be to the radars’ operating software.

NWS will accept written comments on the Draft EA until March 15, 2019. Please submit comments via either email or regular mail to:

James Manitakos
Sensor Environmental LLC
296 West Arbor Avenue
Sunnyvale, CA 94085-3602
Email: jmanitakos@sensorenvirollc.com

Comments sent by regular mail must be postmarked by March 15, 2019. After the end of the review period, NWS will prepare a Final EA containing responses to all comments. NWS will not make any decision on implementing the proposed action until completion of the environmental review. Thank you for your interest in this important project.
Environmental Assessment - Lowering the Minimum Scan Angles of the KGSP, KCAE, AND KRAX WSR-88Ds

ENVIRONMENTAL ASSESSMENT (EA)
LOWERING THE MINIMUM SCAN ANGLES OF THE WEATHER SURVEILLANCE RADARS - MODEL 1988, DOPPLER (WSR-88Ds) SERVING THE GREER, SC; COLUMBIA, SC; AND RALEIGH, NC, AREAS

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EXECUTIVE SUMMARY

The National Weather Service (NWS) owns and operates three existing Weather Surveillance Radars, Model 1988 Doppler (WSR-88Ds) serving the Greer, SC; Columbia, SC; and Raleigh, NC, areas. The WSR-88D serving the Greer area is designated KGSP and the radar is located at Greenville-Spartanburg International Airport in Greer, Spartanburg County, SC. The WSR-88D serving the Columbia area is designated KCAE and the radar is located at Columbia Metropolitan Airport in West Columbia, Lexington County, SC. The WSR-88D serving the Raleigh area is designated KRAX and the radar is located at the North Carolina State University (NCSC) agricultural research facility in Clayton, Johnston County, NC. The KGSP, KCAE, and KRAX WSR-88Ds were commissioned in March 1996, June 1995, and July 1995, respectively, and have all been in continuous operation since being commissioned. The radars are three of the 159 WSR-88Ds in the nationwide network.

The KGSP, KCAE, and the KRAX WSR-88Ds are S-band Doppler, dual polarized weather radars, which NWS uses to collect meteorological data to support weather forecasts and severe weather warnings for central and western South Carolina and central and western North Carolina. The WSR-88D antenna transmits a narrow focused main beam with a width of 1 degree. In normal operation, the WSR-88D antenna rotates horizontally to cover all directions (i.e. azimuths). The radar antenna also varies the scan angle at which it points with respect to the horizon. The scan angle is measured along the axis of the main beam and can be changed in 0.1 deg increments. Currently, the KGSP, KCAE, and the KRAX WSR-88Ds operate at a minimum of scan angle of +0.5 degrees (deg) above the horizon. NWS proposes to reduce the minimum scan angle of the KGSP and KRAX WSR-88Ds from the current minimum of +0.5 deg to +0.2 deg and the minimum scan angle of the KCAE WSR-88Ds from the current minimum of +0.5 deg to +0.4 deg. These changes to the minimum scan angles at which these three WSR-88Ds operate constitute the proposed action. Lowering the minimum scan angles of the three WSR-88Ds would provide enhanced coverage of the lower portions of the atmosphere, especially in the Charlotte metropolitan area and the Triad (i.e. Greensboro, Winston-Salem, and High Point) area in NC. Compared to current situation, operating the KGSP, KCAE and KGSP WSR-88Ds at the proposed minimum scan angles would increase radar coverage area at 2,000 ft above site level (ASL) by 69.7 %, 9.9%, and 74.5 %, respectively. The height of radar coverage over downtown Charlotte, NC, would decrease from 3,300 ft above ground level (AGL) to 1,200 ft AGL and over the Triad from 3,600 ft to 2,800 ft AGL. These radar coverage improvements would be very beneficial to NWS forecasters and others parties (e.g. public safety agencies and emergency responders) using the WSR-88D information. No construction activities or physical modification of the two WSR-88Ds would be required to implement the proposed action; the only change would be to the radar’s operating software.

In April 1993, NWS prepared a National Environmental Policy Act (NEPA) document titled, Supplemental Environmental Assessment (SEA) of the Effects of Electromagnetic Radiation from the WSR-88D Radar. That document analyzed operating the WSR-88D at a minimum scan angle
of +0.5 degree (deg). This Draft EA builds on that prior study by examining the possible effects of operating the KGSP and KRAX WSR-88Ds at a minimum scan angle of +0.2 (i.e., 0.3 deg lower than the minimum scan angle examined in the April 1993 SEA) and the KCAE WSR-88D at a minimum scan angle of +0.4 deg 2 (i.e., 0.1 deg lower than the minimum scan angle examined in the April 1993 SEA).

Table S-1 shows radiofrequency (RF) exposure during normal operation with a rotating antenna at the nearest directly illuminated terrain and structures for each of the WSR-88Ds.

<table>
<thead>
<tr>
<th>Location and Distance from Radar</th>
<th>Time-Averaged Power Density (mW/cm²)</th>
<th>ANSI/IEEE General Public RF Exposure Safety Standard</th>
<th>ANSI/IEEE Occupational RF Exposure Safety Standard</th>
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<tbody>
<tr>
<td>Surface of Radome</td>
<td>0.600</td>
<td>1.0</td>
<td>1.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9.27 to 9.63</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>15.4 to 16</td>
</tr>
<tr>
<td>Base of WSR-88D Tower</td>
<td>0.005</td>
<td>1.0</td>
<td>143</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9.27 to 9.63</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1,850 to 1,920</td>
</tr>
<tr>
<td>Closest Ground and Structures which would be within Main Beam for each WSR-88D</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>KGSP Closest Directly Illuminated Ground, 14,300 ft</td>
<td>0.00004</td>
<td>1.0</td>
<td>25,000</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>9.27</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>232,000</td>
</tr>
<tr>
<td>KGSP Closest Structure ASR-8, 4,200 ft</td>
<td>0.00046</td>
<td>1.0</td>
<td>2,170</td>
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<td></td>
<td></td>
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<td>9.27</td>
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<td>20,150</td>
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<td>KCAE Closest Ground 12,800 ft</td>
<td>0.00004</td>
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<td></td>
<td></td>
<td></td>
<td>241,000</td>
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<tr>
<td>KCAE Closest Structure Water Tower, 1,700 ft</td>
<td>0.0023</td>
<td>1.0</td>
<td>435</td>
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<td>KRAX Closest Ground 15,200 ft</td>
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<td>KRAX Closest Structure Water Tower, 3,800 ft</td>
<td>0.00056</td>
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<td></td>
<td></td>
<td></td>
<td>17,100</td>
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</table>

*Occupational safety level for the WSR-88D band varies with operating frequency: 9.27 mW/cm² for KGSP WSR-88D, 9.63 mW/cm² for KCAE WSR-88D and 9.60 mW/cm² for KRAX WSR-88D
The proposed lower minimum scan angles would not result in the KGSP, KCAE, or the KRAX WSR-88D main beam impinging on the ground in the vicinity of the WSR-88D site. The nearest directly illuminated terrain near would range be at least 12,800 ft (2.4 miles) from the three radars. The proposed action would slightly increase RF exposure levels in the vicinity of the three radars. RF exposure levels at all locations and structures in the vicinity would continue to comply with safety standards for human exposure to RF developed by the Institute of Electrical and Electronic Engineers (IEEE) and the adopted by the American National Standards Institute (ANSI). RF levels would also comply with safety standards for exposure of the general public and workers established by the Federal Communications Commission (FCC) and the Occupational Safety and Health Administration (OSHA). Because the KGSP, KCAE, and KRAX WSR-88Ds operate in a frequency band dedicated to government radiolocation services and the main beam would not impinge on the ground surface in the radar vicinity, the proposed action would not cause radio interference with television, radio, cellular telephone, personal communications devices (PCDs), electro-explosive devices, fuel handling, or active implantable medical devices.

NWS may very infrequently operate the WSR-88Ds with a stationary antenna. During stationary antenna operation, RF levels within the WSR-88D main beam would exceed RF safety levels within 1,740 ft of the WSR-88D. KCAE WSR-88D RF emissions could exceed RF safety levels for exposure of the general public nearby water tower (1,700 ft north-northwest). To prevent RF exposure exceeding the safety standards, NWS would implement Mitigation Measure 1, which requires that the KCAE WSR-88D antenna be directed away from the water tower 1,700 ft to the north-northwest during stationary antenna operations.

The WSR-88D can cause harmful electromagnetic interference (EMI) with charge-couple devices (CCDs) which electronically record data collected by astronomical telescopes (NEXRAD JSPO 1993). The potential for harmful EMI would arise if the WSR-88D’s main beam would directly impinge on an astronomical observatory during low angle scanning. NWS identified all astronomical observatories within 150 miles of each of the three WSR-88Ds, and the only observatory that could be affected by RF emissions from the proposed lower scan angles is Melton Memorial Observatory at the University of South Carolina in Columbia, SC. The main beam of the KCAE WSR-88D does not currently impinge on the Melton Memorial Observatory, but would impinge on the observatory if the minimum scan angle is lowered to +0.4 deg. To mitigate that potential impact, NWS would implement Mitigation Measure 2 and would consult with Melton Memorial Observatory staff to determine the potential for electromagnetic interference with observatory operations if the WSR-88D minimum scan angle is lowered. If significant interference is expected, operational changes to the WSR-88D (e.g. spot blanking in the direction of the observatory at azimuth 60 deg) would be implemented.
Lowering the minimum scan angles of the three WSR-88Ds would not require physical changes to the radar, vegetation removal, or ground disturbance. The proposed action would not result in significant effects in the following subject areas:

- Land Use and Coastal Zone Management
- Geology, Soils, and Seismic Hazards
- Drainage and Water Quality
- Transportation
- Air Quality
- Flood Hazards
- Wetlands
- Biological Resources / Protected Species
- Cultural and Historic Resources
- Environmental Justice Socioeconomic Impacts
- Farmlands
- Energy Consumption
- Visual Quality/ Light Emissions
- Solid and Hazardous Waste
- Wild and Scenic Rivers

NWS evaluated the benefits and potential impacts of lowering the minimum center of beam scan angle of the KGSP, KCAE, and KRAX WSR-88Ds to each angle between +0.4 and -0.2 deg in 0.1 degree increments (see Appendices E and F for detailed analyses). In regards to the KGSP and KRAX WSR-88Ds, alternative minimum scan angles between +0.4 deg and -0.2 deg would result in similar environmental effects as the proposed action. Like the proposed action, significant environmental effects would not result. Minimum scan angles of +0.4 or +0.3 would increase the radar’s coverage area, but by less than the proposed action deg. Lowering the minimum scan angle to less than +0.2 deg would not improve radar coverage and would have the drawback of increasing ground clutter returns. NWS selected the proposed action (a minimum scan angle of +0.2 for the KGSP and KRAX WSR-88Ds) because it would result in the greatest improvement in radar coverage area while eliminating unnecessary ground clutter returns.

In regards to the KCAE WSR-88D, the alternative action of lowering the minimum scan angle of the existing KCAE WSR-88D to +0.3 deg or lower would result in minimal improvement in radar coverage area and would increase ground clutter returns. It would also result in the WSR-88D main beam impinging on the cab of the Columbia Metropolitan Airport Traffic Control Tower; which would not occur for the proposed action. For those reasons, NWS selected a minimum scan angle of +0.4 as the proposed action for the KCAE WSR-88D.

The no action alternative would result in continued operation of the KGSP, KCAE, and KRAX WSR-88Ds at the existing minimum scan angle of +0.5 deg. The improvements in radar coverage resulting from the proposed project would not be achieved. The no-action alternative
would not change RF exposure levels from existing. Similar to the proposed action, the no-action alternative would not cause significant effects to the natural or man-made environment.

The NWS will distribute this Draft EA to interested members of the public and government agencies for review and comment. Comments on the Draft EA will be accepted by NWS during a 30-day comment period ending on March 15, 2019. NWS will make no decision on implementing the proposed action until after the environmental review process is complete.
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# ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>AGL</td>
<td>above ground level</td>
</tr>
<tr>
<td>AAMI</td>
<td>Association for Advancement of Medical Instrumentation</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
</tr>
<tr>
<td>ASL</td>
<td>above site level</td>
</tr>
<tr>
<td>deg</td>
<td>degree(s)</td>
</tr>
<tr>
<td>DoA</td>
<td>Department of Agriculture</td>
</tr>
<tr>
<td>EA</td>
<td>Environmental Assessment</td>
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<tr>
<td>E.O.</td>
<td>Executive Order</td>
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<tr>
<td>EED</td>
<td>electro-explosive device</td>
</tr>
<tr>
<td>EMI</td>
<td>electromagnetic interference</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
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<td>ESA</td>
<td>Endangered Species Act</td>
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<td>FCC</td>
<td>Federal Communications Commission</td>
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<td>FEMA</td>
<td>Federal Emergency Management Agency</td>
</tr>
<tr>
<td>FONSI</td>
<td>Finding of No Significant Impact</td>
</tr>
<tr>
<td>ft</td>
<td>foot, feet</td>
</tr>
<tr>
<td>HERO</td>
<td>Hazards of Electromagnetic Radiation to Ordnance</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
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<td>JSPO</td>
<td>Joint System Program Office</td>
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<td>WSR-88D serving the Greer, SC, area</td>
</tr>
<tr>
<td>KRAX</td>
<td>WSR-88D serving the Raleigh, NC, area</td>
</tr>
<tr>
<td>m</td>
<td>meter(s)</td>
</tr>
<tr>
<td>MBTA</td>
<td>Migratory Bird Treaty Act (of 1918)</td>
</tr>
<tr>
<td>MHz</td>
<td>megahertz</td>
</tr>
<tr>
<td>mi</td>
<td>mile(s)</td>
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<tr>
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<td>maximum permissible exposure</td>
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<tr>
<td>MSL</td>
<td>mean sea level</td>
</tr>
<tr>
<td>mW/cm²</td>
<td>milliwatts per square centimeter</td>
</tr>
<tr>
<td>mya</td>
<td>million years ago</td>
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<td>NOAA Administrative Order</td>
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<td>National Environmental Policy Act</td>
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<td>Next Generation Weather Radar (also known as WSR-88D)</td>
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<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
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<td>National Telecommunications and Information Agency</td>
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<td>National Weather Service</td>
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<td>Abbreviation</td>
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<td>-----------</td>
</tr>
<tr>
<td>PEIS</td>
<td>Programmatic Environmental Impact Statement</td>
</tr>
<tr>
<td>RF</td>
<td>radiofrequency</td>
</tr>
<tr>
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<td>Supplemental Environmental Assessment</td>
</tr>
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<td>State Historic Preservation Office</td>
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<tr>
<td>sq mi</td>
<td>square mile(s)</td>
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<tr>
<td>U.S.</td>
<td>United States</td>
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<td>U.S. Geological Survey</td>
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1 BACKGROUND AND SCOPE OF REPORT

1.1 BACKGROUND

The National Weather Service (NWS) operates a nationwide network of weather radars that provide critical real-time information on atmospheric conditions to weather forecasters. Additional similar weather radars located in Alaska, Hawaii and Puerto Rico are operated by the Department of Transportation Federal Aviation Administration (FAA). The Department of Defense Air Weather Service also operates weather radars located at United States (U.S.) military installations in the U.S. and abroad. The weather radars operated by these three agencies are part of 159 WSR-88Ds in the nationwide network.

The network radars operated by NWS are named Weather Surveillance Radar-Model 1988 Doppler (WSR-88D) after the year they were first put into service and their capabilities to use Doppler shift measurements to determine wind velocities. They are also known as Next Generation Weather Radars (NEXRADS) or Weather Service Radars. Like all active radars, the WSR-88D transmits a radio signal, which reflects off targets and returns to the radar. The radar measures the strength of the return signal, its direction of return, and the time between transmission and return, which allows determination of the targets characteristics. Because the WSR-88D has the potential to cause electromagnetic effects on the environment, NWS carefully considered these effects and strives to prevent effects, or when effects cannot be avoided, mitigate the significance of those effects. To that end, the NEXRAD Joint System Program Office (JSPO) prepared environmental reports evaluating potential electromagnetic effects of the WSR-88D during planning and implementation of the WSR-88D network. In 1984, the JSPO issued the first environmental document which considered electromagnetic effects (among other effects). That report is titled Next Generation Weather Radar Programmatic Environmental Impact Statement (PEIS), Report R400-PE201 [NWS, 1984]. In 1993, JSPO issued a supplemental report updating the analysis contained in the 1984 PEIS to account for changes since 1984 in electromagnetic standards and guidelines and developments in radar design and operational modes. The supplemental report is titled Final Supplemental Environmental Assessment (SEA) of the Effects of Electromagnetic Radiation from the WSR-88D Radar [NEXRAD JSPO, 1993]. The 1993 SEA analyzed the potential electromagnetic effects of operating the WSR-88D at a minimum scan angle of +0.5 degree (deg) above horizontal, measured at the center of the WSR-88D main beam. The minimum scan angle of +0.5 deg represented the lowest scan angle used in operation of the WSR-88Ds at that time.

The National Weather Service (NWS) owns and operates the existing WSR-88Ds serving the Greer, SC; Columbia, SC; and Raleigh, NC, areas. The WSR-88D serving the Greer area is designated KGSP and the radar is located at Greenville-Spartanburg International Airport in Greer, Spartanburg County, SC. The WSR-88D serving the Columbia area is designated KCAE...
and the radar is located at Columbia Metropolitan Airport in West Columbia, Lexington County, SC. The designators for the WSR-88D serving the Raleigh area is KRAX and the radar is located at the North Carolina State University (NCSC) agricultural research farm in Clayton, Johnston County, NC. The KGSP and KRAX WSR-88Ds were commissioned in March 1996 and July 1995, respectively, and are three of the 159 WSR-88Ds in the nationwide network.

The NWS proposes to operate the KGSP and KRAX radars at minimum scan angles of +0.2 deg and the KCAE WSR-88D at +0.4 deg.; the proposed minimum scan angles are lower than the current minimum scan angle of +0.5 deg above the horizon. Operating the KGSP, KCAE, and KRAX WSR-88Ds at this lower scan angle was not analyzed in the 1993 SEA.

The National Oceanic and Atmospheric Administration (NOAA), the parent agency of NWS, require analysis of the potential environmental consequences of proposed actions to comply with the National Environmental Policy Act (NEPA). Procedures to be followed are set forth in NOAA Administrative Order (NAO) 216-6A (NOAA, 2016). Because NWS’s proposed action of operating these two WSR-88Ds at a minimum scan angle below +0.5 deg has the potential to cause environmental effects, there is a need to analyze potential environmental consequences, determine their significance, and develop measures to mitigate adverse impacts if necessary.

1.2 SCOPE OF REPORT

This Draft EA report analyzes the potential effects on persons and activities in the vicinity that could result from implementing the proposed action (i.e. lowering the minimum scan angles of the KGSP and KRAX WSR-88Ds to +0.2 deg and the KCAE WSR-88D to +0.4 deg). Potential environmental effects of alternative minimum scan angles between +0.4 deg and -0.2 deg and the no-action alternative (i.e. continued operation of the KGSP, KCAE, and KRAX WSR-88Ds at the current minimum scan angle of +0.5 deg) are also considered for comparison purposes. As part of that analysis, the findings of the 1993 SEA have been updated to account for changes in safety standards and guidelines that have been occurred since 1993 and site-specific conditions at the KGSP, KCAE, and KRAX WSR-88D sites and vicinities. The scope of this EA is limited to analyzing potential effects from lowering the minimum scan angle of the KGSP, KCAE, and KRAX WSR-88Ds. Because the types of electromagnetic effects that may result and their significance depends on local conditions, including activities and topography of the local area, the analysis and conclusions contained in this EA are specific to the KGSP, KCAE, and KRAX WSR-88Ds, and are not applicable to other WSR-88Ds or the WSR-88D network as a whole.
2 PURPOSE AND NEED

The NWS is the nation’s premiere meteorological forecasting organization. The agency’s official mission is as follows:

“The National Weather Service (NWS) provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy. NWS data and products form a national information database and infrastructure which can be used by other governmental agencies, the private sector, the public, and the global community [NWS, 2009].”

The nationwide network of 159 WSR-88Ds plays a crucial role in meeting the NWS mission. Data from the WSR-88Ds is used by the NWS to improve the accuracy of forecasts, watches, and warnings. As an example, the WSR-88D generates precipitation estimates allowing prediction of river flooding in hydrological basins of the area. The NWS then disseminates advance flood warnings to local and state public safety, emergency managers, and the public, allowing them to take appropriate actions to minimize hazards to life and property. Because the meteorological phenomena of greatest interest occurs with a few thousand feet (ft) of the ground surface, radar coverage of lower portions of the atmosphere is of great value to forecasters.

However, the elevation above the ground at which the WSR-88D can collect atmospheric data rises with distance from the radar due to earth curvature and the upward tilt of the radar beam, which is currently +0.5 deg or greater. The proposed action of lowering the WSR-88D minimum scan angle to +0.2 deg (KGSP and KRAX WSR-88Ds) deg or +0.4 deg (KCAE WSR-88D) would expand the geographic area with radar coverage below 10,000 ft AGL, a substantial benefit to forecasters and other users of WSR-88D data. This EA report describes the improvements in radar coverage that would result if the NWS operates the KGSP and KRAX WSR-88Ds serving the Greer, SC, and Raleigh, NC, areas, respectively, at a minimum scan angle of +0.2 deg and the KCAE WSR-88D serving the Columbia, SC, area at +0.4 deg. This report also analyzes the environmental effects that may result and their significance.

The National Oceanic and Atmospheric Administration (NOAA) is the parent agency of the NWS. NOAA requirements for complying with the National Environmental Policy Act (NEPA) are contained in NOAA Administrative Order (NAO) 216-6A, Compliance with the National Environmental Policy Act, Executive Orders 12114, Environmental Effects Abroad of Major Federal Actions; 11988 and 13690, Floodplain Management; and 11990 Protection of Wetlands (NOAA, 2016), and the Companion Manual for NOAA Administrative Order 216-6A; Policies and Procedures for Compliance with the National Environmental Policy Act and Related Authorities (NOAA, 2017). NWS is subject to those requirements. Appendix E of the NOAA Companion Manual specifies the proper level of NEPA review for actions proposed by NOAA components and lists types of actions that are categorically excluded from the need to prepare a
NEPA analysis document (e.g., an EA or environmental impact statement [EIS]). Categorical Exclusion G6, which addresses NEXRAD Radar Coverage, states that “Actions that change the NEXRAD radar coverage patterns that do not lower the lowest scan angle and do not result in direct scanning of previously non-scanned terrain by the NEXRAD main beam” are categorically excluded from NEPA (NOAA, 2017). The proposed action would not meet these specifications and does not qualify for categorical exclusion treatment. Therefore, NEPA analysis is required for the proposed action of lowering of the minimum scan angle of the KGSP, KCAE, and KRAX WSR-88Ds; this EA report satisfies that requirement.
3 DESCRIPTION OF PROPOSED ACTION AND ALTERNATIVES

3.1 PROPOSED ACTION

3.1.1 Description of KGSP WSR-88D

The NWS of the Department of Commerce, Air Force of the Department of Defense, and FAA of the Department of Transportation operate a nationwide network of Doppler meteorological radars, known as NEXRAD or WSR-88D. The WSR-88D collects data on weather conditions and provides critical inputs to forecasters. The network is composed of 159 radars, most of which were installed in the late 1980s and 1990s. Each radar includes a roughly 28-ft diameter dish antenna mounted on a steel lattice tower of varying height (depending on local conditions), and shelters housing electronic equipment, a standby power generator and fuel tank, and a transitional power maintenance system. The dish antenna rotates 360 deg around a vertical axis and is covered by a fiberglass radome to protect it from the elements.

Figure 1 is a photograph of the KGSP WSR-88D, which was commissioned in March 1996 and has been in continuous operations since being commissioned. The KGSP WSR-88D serves the Greer, SC area and is located at Greenville-Spartanburg International Airport in Greer, SC and is 3.7 miles south of downtown Greer (see Figure 2). Although the airport is located in both Greenville and Spartanburg counties, the WSR-88D is co-located with the Greer Weather Forecast Office (WFO) in Spartanburg County. The radar antenna and radome are standard. Table 1 provides information on the KGSP WSR-88D.

<table>
<thead>
<tr>
<th>Table 1: Information on the KGSP WSR-88D Serving the Greer, SC, Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation, ground surface at tower base (mean sea level, MSL)</td>
</tr>
<tr>
<td>Elevation, center of antenna (MSL)</td>
</tr>
<tr>
<td>Tower Height (m)</td>
</tr>
<tr>
<td>Latitude (WGS84)</td>
</tr>
<tr>
<td>Longitude (WGS84)</td>
</tr>
<tr>
<td>Operating Frequency</td>
</tr>
<tr>
<td>Spot Blanking or Sector Blanking used</td>
</tr>
</tbody>
</table>
Figure 1: Photograph of KGSP WSR-88D Serving the Greer, SC, Area
Figure 2: Location of KGSP and KCAE WSR-88Ds

Scale: 0  20  40 miles
3.1.2 Description of KCAE WSR-88D

The KCAE WSR-88D serves the Columbia, SC, area and is almost identical to the KGSP WSR-88D. Figure 3 is a photograph of the KCAE WSR-88D, which was commissioned in June 1995 and has been in continuous operations since being commissioned. The KCAE WSR-88D is located at Columbia Metropolitan Airport in West Columbia, Lexington County, SC and is about 5.6 miles southwest of downtown Columbia (see Figure 2). The WSR-88D is located about 1,600 ft north of the Columbia, SC, Weather Forecast Office (WFO) which is also at the airport. The radar antenna and radome are standard. Table 2 provides information on the KCAE WSR-88D.

<table>
<thead>
<tr>
<th>Table 2: Information on the KCAE WSR-88D Serving the Columbia SC, Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation, ground surface at tower base (mean sea level, MSL)</td>
</tr>
<tr>
<td>Elevation, center of antenna (MSL)</td>
</tr>
<tr>
<td>Tower Height (m)</td>
</tr>
<tr>
<td>Latitude (WGS84)</td>
</tr>
<tr>
<td>Longitude (WGS84)</td>
</tr>
<tr>
<td>Operating Frequency</td>
</tr>
<tr>
<td>Spot Blanking or Sector Blanking used</td>
</tr>
</tbody>
</table>
Figure 3: Photograph of KCAE WSR-88D Serving the Columbia, SC, Area
3.1.3 Description of KRAX WSR-88D

The KRAX WSR-88D serving the Raleigh, NC, area is the same radar model as the KGSP and KCAE WSR-88Ds and is mounted on the same height tower as the KGSP and KCAE WSR-88Ds. Figure 4 is a photograph of the KGSP WSR-88D, which was commissioned in July 1995 and has been in continuous operations since being commissioned. The KRAX WSR-88D is located at North Carolina State University’s agricultural research facility in Clayton, Johnston County, NC. The radar is about 11.1 miles southeast of downtown Raleigh and 22.4 miles southeast of Raleigh-Durham International Airport (see Figure 5). The radar antenna and radome are standard. Table 3 provides information on the KRAX WSR-88D.

<table>
<thead>
<tr>
<th>Table 3: Information on the KRAX WSR-88D Serving the Raleigh, NC, Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation, ground surface at tower base (mean sea level, MSL)</td>
</tr>
<tr>
<td>Elevation, center of antenna (MSL)</td>
</tr>
<tr>
<td>Tower Height (m)</td>
</tr>
<tr>
<td>Latitude (WGS84)</td>
</tr>
<tr>
<td>Longitude (WGS84)</td>
</tr>
<tr>
<td>Operating Frequencies</td>
</tr>
<tr>
<td>Spot Blanking or Sector Blanking used</td>
</tr>
</tbody>
</table>

3.1.4 Proposed Change in Minimum Scan Angles

The WSR-88D is designed to detect and track weather phenomena within a roughly 230 mi distance of the radar. It accomplishes this task by emitting a narrow main beam from a rotating dish antenna. The antenna rotates continuously around a vertical axis to cover the surrounding area. The main beam scan angle is the number of degrees above or below horizontal at the center of the main beam. The upward tilt of the antenna (and therefore the scan angle of the main beam) can be changed, allowing the radar to scan the sky at angles up to +60.0 deg and down to -1.0 deg; however, in current operation, the maximum scan angle is +19.5 deg and the minimum scan angle is +0.5 deg.

The WSR-88D main beam has a total width of 1 deg in the horizontal and vertical directions (i.e., beam edge is ½ deg from the center of the beam), as shown in Figure 6. The power density of the WSR-88D is greatest at the center of the beam and decreases towards the edge of the beam. At the edge of the main beam, the power density is one half of the center of beam power density. In current operation, the minimum scan angle of the main beam is +0.5 deg (i.e., 0.5 deg above horizontal at the center of the main beam) and the lower edge of the main beam (i.e. lower half-power point) is at 0.0 deg or horizontal.
Figure 4: Photograph of KRAX WSR-88D Serving the Raleigh, NC, area
Figure 5: Location of KRAX WSR-88D

Scale: 0 25 50 miles
Figure 6: Schematic of WSR-88D Main Beam
(Not to scale, width of main beam exaggerated)
NWS proposes to reduce the minimum center of beam scan angle of the KGSP and KRAX WSR-88Ds to +0.2 deg, which is 0.3 deg lower than the current minimum scan angle. NWS proposes to reduce the minimum center of beam scan angle of the KCAE WSR-88D to +0.4 deg, which is 0.1 deg lower than the current minimum scan angle. Figure 7 is a schematic drawing showing the change in coverage that would result from lowering the minimum scan angles of the KGSP, KCAE, and KRAX WSR-88Ds. The height of coverage above ground level (AGL) would decrease slightly, but the WSR-88D main beam would not impinge on the ground surface in the vicinity. The nearest directly illuminated ground would be between 12,800 and 15,200 ft (2.4 and 2.9 miles) from the three WSR-88Ds. Because the lowered radar main beam would not be significantly obstructed by nearby terrain, buildings, or trees, the radar would cover portions of the atmosphere which are currently not covered. Table 4 shows the improvement in radar coverage that would be achieved for each of the three WSR-88Ds. At 2,000 above site level (ASL) the increase in coverage areas would be 69.7%, 9.9%, and 74.5% for the KGSP, KCAE, and KRAX WSR-88Ds, respectively. The height of radar coverage over Charlotte, NC, would decrease from 3,300 ft to 1,200 ft AGL and over the Triad area of NC (cities of Greensboro, Winston-Salem, and High Point) from 3,600 to 2,800 ft AGL. Figures 8 through 16 show the improvement in radar coverage at 2,000 ft, 5,000 ft, and 10,000 ft ASL, for each of the WSR-88Ds.

<table>
<thead>
<tr>
<th>WSR-88D</th>
<th>Center of Beam Scan Angle (deg)</th>
<th>Bottom Edge of Main Beam</th>
<th>Area Covered at 2,000 ft ASL (sq mi)</th>
<th>Area Covered at 5,000 ft ASL (sq mi)</th>
<th>Area Covered at 10,000 ft ASL (sq mi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KGSP</td>
<td>+0.5 (existing)</td>
<td>0.0</td>
<td>8,359</td>
<td>22,597</td>
<td>47,557</td>
</tr>
<tr>
<td></td>
<td>+0.2 (proposed)</td>
<td>-0.3</td>
<td>14,185 (+69.7%)</td>
<td>31,125 (+37.7%)</td>
<td>59,477 (+25.1%)</td>
</tr>
<tr>
<td>KCAE</td>
<td>+0.5 (existing)</td>
<td>0.0</td>
<td>8,915</td>
<td>24,736</td>
<td>51,831</td>
</tr>
<tr>
<td></td>
<td>+0.4 (proposed)</td>
<td>-0.1</td>
<td>9,794 (+9.9%)</td>
<td>26,233 (+6.1%)</td>
<td>54,103 (+4.4%)</td>
</tr>
<tr>
<td>KRAX</td>
<td>+0.5 (existing)</td>
<td>0.0</td>
<td>10,548</td>
<td>27,324</td>
<td>55,288</td>
</tr>
<tr>
<td></td>
<td>+0.2 (proposed)</td>
<td>-0.3</td>
<td>18,410 (+74.5%)</td>
<td>39,245 (+43.6%)</td>
<td>72,099 (+30.4%)</td>
</tr>
</tbody>
</table>
Environmental Assessment - Lowering the Minimum Scan Angles of the KGSP, KCAE, AND KRAX WSR-88Ds

Existing Coverage

+19.5 deg

0 deg

-0.3 deg (KGSP and KRAX)
-0.1 deg (KCAE WSR-88D)

Proposed Additional Radar Coverage Area

Figure 7: Drawing Showing Proposed Additional Radar Coverage
Figure 8: Existing and Proposed KGSP WSR-88D Coverage at 2,000 ft above Site Level
Figure 9: Existing and Proposed KGSP WSR-88D Coverage at 5,000 ft above Site Level
Figure 10: Existing and Proposed KGSP WSR-88D Coverage at 10,000 ft above Site Level
Figure 11: Existing and Proposed KCAE WSR-88D Coverage at 2,000 ft above Site Level
Figure 12: Existing and Proposed KCAE WSR-88D Coverage at 5,000 ft above Site Level
Figure 13: Existing and Proposed KCAE WSR-88D Coverage at 10,000 ft above Site Level
Figure 14: Existing and Proposed KRAX WSR-88D Coverage at 2,000 ft above Site Level
Figure 15: Existing and Proposed KRAX WSR-88D Coverage at 5,000 ft above Site Level
Figure 16: Existing and Proposed KRAX WSR-88D Coverage at 10,000 ft above Site Level
The existing WSR-88D transmitter and antenna are physically equipped to operate at the proposed minimum scan angle. The only change required to implement the proposed change would be modifications to the software that controls radar operations and processes data collected by the radar. No construction activities or ground disturbance would be required to implement the proposed action. The transmit power of the radar would also be unchanged.

3.2 ALTERNATIVES
NAO 216-6A requires analysis of the no-action alternative in EAs. For purposes of this EA report, the no-action alternative is defined as continuing to operate the KGSP, KCAE, and KRAX WSR-88Ds with the current minimum center of main beam scan angle of +0.5 deg. This is the same minimum scan angle used by most other WSR-88Ds in the nationwide network. The no-action alternative and alternative minimum scan angles between +0.4 and -0.2 deg considered by the NWS are analyzed in Section 5 of this EA.
4 ENVIRONMENTAL SETTING, CONSEQUENCES, AND MITIGATION

4.1 EXPOSURE OF PERSONS TO RF RADIATION

Safety Standards

The electromagnetic environment at a specific location and time is composed of all the electromagnetic fields from various sources (natural and manmade) that arrive there. The electromagnetic spectrum in an area is a continuously usable resource whose dimensions are amplitude, time, frequency, and space. In areas large enough to permit adequate spatial separation of users, the electromagnetic spectrum can simultaneously accommodate many users if they are sufficiently separated in frequency. The electromagnetic environment at any point can change nearly instantaneously and will vary spatially, even at locations in close proximity; therefore, it is convenient to measure and characterize electromagnetic phenomena using averages over time and space.

Manmade contributions to the electromagnetic environment are both intentional and unintentional. Radio and television broadcasts, cellular telephone transmissions, and radar signals are examples of intentional contributions. Electromagnetic noise generated by power lines, fluorescent lights, and motors of all sorts are examples of unintentional human contributions. The KGSP, KCAE, and KRAX WSR-88Ds transmit radio signals at operating frequencies of 2,780 MHz, 2,890 MHz, and 2,880 MHz respectively. These radio signals are within the RF or microwave portion of the electromagnetic spectrum. Although microwaves can add heat to objects, they do not contain enough energy to remove electrons from biological tissue, and are a form of non-ionizing radiation. In this regard, microwaves are fundamentally different from ionizing radiations (e.g., X-rays, ultraviolet rays) which occur at higher frequency portions of the electromagnetic spectrum. Ionizing radiation occurs only at frequencies greater than $10^9$ MHz. RF or microwave fields are non-ionizing radiation. Due to the fundamental differences between ionizing and non-ionizing radiation, safety standards and guidelines vary greatly for the two types of electromagnetic radiation. In this section only standards for non-ionizing radiation are addressed because the WSR-88D RF emissions are non-ionizing.

The Institute of Electrical and Electronics Engineers (IEEE) developed safety guidelines for human exposure to RFR, and those standards have been adopted by the American National Standards Institute (ANSI) [ANSI/IEEE, 2006]. The ANSI/IEEE safety standard is designed to protect all persons (including infants, elderly persons, and pregnant women) from adverse health effects from exposure to radiofrequency (RF), even if exposure should last over an entire lifetime. These guidelines set safety levels for maximum permissible exposure (MPE) to RF signals, which include a 10- to 50-fold safety margin and are intended to protect all members of the population.

MPEs are specified in power density of the radio signal in milliwatts per square centimeter (mW/cm$^2$) and vary with operating frequency. Separate MPEs have been established for exposure of the general public and workers and for time-averaged exposure and peak exposure.
Occupational safety standards are higher than those for the general public because workers are trained in RF safety practices and have greater ability to use that knowledge to protect themselves from potentially harmful RF exposure. At the operating frequencies used by the KGSP, KCAE, and KRAX WSR-88Ds, the IEEE/ANSI safety standards are 1.0 mW/cm² for the general public (averaged over 30 minutes) and 9.27 to 9.63 mW/cm² for workers (averaged over 6 minutes).

The Occupational Health and Safety Administration (OSHA) regulates occupational exposure to RF emissions. The OSHA safety standard is similar to the ANSI/IEEE occupational safety standard: 10.0 mW/cm² averaged over 6 minutes (OSHA, 2015). Federal Communications Commission (FCC) RF exposure standards for RF exposure of the general public are the same as the ANSI/IEEE: 1.0 mW/cm² averaged over 30 minutes. FCC RF exposure standards for occupational exposure are somewhat lower than the ANSI/IEEE safety levels: 5.0 mW/cm² averaged over 6 minutes.

**RF Exposure Levels**

The KGSP, KCAE, and KRAX WSR-88Ds are mounted on 30 m tall steel-lattice towers. The center of the rotating antenna for each WSR-88D is 113 ft AGL. When operating at the current minimum scan angle of 0.5 deg, the lower edge of the beam is at 0.0 deg (i.e. horizontal) and the radar’s main beam does not impinge on the ground surface in proximity to the radar. Operating at the proposed minimum scan angles of +0.2 deg, the main beam of the KGSP and KRAX WSR-88Ds would still not impinge on the ground surface within 2.7 and 2.9 miles respectively. Operating at the proposed minimum scan angles of +0.4 deg, the main beam of the KCAE WSR-88D would still not impinge on the ground surface within 2.4 miles.

Compared to the existing minimum scan angle of +0.5 deg, lowering the minimum scan angle to +0.2 or +0.4 deg would result in a slight increase in RF exposure levels at air space in the vicinity of the radar. Appendix A includes calculations of the existing time-averaged RF exposure levels in the vicinity of the KGSP, KCAE, and KRAX WSR-88Ds, and the RF exposure that would result if NWS lowers the minimum scan angles. Table 5 summarizes the results from Appendix A and shows the RF exposure levels that would result at various locations near the radar during normal operations at the proposed minimum scan angles.

**Elevated Structures in the Area**

Table 5 shows the level of RF exposure that would result at nearby locations, including the closest ground surface and structures that would be within the WSR-88D main beam when operated at the proposed minimum scan angles, compared to the ANSI/IEEE safety standards. During normal operation of the WSR-88D with a rotating antenna, RF exposure levels at each of these locations would comply with safety standards for exposure of both workers (i.e. occupational exposure) and the general public.
### Table 5. RF Emissions of KGSP, KCAE, and KRAX WSR-88Ds Compared to Safety Standards

<table>
<thead>
<tr>
<th>Location and Distance from Radar</th>
<th>Within WSR-88D Main Beam?</th>
<th>Time-Averaged Power Density (mW/cm²)</th>
<th>ANSI/IEEE General Public RF Safety Standard</th>
<th>ANSI/IEEE Occupational RF Safety Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Safety Standard (mW/cm²)</td>
<td>Factor Below Std</td>
</tr>
<tr>
<td>Surface of Radome</td>
<td>Yes</td>
<td>0.603</td>
<td>1.0</td>
<td>1.66</td>
</tr>
<tr>
<td>Base of WSR-88D Tower</td>
<td>No</td>
<td>0.005</td>
<td>1.0</td>
<td>143</td>
</tr>
</tbody>
</table>

**KGSP WSR-88D**

| Closest Ground 14,300 ft        | Yes                       | 0.00004                              | 1.0                         | 25,000                      | 9.27                     | 232,000           |
| Closest Structure ASR-8, 4,200 ft | Yes                    | 0.00046                              | 1.0                         | 2,170                       | 9.27                     | 20,100             |

**KCAE WSR-88D**

| Closest Ground 12,800 ft        | Yes                       | 0.000035                             | 1.0                         | 28,500                      | 9.63                     | 275,000           |
| Closest Structure: Water Tower, 1,700 ft | Yes             | 0.0023                               | 1.0                         | 435                         | 9.63                     | 4,190              |

**KRAX WSR-88D**

| Closest Ground 15,200 ft        | Yes                       | 0.00004                              | 1.0                         | 25,000                      | 9.60                     | 240,000           |
| Closest Structure: Water Tower, 3,800 ft | Yes  | 0.00056                             | 1.0                         | 1,790                       | 9.60                      | 17,100             |

NWS may infrequently operate the WSR-88D with a stationary antenna for calibration purposes. Operation with a stationary antenna would result in higher RF exposure levels than during normal operation with a rotating antenna. RF exposure of 1.0 mW/cm² (ANSI/IEEE and FCC general public safety level) would occur at a distance of 1,740 ft from the radar. The FCC occupational safety level of 5.0 mW/cm² would occur at 780 ft and the ANSI/IEEE occupational safety level would occur at 560 ft (see Appendix A). During stationary antenna operation, RF exposure within the WSR-88D main beam would exceed safety levels at locations closer to the radar than these distances. The power density of the WSR-88D main beam would decrease with increasing distance and RF exposure at all distances beyond 1,740 ft would comply with all safety standards. The only structure or terrain within 1,740 ft that would be directly illuminated
by the WSR-88D main beam operating at the proposed minimum scan angles, would be a water tower 1,700 ft north-northwest of the KCAE WSR-88D. The following measure would prevent RF exposure levels exceeding safety standards at the water tower near the KCAE WSR-88D:

Mitigation Measure 1: During stationary antenna operation, the KCAE WSR-88D antenna would not be directed at the water tower 1,700 ft ENE of the WSR-88D.

RF Electro-stimulation
The ANSI/IEEE safety guidelines also cover possible induction of currents within the bodies of persons and the potential for electro-stimulation of persons who make contact with conductive objects in the RFR field. The result is potentially harmful sensation of shock and/or burn. These effects only occur for RF fields at frequencies below 110 MHz (ANSI/IEEE, 2006). All three WSR-88Ds would continue to operate outside the frequency range where induced currents or electro-simulation occur, and would not cause these effects.

Cumulative RF Exposure
As shown in Table 5, the power density of RF transmissions decreases exponentially with distance from the antenna. At all locations in the vicinity, RF emitted by the WSR-88D during normal operation would be at substantially below the safety standard for RF exposure of the general public. It is improbable that radio emissions from an external source would add to the WSR-88D RF emissions during normal operation to cause cumulative RF exposure levels exceeding safety standards.

4.2 RF EXPOSURE OF EQUIPMENT AND ACTIVITIES

4.2.1 Television, Radio, Cellular Telephone, and Personal Communications Devices (PCDs)
High-power radar, such as the WSR-88D, can interfere with operation of radio, television, cellular telephone, and PCDs in close vicinity to the radar antenna. However, these devices operate at different frequencies from the WSR-88D, reducing the potential for radio interference. NTIA regulations reserve the 2,700 to 3,000 MHz band for government radiolocation users (e.g., meteorological and aircraft surveillance radars) [NTIA, 2009]. The WSR-88D operates outside the frequencies used by television and radio broadcasts, cellular telephones, and personal communication devices. NWS has not received any reports of the KCAE or KRAX WSR-88Ds interfering with operation of other radio uses (Schultz, 2018). Lowering the minimum scan angle would not result in the main beam impinging on the ground surface within 2.4, 2.7, or 2.9 miles of the KGSP, KCAE, or KRAX WSR-88Ds, respectively and the potential for radio interference would be low.

There have been reports of mutual electromagnetic interference (EMI) between the ASR-8 operated by the Federal Aviation Administration (FAA) at Greenville-Spartanburg International Airport and the KGSP WSR-88D. The FAA installed a filter on the ASR-8 to attenuate the
WSR-88D signal and reduce the potential for EMI with ASR-8 operations. NWS is similarly in the process of installing a filter on the KGSP WSR-88D to prevent EMI with WSR-88D operations. The ASR-8 is directly illuminated by the WSR-88D main beam under current operations and that situation would not be changed by lowering the minimum scan angle of the KGSP WSR-88D. Additionally, the proposed action would not change the power output or operating frequency of the WSR-88D. Thus the effectiveness of the FAA filter at preventing EMI would not change. Mitigation is not necessary.

4.2.2 Electro-explosive Devices (EEDs)

Electro-explosive devices are used to detonate explosives, separate missiles from aircraft, and propel ejection seats from aircraft. Under extreme circumstances, electromagnetic radiation can cause unintended firing of EEDs. Calculations based on a U.S. Air Force (USAF) standard indicate that using electric blasting caps at distances beyond approximately 900 ft from the WSR-88D is a safe practice, even in the main beam of the radar, where the power density of the WSR-88D radio signal is greatest [USAF, 1982]. The U.S. Navy Hazards of Electromagnetic Radiation to Ordnance (HERO) regulations classify ordnance as safe, susceptible, or unsafe and unreliable, based on compliance with MIL-STD 664 (series). HERO safe ordnance is considered safe in all RFR environments. HERO susceptible ordnance may be detonated by RF energy under certain circumstances. HERO unsafe or unreliable ordnance has not been evaluated for compliance with MILSTD 664 or is being assembled, disassembled, or subject to unauthorized conditions, which can increase its sensitivity to RF emissions. Safe separation distances vary for susceptible and unsafe or unreliable ordnance and also by radar operating frequency [Naval Sea Systems Command, 2008]. For HERO susceptible ordnance, the safe separation distances for the three radars are: KGSP WSR-88D - 1,672 ft; KCAE WSR-88D - 1,608 ft; and KGSP WSR-88D - 1,613 ft. For HERO unsafe or unreliable ordnance, the safe separation distances for the three radars are: KGSP WSR-88D - 6,150 ft; KCAE WSR-88D - 5,916 ft; and KGSP WSR-88D - 5,937 ft. HERO concerns are only applicable in locations illuminated by the main beam of the radar. When operating at the proposed minimum scan angles, the main beams of the KGSP, KCAE, and KRAX WSR-88Ds would not illuminate the ground within any of the HERO safe setback distances. The WSR-88D would not be a hazard to EEDs use in the vicinity. No mitigation is necessary.

4.2.4 Fuel Handling

Electromagnetic fields can induce currents in conductive materials and those currents can generate sparks when contacts between conductive materials are made or broken. Sparks can ignite liquid fuels, such as gasoline. This phenomenon is rare, but can result in hazards to human health and property. This potential hazard arises during the transfer of fuel from container to another (e.g., fueling an automobile, boat, or airplane). The U.S. Navy developed a Technical Manual identifying the circumstances where this hazard may occur and providing direction on how to prevent it. The Technical Manual identifies a safe standoff distance based on radar operating characteristics [Naval Sea Systems Command, 2003]. Using formula contained in the
Technical Manual, the distance from the WSR-88D at which RFR hazards to fuel may occur is 537 ft. This hazard only exists in areas directly illuminated by the main beam. When operating at the proposed minimum scan angles, the main beams of the KGSP, KCAE, and KRAX WSR-88Ds would not illuminate the ground within 537 ft. The existing fuel tank for the standby generators at the base of the WSR-88D towers would not be illuminated by the WSR-88D main beam and hazards to fuel handling activities would not result. No mitigation is required.

4.2.5 Active Implantable Medical Devices

ANSI and the Association for Advancement of Medical Instrumentation (AAMI) developed the PC69:2007 standard to prevent external electromagnetic sources from causing electromagnetic interference with active implantable medical devices, including cardiac pacemakers and implantable cardiac defibrillators [ANSI/AAMI, 2007]. This standard specifies that cardiac pacemakers and ICDs must be tested by exposing them to a specified magnetic field and that the device must operate without malfunction or harm to the device. The specified field strength varies with frequency. For the WSR-88D operating frequencies of 2,700 to 2,900 MHz, the field strength is 3 A/m. This is converted to power density (S) in units of W/m² by assuming free air impedance of 377 ohms, which gives a value of 339.3 mW/cm². This level is not exceeded at any locations outside the WSR-88D main beam. There would also be no hazards to implantable medical devices at locations outside the main beam. The peak pulse power of the WSR-88D main beam falls below that power density at a distance of 2,060 ft. At all distances greater than 2,060 ft from the WSR-88D, RF exposure would comply with the ANSI/AAMI safety standard for implantable medical devices. When operating at the proposed minimum scan angles, the main beams of the KGSP, KCAE, and KRAX WSR-88Ds would not illuminate the ground within 2,060 ft and no hazards would result to persons with implanted devices.

Theoretically, persons in aircraft flying within 2,060 ft of the radar or on the water tower 1,700 ft from the KCAE WSR-88D could be exposed to RF levels above the device susceptibility threshold set by ANSI/AAMI, but the likelihood of significant harm is extremely low. For persons in aircraft, the airframe would attenuate the RF level and the duration of exposure would be far less than the averaging time (6 to 30 minutes) specified in the RF safety standards, reducing the amount of RF exposure. For persons on the water tower, Mitigation Measure 1 would prevent long-duration exposure. Exposure to the main beam of the WSR-88D during normal operation with a rotating antenna would last only for microseconds and would not exceed device susceptibility threshold. Additionally, device susceptibility threshold in the PC69:2007 standard is based on coupling of the RF energy directly into the device leads (which is the test protocol); the WSR-88D signal would be incident upon the surface of the body and would decrease considerably in strength at the location of the device leads within the body. Even in the unlikely event that the WSR-88D RF emissions couple into the device at levels above the susceptibility threshold, the device would revert to safe mode of operation that would prevent significant harm to the wearer or damage to the device [ANSI/AAMI, 2007].
FCC regulations at 47 CFR Part 95.1221 require that MedRadio medical implant devices and medical body-worn transmitters be able to withstand exposure to RF at the MPEs specified in FCC regulations at 47 CFR 1.1310 (FCC, 2017). As described in Section 4.1 above, RF exposure levels in the vicinity of the KGSP, KCAE, or KRAX WSR-88Ds would comply with the FCC safety standards. Exposure of persons wearing implantable medical devices to the WSR-88D radio emissions would not result in adverse effects.

4.2.6 Astronomical Observatories

The WSR-88D can cause harmful electromagnetic interference (EMI) with charge-couple devices (CCDs) which electronically record data collected by astronomical telescopes (NEXRAD JSPO 1993). The potential for harmful EMI would arise if the WSR-88D’s main beam would directly impinge on an astronomical observatory during low angle scanning. Eight astronomical observatories are located within 150 miles of the KGSP WSR-88D. The Charles E. Daniel Observatory in Greenville, SC is currently directly illuminated by the KGSP WSR-88D main beam operating at a minimum scan angle of +0.5 deg. It would continue to be directly illuminated at the proposed lower scan angle of +0.2 deg. The KGSP WSR-88D main beam does not currently impinge on any of the other seven observatories and would not do so when operating at the proposed minimum scan angle of +0.2 deg. Because the proposed action would not change in the RF exposure level at the Charles E. Daniel Observatory, adverse effects to observatory operations are not expected (see Appendix E).

Seven astronomical observatories are located within 150 miles of the KCAE WSR-88D. At the current minimum scan angle of +0.5 deg, the KCAE WSR-88D main beam does not impinge on any of the seven observatories. However, when operating at the proposed minimum scan angle of +0.4 deg, the KCAE WSR-88D main beam would impinge on the Melton Memorial Observatory at the University of South Carolina, located about 6.5 miles east northeast of the WSR-88D (see Appendix E). This creates the potential for electromagnetic interference with observatory operations. To mitigate that potential impact, NWS would implement Mitigation Measure 2. The KCAE WSR-88D main beam would not impinge on any of the six other observatories when operating at the proposed minimum scan angle of +0.4 deg.

Three astronomical observatories are located within 150 miles of the KRAX WSR-88D. The KRAX WSR-88D main beam would not impinge on any of the three observatories when operating at the proposed minimum scan angle of +0.2 deg. (see Appendix F).

**Mitigation Measure 2**: NWS would consult with Melton Memorial Observatory staff to determine the potential for electromagnetic interference with observatory operations if the KCAE WSR-88D minimum scan angle is lowered. If significant interference is expected, operational changes to the WSR-88D (e.g. spot blanking in the direction of the observatory at azimuth 60 deg) would be implemented.
Summary of RF Exposure Effects

Table 6 summarizes impacts to potentially RF-sensitive equipment and activities. The potential for the proposed action to cause radio interference with other radio users (except the Melton Memorial Observatory) would be low.

<table>
<thead>
<tr>
<th>Equipment / Activity</th>
<th>Applicable Standard</th>
<th>Setback Distance</th>
<th>Would Main Beam Impinge on Ground Within Setback Distance?</th>
<th>Potential for Significant Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Television, Radio, and Cellular Telephone, and Personal Communications Devices (PCDs)</td>
<td>NTIA Frequency Allocations</td>
<td>n/a</td>
<td>n/a</td>
<td>Very Low</td>
</tr>
<tr>
<td>EEDs</td>
<td>U.S. Navy HERO</td>
<td>5,916 to 6,150 ft</td>
<td>No</td>
<td>Very Low</td>
</tr>
<tr>
<td>Fuel Handling</td>
<td>U.S. Navy Hazards to Personnel, Fuel, and Other Flammable Material</td>
<td>537</td>
<td>No</td>
<td>Very Low</td>
</tr>
<tr>
<td>Active Implantable Medical Devices</td>
<td>AAMI PC69:2007, FCC 47 CFR Part 95.1221</td>
<td>2,060</td>
<td>No</td>
<td>Very Low</td>
</tr>
<tr>
<td>Astronomical Observatories</td>
<td>Exposure to WSR-88D Main Beam</td>
<td>n/a</td>
<td>n/a</td>
<td>Very Low except Melton Memorial Observatory</td>
</tr>
</tbody>
</table>

4.3 LAND USE AND COASTAL ZONE MANAGEMENT

South Carolina and North Carolina are coastal states with Coastal Zone Management Programs (NOAA Office of Coastal Management, 2018). The three WSR-88Ds are not located in or near coastal management zones and the proposed action would not affect the coastal zone.

The KGSP and the KCAE WSR-88Ds are located in close proximity to Weather Forecast Offices (WFOs) at major airports with commercial air service. The proposed action would not change
the existing use of all the two WSR-88D sites for weather data collection. Additionally, the proposed action would not adversely affect or limit nearby aviation and commercial land uses. The KRAX WSR-88D is located at an agricultural research farm operated by North Carolina State University (NCSU). The proposed action would not change the existing use of the KRAX WSR-88D site for weather data collection. Additionally, the proposed action would not affect or limit nearby agricultural, research, and commercial land uses. No adverse impacts to land uses would result.

4.4 GEOLOGY, SOILS, AND SEISMIC HAZARDS

The Natural resources Conservation Service (NRCS) maps soil at the KGSP WSR-88D site as Udorthents, loamy on 6 to 12% slopes. Soil at the KCAE WSR-88D site is mapped as Troup-Urban Land complex on 0 to 6% slopes. Neither of these soils is hydric and they are not classified as prime farmland. Soil at the KRAX WSR-88D site is mapped as Varina and Norfolk loamy sands and is not hydric. These soils are considered prime farmland. (Soil Survey Staff, Natural Resources Conservation Service, U.S. Department of Agriculture, 2018).

The risk of an earthquake at each is modest. USGS estimates the potential for an earthquake strong enough to cause minor damage or greater at each of the three WSR-88D sites at less than 1% per year (USGS, 2018).

Lowering the minimum scan angles of the KGSP, KCAE, and KRAX WSR-88Ds would not require physical changes to the radar or result in ground disturbance. The proposed action would have no effect on geology soils, or seismicity. No mitigation measures are required.

4.5 DRAINAGE AND WATER QUALITY

Lowering the minimum scan angles of the KGSP, KCAE, and KRAX WSR-88Ds would not result in ground disturbance. The proposed action would not affect the amount of impervious surface area at the radar site, the rate of storm runoff flowing from the site during or after precipitation events, or generate pollutants. The proposed action would have no effect on drainage or water quality. No mitigation measures are required.

4.6 TRANSPORTATION

The KGSP and KCAE, WSR-88Ds are located in developed areas at airports and are accessible by paved public roads and short paved driveways. The KRAX WSR-88D is located in the interior of a university research farm. Access is via U.S. Business Highway 70, about 1,100 ft of paved driveway, and about 1,600 ft of unpaved farm roads. The proposed action requires modification of the WSR-88D software to be able to scan at angles below +0.5 deg. To implement the change in scan angle, NWS technicians and engineers would travel to the each of the three WSR-88D sites to perform initial testing and ensure that the modified software is operating properly. Travel to the site would be minimal and would not result in significant congestion on local roads. Transportation effects would not be significant. No mitigation measures are required.
4.7 AIR QUALITY
The KGSP, KCAE, and KRAX WSR-88Ds are each equipped with an on-site standby generator that is used if primary power is interrupted and also periodically for testing. The proposed action would not change the power consumption of the WSR-88D or affect the hours of operation of the standby generator, and no change in air emissions would result. A Clean Air Act Federal Conformity Determination is not required. No mitigation measures are required.

4.8 FLOOD HAZARDS
Executive Order (E.O.) 11988, Floodplain Management, requires the Federal Government to avoid adverse impacts to the 100-year or base floodplain (that is, the area subject to a 1 percent annual chance of flooding), unless there is no practicable alternative [President, 1977a]. The KGSP, KCAE, and KRAX WSR-88D sites are within areas that have been mapped by the Federal Emergency Management Agency for flood hazards. All three WSR-88D sites are outside the 100-year and 500-year flood hazards areas (FEMA, 2018). The proposed action of lowering the minimum scan angles of the KGSP, KCAE, and KRAX WSR-88Ds would not affect floodplains or flood hazards. Indirectly, improved meteorological data collection enabled by the proposed action may assist meteorologists and emergency response managers in forecasting, preparing for, and responding to flood events. No mitigation measures are required.

4.9 WETLANDS
E.O. 11990, Protection of Wetlands, requires the Federal Government avoid funding or implementing projects which would adversely impact wetlands unless there is no practicable alternative [President, 1977b]. Based on National Wetland Inventory maps prepared by the U.S. Fish and Wildlife Service (USFWS), the three WSR-88D sites do not contain federal jurisdictional wetlands. The closest wetlands to each are: KGSP WSR-88D - palustrine forested (PFO1A) wetlands located 1,600 ft to the east of the site; KCAE WSR-88D – palustrine emergent (PEM1Ch) wetlands located 750 ft to the west; and KRAX WSR-88D – freshwater pond (PUBHh) wetlands located 500 ft to the east (USFWS, 2018). The proposed action would not involve ground disturbance and would not affect federal jurisdictional wetlands; no mitigation is required.

4.10 BIOLOGICAL RESOURCES / PROTECTED SPECIES
The USFWS administers the Endangered Species Act and Migratory Bird Treat Acts. The KGSP, KCAE, and KRAX WSR-88Ds are located within the areas served by the USFWS South Carolina and Raleigh Ecological Services Field Offices. Protected species lists were obtained from those two offices (see Appendices B, C and D). The species listed or proposed for listing under the Endangered Species Act that could potentially occur in the general areas of each of the three WSR-88Ds are listed in Table 7.
Table 7: Endangered and Threatened Species Potentially Occurring near the WSR-88Ds

<table>
<thead>
<tr>
<th>Species (scientific name)</th>
<th>Type</th>
<th>Status</th>
<th>Is WSR-88D site in Critical Habitat?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>KGSP WSR-88D</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dwarf-flowered heartleaf (<em>Hexastylis naniflora</em>)</td>
<td>Plant</td>
<td>Threatened</td>
<td>No</td>
</tr>
<tr>
<td><strong>KCAE WSR-88D</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red-cockaded woodpecker (<em>Picoides borealis</em>)</td>
<td>Bird</td>
<td>Endangered</td>
<td>No</td>
</tr>
<tr>
<td>Carolina Heelsplitter (<em>Lasmigona decorata</em>)</td>
<td>Clam</td>
<td>Endangered</td>
<td>No</td>
</tr>
<tr>
<td>Smooth coneflower (<em>Echinacea laevigata</em>)</td>
<td>Plant</td>
<td>Endangered</td>
<td>No</td>
</tr>
<tr>
<td><strong>KRAX WSR-88D</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red-cockaded woodpecker (<em>Picoides borealis</em>)</td>
<td>Bird</td>
<td>Endangered</td>
<td>No</td>
</tr>
<tr>
<td>Atlantic pigtoe (<em>Fusconaia masoni</em>)</td>
<td>Clam</td>
<td>Proposed Threatened</td>
<td>No</td>
</tr>
<tr>
<td>Dwarf wedgemussel (<em>Alasimidonta heterodon</em>)</td>
<td>Clam</td>
<td>Endangered</td>
<td>No</td>
</tr>
<tr>
<td>Yellow lance (<em>Elliptio lancelata</em>)</td>
<td>Clam</td>
<td>Threatened</td>
<td>No</td>
</tr>
<tr>
<td>Michaux’s sumac (<em>Rhus michauxii</em>)</td>
<td>Plant</td>
<td>Endangered</td>
<td>No</td>
</tr>
</tbody>
</table>

The listed species that occur in the general vicinities of the three WSR-88Ds include three plants, four clams, and one bird species. Dwarf-flowered heartleaf is an herbaceous plant known to occur in Greenville and Spartanburg counties, SC. It grows on bluffs and boggy areas with acidic soils that are adjacent to headwater streams. The proposed action would not result in vegetation removal or ground disturbance and no impacts to dwarf-flowered heartleaf would result.

Red-cockaded woodpeckers inhabit open and mature pine ecosystems, especially long-leaf pine forest. The proposed action does not include construction activities and would not result in
ground disturbance or vegetation removal. No impacts to the red-cockaded woodpecker or its habitat would result.

Carolina heelsplitter, Atlantic pigtoe, dwarf wedgemussel, and yellow lance are freshwater mussels. The range of Carolina heelsplitter includes Saluda and Kershaw counties, SC, about 20 miles east and west of the KCAE WSR-88D. Atlantic pigtoe, dwarf wedgemussel, and yellow lance are known or believed to occur in Johnston County, NC. These mussels inhabit streams of varying sizes with clean water, high dissolved oxygen, and sandy to rocky substrates. Moderate water flow and minimal silt deposition are required. The proposed action would not disturb aquatic habitats or affect water quality and would not impact any of these clam species or their habitat.

Smooth coneflower is a perennial herb that inhabits open areas, including open woods, cedar barrens, roadsides, clearcuts, dry limestone bluffs, and powerline rights of way. Its range includes Lexington County, SC. The proposed action does not include construction activities and would not result in ground disturbance or vegetation removal. No impacts to smooth coneflower or its habitat would result.

Michaux’s sumac is rhizomatous shrub that inhabits sandy and rocky areas in open woods. Basic soils are usually necessary. The proposed action does not include construction activities and would not result in ground disturbance or vegetation removal. No impacts to Michaux’s sumac or its habitat would result.

Lowering the minimum scan angles of the three WSR-88Ds would result in a thin sliver of the atmosphere, which is currently below the main beam overage area, being exposed to the main beam of the WSR-88D (see Figure 7). The nearest terrain which the WSR-88D main beam would impinge on is 2.7 miles north-northwest of the KGSP WSR-88D, 2.4 miles northwest of the KCAE WSR-88D, and 2.9 miles north-northwest of the KRAX WSR-88D. RF emissions would comply with all safety standards.

The sliver of the atmosphere where new main beam coverage would result in increased RF exposure levels would be very small in close proximity to the WSR-88D. At 500 ft from the KGSP or KRAX WSR-88Ds the sliver would be 3 ft thick and at one mile it would be 28 ft thick. At 500 ft from the KCAE WSR-88D the sliver would be 1 ft thick and at one mile it would be 9 ft thick. Migratory birds or bats flying within the newly covered sliver of the atmosphere would be exposed to RF emissions from the WSR-88D. The RF levels in the sliver of airspace would be no greater than in RF levels in the existing covered airspace, which occurs just above the newly exposed air space. At a distances of several miles or greater where the volume of newly covered airspace would be substantial, RF levels would be very low. At distances of 500 ft and 1 mile, RF exposure levels would be 700 and 3,200 times less than safety standards for human exposure, respectively. Based on the extremely low RF levels at distance from the WSR-88D, RF exposure of listed migratory birds flying within the newly covered airspace would not be harmful.
Prolonged RF exposure could result if birds fly in a path that keeps it within the WSR-88D main beam for extended periods of time. However, during normal operation the WSR-88D main beam is continuously moving. At a distance of 1,000 ft the WSR-88D main beam is moving at an effective speed of about 89 miles per hour and it is very unlikely that a bird or bat in flight would remain within the WSR-88D main beam for any length of time.

The proposed action would not result in significant impacts to protected species, critical habitat, or migratory birds. No mitigation measures are required.

4.11 CULTURAL AND HISTORIC RESOURCES

Section 106 of the National Historic Preservation Act of 1966 (as amended) requires that federal agencies consider the effects of their actions on historic places and, if effects may result, provide the State Historic Preservation Officer (SHPO) with an opportunity to comment on their actions. Section 106 regulations are set forth in 36 CFR Part 800, Protection of Historic Properties (Advisory Council on Historic Preservation, 2010).

Because the proposed action would not involve ground disturbance, no impacts to archaeological or paleontological resources would result. The proposed action’s area of potential effect (APE) is defined as area within 2,060 ft of the three WSR-88Ds where RF exposure of persons within the WSR-88D main beam could potentially exceed safety levels (see Table 4). The South Carolina and North Carolina State Historic Preservation Offices websites were searched for historic places in the vicinity of the KGSP, KCAE, and KRAX WSR-88D (South Carolina Department of Archives and History, 2018; North Carolina SHPO, 2018).

The South Carolina archives were searched for Places listed on the National Register of Historic Places (NRHP), above-ground historic and architectural properties, areas surveyed for cultural resources, and archaeological sites. Five structures located east of Lexington Avenue and north of the John N. Hardee Expressway and within the APE for KCAE WSR-88D are listed because they were previously studied for historic or cultural value, but all five were found to be not eligible for the NRHP (South Carolina Department of Archives and History, 2018). There are no listings within the APE for KGSP WSR-88D. No historic places are present within the APEs for the KGSP or KCAE WSR-88Ds.

The North Carolina archives were searched for Places listed on the NRHP, places studied for NRHP eligibility, places determine to be eligible for NRHP, areas surveyed for cultural resources, and local landmarks and districts. The nearest place to the KRAX WSR-88D is the Ellington-Ellis Farm, which was added to NRHP in 1983. That farm is 2,700 ft northeast of the KRAX WSR-88D and outside the APE (North Carolina SHPO, 2018). No historic places are present within the APE for KRAX WSR-88D.

Under Section 106 Regulations 36 CFR Section 800.2 (a)(1), Protection of Historic Properties, if the proposed action doesn’t have the potential to affect historic properties, NWS “has no further obligations under section 106” and consultation with South Carolina and North Carolina...
SHPOs regarding possible impacts on historic properties is not required [Advisory Council on Historic Preservation, 2010].

4.12 ENVIRONMENTAL JUSTICE AND SOCIOECONOMIC IMPACTS

E.O. 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations*, requires federal agencies to identify and address, as appropriate, disproportionately high and adverse environmental or human health effects on minority populations and low income populations (President, 1994).

The KGSP and KCAE WSR-88Ds are located at Grenville-Spartanburg International Airport in Greer, SC and Columbia Metropolitan Airport in West Columbia, SC, respectively. The nearest residences to KGSP WSR-88D are low-density rural residences about 3/4 mile to the southeast. Higher-density suburban residential development is located about 1 mile to the west and across the airport runways from the radar. The nearest residences to KCAE WSR-88D are multi-family residences located about 2,000 ft to the northeast.

The KRAX WSR-88D is located at an agricultural research station in Clayton, NC. The area is predominantly commercial and the nearest residences are located about 1/4 mile to the northeast and southeast of the radar.

The proposed action would not generate air or water pollutants or hazardous waste. The project would modify the operation of the three WSR-88Ds by reducing the minimum scan angle from +0.5 deg to +0.2 deg or +0.4 deg. The lowered WSR-88D main beam would not impinge on the ground in proximity to the radar and would comply with safety standards for human exposure to RF energy and setbacks for activities, such as fuel handling and EED use, that are potentially sensitive to RF exposure. No disproportionately high and adverse effects would result to any persons, including minority or low income populations. No mitigation is required.

4.13 FARMLANDS

The Farmland Protection Policy Act sets forth federal policies to prevent the unnecessary conversion of agricultural land to non-agricultural use. NRCS regulations at 7 CFR Part 658, *Farmland Protection Policy Act*, are designed to implement those policies. Completion of Form AD-1006 and submission to the U.S. Department of Agriculture (DoA) is required if a federal agency proposes to convert land designated as prime farmland, farmland of statewide importance, or unique farmland to non-agricultural use.

As noted in section 4.4 above, the KGSP and KCAE WSR-88D site are not in agricultural use and do not contain prime farmland. The KRAX WSR-88D site is on soil that supports prime farmland. (Soil Survey Staff, Natural Resources Conservation Service, U.S. Department of Agriculture, 2018). Agricultural uses occur at the research facility hosting the WSR-88D although the WSR-88D site itself is not in agricultural use. The KRAX WSR-88D site is committed to meteorological data collection. The proposed action would not impede continued agricultural use of surrounding lands and would not convert farmland to non-agricultural use.
The proposed action would indirectly benefit agriculture in the area by facilitating improved meteorological data collection. No mitigation is necessary.

4.14 ENERGY CONSUMPTION
The proposed action would not change electric use by the WSR-88D and would have no effect on energy consumption. No mitigation is necessary.

4.15 VISUAL QUALITY/ LIGHT EMISSIONS
The proposed action would not change the appearance of the three WSR-88Ds or result in new emissions of visible light. The proposed action would have not change the visual appearance of the WSR-88Ds. No mitigation is necessary.

4.16 SOLID AND HAZARDOUS WASTE
The proposed action would result in no changes to solid or hazardous waste generation. No mitigation is necessary.

4.17 WILD AND SCENIC RIVERS
The Wild and Scenic Rivers Act of 1968 protects free-flowing rivers of the U.S. These rivers are protected under the Act by prohibiting water resource projects from adversely impacting values of the river: protecting outstanding scenic, geologic, fish and wildlife, historic, cultural, or recreational values; maintaining water quality; and implementing river management plans for these specific rivers.

The wild and scenic river closest to the KGSP WSR-88D is the Chatooga River on the South Carolina/Georgia border, about 50 miles west of the radar. No wild and scenic rivers occur within 100 miles of the KCAE WSR-88D. The wild and scenic river closest to the KRAX WSR-88D is the Lumber River in Robeson County, NC, about 70 miles south of the radar (National Park Service, 2018). The proposed action would not affect wild and scenic rivers. No mitigation is necessary.
5 ALTERNATIVES TO THE PROPOSED ACTION

5.1 MINIMUM SCAN ANGLES OTHER THAN THE PROPOSED ACTION

NWS evaluated the benefits and potential impacts of lowering the minimum center of beam scan angle of the KGSP, KCAE, and KRAX WSR-88Ds to each angle between +0.4 and -0.2 deg in 0.1 degree increments (see Appendices E and F). Those analyses found that the proposed action of lowering the minimum scan angle of KGSP and KRAX WSR-88Ds to +0.2 deg would maximize improvements in radar coverage while avoiding adverse RF effects to potentially sensitive uses and activities in the vicinity of the radar.

Operating the KGSP or KRAX WSR-88Ds at alternative minimum scan angles between +0.4 deg and -0.2 deg (i.e. minimum can angles other than the proposed +0.2 deg) would result in similar environmental effects as the proposed action. Like the proposed action, those environmental effects would not be significant. Minimum scan angles of +0.4 or +0.3 deg would increase the radar’s coverage area, but by less than the proposed action. Lowering the minimum scan angle to less than +0.2 deg would not increase coverage area of either radar compared to the proposed action, and would increase unwanted ground clutter returns to the radar. Because a minimum scan angle of +0.2 deg would achieve all of the feasible increase in radar coverage area while avoiding detrimental increase in ground clutter, NWS proposes +0.2 as the minimum scan angle for both the KGSP and KRAX WSR-88Ds, and rejected the alternatives of operating these WSR-88Ds at other minimum scan angles.

Operating the KCAE WSR-88D at alternative minimum scan angle lower than +0.4 deg would result in greater environmental effects than the proposed action. Lower minimum scan angles would result in a minimal increase in the radar’s coverage area, and would increase unwanted ground clutter returns to the radar. They would also result in the WSR-88D main beam impinging on the Columbia Metropolitan Airport ATCT cab, which would be avoided by the proposed action. Therefore, NWS proposes +0.4 as the minimum scan angle for the KCAE WSR-88D, and rejected the alternative of operating this WSR-88D at a lower minimum scan angle.

5.2 NO ACTION

The no action alternative consists of continued operation of the KGSP, KCAE, and KRAX WSR-88Ds at the existing minimum scan angle of +0.5 deg. The improvements in radar coverage summarized in Section 3 would not be achieved and the project objectives would not be met.

The proposed action would result in increased RF exposure compared to existing WSR-88D operations as described in section 4.1; the no-action alternative would not change RF exposure levels from existing. Under both the proposed action and the no action alternative, RF exposure during normal WSR-88D operations would conform to safety standards established by
ANSI/IEEE, FCC, and OSHA. RF exposure of the water tank to the north-northwest of the KCAE WSR-88D would continue to occur as would be the case for the proposed action. This alternative would avoid the KCAE WSR-88D main beam directly impinging on the Melton Memorial Observatory, but the potential for EMI with observatory operations would be mitigated through application of Mitigation Measure 2 described in this report.

Similar to the proposed action, the no-action alternative would have no effect in the following topic areas:

- Land Use and Coastal Zone Management
- Geology, Soils, and Seismic Hazards
- Drainage and Water Quality
- Transportation
- Air Quality
- Flood Hazards
- Wetlands
- Biological Resources / Protected Species
- Cultural and Historic Resources
- Environmental Justice and Socioeconomic Impacts
- Farmlands
- Energy Consumption
- Visual Quality/ Light Emissions
- Solid and Hazardous Waste
- Wild and Scenic Rivers
6 FINDING

The proposed action of lowering the minimum scan angles of the KGSP, KCAE, and KRAX WSR-88Ds from the current minimum of +0.5 deg to +0.2, +0.4, and +0.2 deg, respectively, would not result in significant changes in the quality of the human environment.

Lowering the minimum scan angles of these three existing radars would also not add to the environmental effects of past, present, and reasonably foreseeable future actions to cause cumulatively significant effects.

The proposed action would improve the quality of meteorological radar data available to NWS forecasters and others users of the data. This may indirectly benefit the residents of western and central South Carolina and western and central North Carolina by improving the accuracy of forecast and severe weather alerts, which could result in environmental benefits if weather dependent economic activities (e.g., agriculture, timber production, construction, outdoor recreation, transportation, water management) become more efficient or safer as a result of improved weather services. The resulting environmental benefits are difficult to quantify, but are unlikely to be significant.

Implementation of the proposed action would not have the potential to cause significant changes in the environmental. A Finding of No Significant Impact is warranted for the proposed action.
7 DOCUMENT PREPARERS

This Draft EA was prepared by Sensor Environmental LLC under contract to Centuria Corporation. Centuria Corporation provides support to the NWS Radar Operations Center (ROC) in Norman, OK.

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8 REFERENCES


NEXRAD JSPO. *Final Supplemental Environmental Assessment (SEA) of the Effects of Electromagnetic Radiation from the WSR-88D Radar* (April 1993).

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Schultz, Jessica. Radar Focal Point, NWS Radar Operations Center. email to jmanitakos@sensorenvirollc.com (September 13, 2018).


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ENVIRONMENTAL ASSESSMENT (EA)
LOWERING THE MINIMUM SCAN ANGLES OF THE WEATHER SURVEILLANCE RADARS - MODEL 1988, DOPPLER (WSR-88Ds) SERVING THE GREER, SC; COLUMBIA, SC; AND RALEIGH, NC AREAS

APPENDICES
APPENDIX A

RADIOFREQUENCY RADIATION POWER DENSITY CALCULATIONS
1. OBJECTIVE

This appendix quantifies the power densities of the radiofrequency radiation (RFR) emitted by the Weather Surveillance Radar, Model 1988 Doppler (WSR-88D) during operations that include minimum scan angles of +0.5 degrees (deg) (current minimum scan angle) and +0.2 deg (proposed minimum scan angle). The calculated power densities will be used to analyze the potential for effects to result from exposure of humans, equipment, and activities to the WSR-88D radio signal, and the significance of any identified potential effects.

2. METHODOLOGY

This memorandum builds upon the analysis included in the 1993 Supplemental Environmental Assessment (SEA) of the Effects of Electromagnetic Radiation from the WSR-88D Radar [NEXRAD Joint System program Office, 1993]. The 1993 analysis analyzed the potential electromagnetic effects of the WSR-88D signal when the radar operates at a minimum center of beam scan angle of +0.5 deg. This memorandum builds on that analysis by considering operation at a lower minimum scan angle of +0.2 deg. Table A-1 shows parameters of the WSR-88D, which have not changed from the 1993 analysis:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Frequency</td>
<td>2,700 to 3,000 megahertz (MHz)</td>
</tr>
<tr>
<td>Wavelength at center frequency (2,850 MHz)</td>
<td>0.345 ft, 10.5 cm</td>
</tr>
<tr>
<td>Maximum radiated pulse power</td>
<td>475 kiloWatts (kW)</td>
</tr>
<tr>
<td>Maximum duty cycle</td>
<td>0.21%</td>
</tr>
<tr>
<td>Antenna diameter</td>
<td>28 ft, 853 cm</td>
</tr>
<tr>
<td>Antenna gain</td>
<td>35,500:1, 45.5 dB</td>
</tr>
<tr>
<td>Beam width to half-power points</td>
<td>1.0 deg</td>
</tr>
<tr>
<td>First sidelobe relative power density, maximum</td>
<td>0.00325, -25 dB</td>
</tr>
<tr>
<td>Other sidelobe maximum power density, relative to main beam</td>
<td>0.0004, -34 dB</td>
</tr>
</tbody>
</table>

The NWS proposes to modify the minimum center of beam scan angle used during operation of the KGSP WSR-88D serving the Greer, SC area; KCAE WSR-88D serving the Columbia, SC area; and KRAX WSR-88D serving the Raleigh, NC area below the +0.5 angle currently in use. This would not require changes to the antenna, other hardware which composes the WSR-88D, or the radiated pulse power of the WSR-88D. However, incorporating scans at angles below +0.5 deg could affect the amount of RFR exposure experienced by persons, equipment, and activities at or near ground level in the vicinity of the radar. This memorandum quantifies that change.
3. VOLUME SCAN PATTERN 31 MODIFIED BY ADDING +0.2 DEG SCANS (KGSP and KRAX WSR-88Ds)

The WSR-88D uses a number of complex volume scan patterns to maximize the quality and usefulness of the meteorological data it collects. The 1993 report analyzed volume scan pattern 31, which results in the highest levels of ground-level RFR exposure. Volume Scan Pattern (VCP) 31 consists of eight 360 deg rotations of the antenna at various scan angles. NWS proposed to add two additional antenna rotations at a scan angle less than +0.5 deg to this scan pattern to increase the range at which the radar can detect and track meteorological phenomena, especially at low elevations within the atmosphere. For the KGSP and KRAX WSR-88Ds, the two added scans would be at +0.2 deg (i.e. lower half power point of -0.3 deg). Adding two +0.2 degree scans would result in the greatest possible increase in ground level RFR exposure. The modified VCP 31 would be as follows:

- Two complete rotations at +0.2 deg
- Two complete rotations at +0.5 deg
- Two complete rotations at +1.5 deg
- Two complete rotations at +2.5 deg
- One complete rotation at +3.5 deg
- One complete rotation at +4.5 deg

The complete pattern would include 10 rotations of the antenna at a speed of 0.8 revolutions per minute (rpm), the pattern would take about 12 minutes and 22 seconds to complete [Turner, 2011].

4. CALCULATION OF RFR POWER DENSITIES FOR KGSP and KRAX WSR-88Ds

Appendix A of the 1993 SEA includes detailed calculations of the RFR power density and exposure levels resulting from volume scan pattern 31. The proposed scan change would not affect the distance of the transition from the near field to the far field, calculated at 640 to 800 ft in section A.3 of the 1993 SEA Appendix A.

4.1 Far Field

The values of $U_1$, $U_2$, and $U_3$ would be unchanged from the values derived in 1993 Appendix A. The maximum pulse power density within the main beam ($U_1$) is given by the formula:

$$U_1 = 1.44 \times 10^9/R^2 \text{ milliWatts per square centimeter (mW/cm}^2)$$

where $R$ is the distance from the antenna in ft. The maximum pulse power density at locations greater than 6 deg off the main beam axis (i.e. outside the area illuminated by the main beam and first five sidelobes is $U_2$ (unchanged from 1993 Appendix A), given below:

$$U_2 = 5.76 \times 10^5/R^2 \text{ mW/cm}^2$$

The RF human exposure standards are based on time-averaged RF exposure for six minutes (occupational exposure) or 30 minutes (general public exposure) [American National Standards Institute/Institute of Electrical and Electronic Engineers, 2005]. We use six minutes as the
averaging time as a worst-case analysis. The time-averaged power density for the main beam rotating continuously at +0.5 deg, considering the contributions from both the main beam and the first five sidelobes is given by $U_3$ (unchanged from 1993 Appendix A), below:

$$U_3 = 1.35 \times 10^4 / R^2 \text{ mW/cm}^2$$

At this point the analysis must consider the proposed modifications to VCP 31. The modified VCP 31 would have two additional +0.2 deg scans. Within our six minute averaging time, these two added scans would replace the RFR contribution from one +1.5 deg and one +2.5 deg scan. As described in the 1993 appendix, $U_4$ sums the RFR contributions at center of antenna level from each of the scans performed during the six minute period of interest. The coefficients for the 0.0 deg scans are 2.4/6 reflecting the proportion of the 6 minutes and 1.0 because the center of beam will essentially be at antenna level (i.e. +0.2 deg which equates to 2.8 ft, or one-tenth of the beam width at the far field transition distance of 800 ft). The corresponding coefficients for the two +0.5 deg scans within the six minutes are 2.4/6 and 0.5, and for the one +1.5 deg scan within the six minutes are 1.2/6 and 0.012. The modified $U_4$ calculation is given below

$$U_4 = [(2.4/6) (1.0) + (2.4/6) (0.5) + (1.2/6) (0.012)] U_3$$

$$U_4 = (0.6024) U_3$$

Inserting the $U_3$ value of $1.35 \times 10^4 / R^2$ milliwatts/cm$^2$ (mw/cm$^2$), yields:

$$U_4 = 8.132 \times 10^3 / R^2 \text{ mW/cm}^2$$

$U_4$ is the 6-minute time-averaged power density at locations in the far field directly illuminated by the main beam and at the same elevation as the WSR-88D antenna, considering the RFR contributed from the main beam and the first five sidelobes. According to the WSR-88D specification, sidelobes of higher order than the first five will contain less than 5% of the eradiated energy. The 1993 SEA calculated the average power density of these higher order sidelobes at $4 / R^2 \text{ mW/cm}^2$. We add this to $U_4$ to obtain $U_5$, the total time-averaged power density at an elevation even with the center of antenna elevation and distances greater than 800 ft from the antenna:

$$U_5 = 8.132 \times 10^3 / R^2 + 4 / R^2 = 8.136 \times 10^3 / R^2 \text{ mW/cm}^2$$

### 4.2 Near Field

Appendix A of the 1993 SEA calculates the height $Y$ of the mathematical cylinder illuminated by all scans during the six-minute period using the formula $Y = 28 / R \tan 2 \deg + 0.035R$. Since the modified scan pattern of interest includes scans of +0.2, +0.5, and +1.5 degress, the angular range is 1.3 deg, and we recalculate $Y$ as follows:

$$Y = 28 + R \tan (1.3 \deg) = 28 + 0.023R$$

The circumference of the illumination cylinder is $2\pi RY$ and the total area $A$ is

$$A = 2\pi RY = 176R + 0.14R^2$$
The average power radiated is less than or equal to 1 kW, and the average power over the cylindrical surface cannot exceed this value divided by the area. At the mid-height of the cylinder, the local power density will exceed the average value by a factor of 2 (unchanged from the 1993 analysis). We introduce this factor, multiply by $10^6$ to convert from kW to mW, and divide by 929 to convert from sq ft to square centimeters (sq cm):

$$U_6 = 2 \times 10^6 / (929) (176R + 0.14R^2) = 15,378 / (R^2 + 1,257 R) \text{ mW/cm}^2$$

$U_6$ is the time-averaged RFR exposure within the area illuminated by the WSR-88D main beam up to distances of 640 ft where the beam begins to spread.

### 4.3 Combined Result

Table A-2 shows the time-averaged RFR power densities that would result at locations directly illuminated by the main beam of the KGSP or KRAX WSR-88Ds when operating in modified VCP 31. The near field is within 640 ft of the radar and the $U_6$ formula is used to calculate these near field values. At greater distances, the far field formula for $U_5$ is used. For comparison purposes, corresponding values for the original VCP 31 are also shown. As can be seen from Table A-1, use of modified scan pattern 31 would lower the elevation at which the lower half-power point (i.e. bottom edge) of the main beam occurs and would also slightly increase the time-averaged power densities in both the near and far fields.

<table>
<thead>
<tr>
<th>Distance (ft)</th>
<th>Distance (mi)</th>
<th>Change in Elevation of Lower Half-Power Point (ft)</th>
<th>Original VCP 31 Time-Avg Power Density (mW/cm²)</th>
<th>Modified VCP 31 Time-Avg Power Density (mW/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.004</td>
<td>No change</td>
<td>0.598</td>
<td>0.602</td>
</tr>
<tr>
<td>900</td>
<td>0.17</td>
<td>-5</td>
<td>0.0072</td>
<td>0.0100</td>
</tr>
<tr>
<td>5,280</td>
<td>1</td>
<td>-28</td>
<td>0.00021</td>
<td>0.00029</td>
</tr>
<tr>
<td>25,400</td>
<td>5</td>
<td>-133</td>
<td>0.000009</td>
<td>0.000013</td>
</tr>
</tbody>
</table>

### 4.4 RF Exposure Levels near KGSP and KRAX WSR-88Ds

Table A-3 shows the time-averaged RF power densities that would result at locations directly illuminated by the main beam of the KGSP and KRAX WSR-88Ds when operating in modified VCP 31. The near field formula $U_6$ is used within 640 ft of the radar and the far field formula $U_5$ is used beyond 640 ft. For comparison purposes, corresponding values for the original VCP 31 are also shown. As can be seen from Table A-3, modified scan pattern 31 would slightly increase the level of RF exposure.
Table A-3: Time-Average RFR Power Densities at Terrain and Structures Directly Illuminated by the KGSP and KRAX WSR-88Ds Main Beam

<table>
<thead>
<tr>
<th>Place or Structure</th>
<th>Distance (ft) and Direction</th>
<th>Original VCP 31 Time-Avg Power Density (mW/cm²)</th>
<th>Modified VCP 31 Time-Avg Power Density (mW/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KGSP WSR-88D</td>
<td>Closest Terrain 14,300 NNW</td>
<td>0.00003</td>
<td>0.00004</td>
</tr>
<tr>
<td></td>
<td>Closest Structure ASR-8 4,200 ENE</td>
<td>0.00033</td>
<td>0.00046</td>
</tr>
<tr>
<td>KRAX WSR-88D</td>
<td>Closest Terrain 15,200 NW</td>
<td>0.00003</td>
<td>0.00004</td>
</tr>
<tr>
<td></td>
<td>Closest Structure Water Tower 3,800 ENE</td>
<td>0.00040</td>
<td>0.00056</td>
</tr>
</tbody>
</table>

NWS may infrequently operate the KGSP or KRAX WSR-88D with a stationary antenna, resulting in the main beam being continuously pointed at the same location for a period of time. The RF exposure level within the main beam can be calculated using equation U₁ multiplied by the radar duty cycle

\[ U_7 = \left(1.44 \times 10^9/R^2\right) 0.0021 = 3.024 \times 10^6/R^2 \text{ (mW/cm}^2)\]

When operating in stationary antenna mode, the KGSP and KRAX WSR-88Ds would exceed the ANSI/IEEE safety levels within the following distances:

- ANSI/IEEE and FCC General Public Safety Level (1.0 mW/cm²): 1,740 ft
- FCC Occupational Safety Level (5.0 mW/cm²): 780 ft
- ANSI/IEEE Occupational Safety Level (9.26 mW/cm²): 570 ft

*Frequency-dependent safety standard calculated for KGSP operating frequency of 2,780 MHz.

5. **VOLUME SCAN PATTERN 31 MODIFIED BY ADDING +0.4 DEG SCANS (KCAE WSR-88D)**

For the KCAE WSR-88D, the two added scans would be at +0.4 deg (i.e. lower half power point of -0.1 deg). Adding two +0.4 degree scans would result in the greatest possible increase in ground level RFR exposure. The modified VCP 31 would be as follows:

- Two complete rotations at +0.4 deg
- Two complete rotations at +0.5 deg
- Two complete rotations at +1.5 deg
- Two complete rotations at +2.5 deg
- One complete rotation at +3.5 deg
- One complete rotation at +4.5 deg
The complete pattern would include 10 rotations of the antenna at a speed of 0.8 revolutions per minute (rpm), the pattern would take about 12 minutes and 22 seconds to complete [Turner, 2011].

6. Calculation of RFR Power Densities for KCAE WSR-88D

Appendix A of the 1993 SEA includes detailed calculations of the RFR power density and exposure levels resulting from volume scan pattern 31. The proposed scan change would not affect the distance of the transition from the near field to the far field, calculated at 640 to 800 ft in section A.3 of the 1993 SEA Appendix A.

6.1 Far Field

The values of \(U_1\), \(U_2\), and \(U_3\) would be unchanged from the values derived in 1993 Appendix A and given in section 4.1 above. At this point the analysis must consider the proposed modifications to VCP 31. The modified VCP 31 would have two additional +0.4 deg scans. Within our six minute averaging time, these two added scans would replace the RFR contribution from one +1.5 deg and one +2.5 deg scan. As described in the 1993 appendix, \(U_4\) sums the RFR contributions at center of antenna level from each of the scans performed during the six minute period of interest. The coefficients for the 0.0 deg scans are 2.4/6 reflecting the proportion of the 6 minutes and 0.5 because the center of beam will essentially be at ½ deg from antenna level during the +0.4 deg scan. The corresponding coefficients for the two + 0.5 deg scans within the six minutes are 2.4/6 and 0.5, and for the one +1.5 deg scan within the six minutes are 1.2/6 and 0.012. The modified \(U_4\) calculation is given below

\[
\begin{align*}
U_4 &= [(2.4/6) (0.5) + (2.4/6) (0.5) + (1.2/6) (0.012)] U_3 \\
U_4 &= (0.4024) U_3 \\
\end{align*}
\]

Inserting the \(U_3\) value of \(1.35 \times 10^4/R^2\) milliwatts/cm\(^2\) (mw/ cm\(^2\)), yields:

\[
U_4 = 3.272 \times 10^3/R^2 \text{ mW/cm}^2
\]

Recalling the contribution of the main beam is dominant and doubles at 0.0 deg vs. 0.5 deg, we may double \(U_4\):

\[
U_5 = 2 \times (3.272 \times 10^3/R^2) = 6.545 \times 10^3/R^2 \text{ mW/cm}^2
\]

\(U_5\) is the 6-minute time-averaged power density at locations in the far field directly illuminated by the main beam and at the same elevation as the WSR-88D antenna, considering the RFR contributed from the main beam and the first five sidelobes. According to the WSR-88D specification, sidelobes of higher order than the first five will contain less than 5% of the eradiated energy. The 1993 SEA calculated the average power density of these higher order sidelobes at \(4/R^2\) mW/cm\(^2\). We add this to \(U_5\) to obtain \(U_6\), the total time-averaged power density at an elevation even with the center of antenna elevation and distances greater than 800 ft from the antenna:

\[
U_6 = 6.545 \times 10^3/R^2 + 4/R^2 = 6.549 \times 10^3/R^2 \text{ mW/cm}^2
\]
6.2 Near Field

Appendix A of the 1993 SEA calculates the height \( Y \) of the mathematical cylinder illuminated by all scans during the six-minute period using the formula \( Y = 28 ÷ R \tan 2 \text{ deg} + 0.035R \). Since the modified scan pattern of interest includes scans of +0.4, +0.5, and +1.5 degs, the angular range is 1.1 deg, and we recalculate \( Y \) as follows:

\[
Y = 28 + RTan(1.1 \text{ deg}) = 28 +0.019R
\]

The circumference of the illumination cylinder is \( 2\pi RY \) and the total area \( A \) is

\[
A = 2\pi RY = 176R + 0.12R^2
\]

The average power radiated is less than or equal to 1 kW, and the average power over the cylindrical surface cannot exceed this value divided by the area. At the mid-height of the cylinder, the local power density will exceed the average value by a factor of 2 (unchanged from the 1993 analysis). We introduce this factor, multiply by \( 10^6 \) to convert from kW to mW, and divide by 929 to convert from sq ft to square centimeters (sq cm):

\[
U_7 = 2 * 10^6 / (929) (176R + 0.12R^2) = 17,940 / (R^2 + 1,467 R) \text{ mW/cm}^2
\]

\( U_7 \) is the time-averaged RFR exposure within the area illuminated by the WSR-88D main beam up to distances of 640 ft where the beam begins to spread.

6.3 Combined Result

Table A-4 shows the time-averaged RFR power densities that would result at locations directly illuminated by the main beam of the KCAE WSR-88D when operating in modified VCP 31. The near field is within 640 ft of the radar and the \( U_6 \) formula is used to calculate these near field values. At greater distances, the far field formula for \( U_5 \) is used. For comparison purposes, corresponding values for the original VCP 31 are also shown. As can be seen from Table A-1, use of modified scan pattern 31 would also slightly increase the time-averaged power densities in both the near and far fields.

<p>| Table A-4: Time-Average RFR Power Densities at Various Distances within the Illuminated Area for KCAE WSR-88D |
|---------------------------------|----------------|------------------------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Distance (ft)</th>
<th>Distance (mi)</th>
<th>Change in Elevation of Lower Half-Power Point (ft)</th>
<th>Original VCP 31 Time-Avg Power Density (mW/cm²)</th>
<th>Modified VCP 31 Time-Avg Power Density (mW/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.004</td>
<td>No change</td>
<td>0.598</td>
<td>0.603</td>
</tr>
<tr>
<td>900</td>
<td>0.17</td>
<td>-2</td>
<td>0.0072</td>
<td>0.0081</td>
</tr>
<tr>
<td>5,280</td>
<td>1</td>
<td>-9</td>
<td>0.00021</td>
<td>0.00024</td>
</tr>
<tr>
<td>25,400</td>
<td>5</td>
<td>-44</td>
<td>0.000009</td>
<td>0.000010</td>
</tr>
</tbody>
</table>
6.4 RF Exposure Levels near KCAE WSR-88D

Table A-5 shows the time-averaged RF power densities that would result at locations directly illuminated by the main beam of the KCAE WSR-88D when operating in modified VCP 31. The near field is within 640 ft of the radar and the $U_6$ formula is used to calculate these near field values. At greater distances, the far field formula for $U_5$ is used. For comparison purposes, corresponding values for the original VCP 31 are also shown. As can be seen from Table A-5, use of modified scan pattern 31 would slightly increase the level of RF exposure.

<table>
<thead>
<tr>
<th>Place or Structure</th>
<th>Distance (ft) and Direction</th>
<th>Original VCP 31 Time-Avg Power Density (mW/cm²)</th>
<th>Modified VCP 31 Time-Avg Power Density (mW/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closest Terrain</td>
<td>12,800 NW</td>
<td>0.000035</td>
<td>0.000040</td>
</tr>
<tr>
<td>KCAE WSR-88D</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Closest Structure ATCT (cab illuminated at +0.3 deg but not at +0.4 deg)</td>
<td>1,600 S</td>
<td>0.0023</td>
<td>0.0026</td>
</tr>
<tr>
<td>2nd Closest Structure Water tank</td>
<td>1,700 ft NNW</td>
<td>0.0020</td>
<td>0.0023</td>
</tr>
</tbody>
</table>

NWS may infrequently operate the KGSP or KRAX WSR-88D with a stationary antenna, resulting in the main beam being continuously pointed at the same location for a period of time. When operating in stationary antenna mode, the KCAE WSR-88D would exceed the ANSI/IEEE safety levels within the following distances:

- ANSI/IEEE and FCC General Public Safety Level (1.0 mW/cm²): 1,740 ft
- FCC Occupational Safety Level (5.0 mW/cm²): 780 ft
- ANSI/IEEE Occupational Safety Level (9.63 mW/cm²)*: 560 ft

*Frequency-dependent safety standard calculated for KCAE operating frequency of 2,890 MHz.

7. REFERENCES


Edward Ciardi, Program Manager, EVP weather Systems, Centuria Corporation. email to James Manitakos, Sensor Environmental LLC (February 14, 2018).
APPENDIX B

PROTECTED SPECIES LIST FOR KGSP WSR-88D
In Reply Refer To: November 26, 2018
Consultation Code: 04ES1000-2019-SLI-0145
Event Code: 04ES1000-2019-E-00286
Project Name: KGSP WSR-88D Lower Scan Angle

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed and candidate species, as well as proposed and final designated critical habitat, that may occur within the boundary of your proposed project and/or may be affected by your proposed project. The species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under section 7(c) of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 et seq.).

New information based on updated surveys, changes in the abundance and distribution of species, changed habitat conditions, or other factors could change this list. Please feel free to contact us if you need more current information or assistance regarding the potential impacts to federally proposed, listed, and candidate species and federally designated and proposed critical habitat. Please note that under 50 CFR 402.12(e) of the regulations implementing section 7 of the Act, the accuracy of this species list should be verified after 90 days. This verification can be completed formally or informally as desired. The Service recommends that verification be completed by visiting the ECOS-IPaC website at regular intervals during project planning and implementation for updates to species lists and information. An updated list may be requested through the ECOS-IPaC system by completing the same process used to receive the enclosed list.

The purpose of the Act is to provide a means whereby threatened and endangered species and the ecosystems upon which they depend may be conserved. Under sections 7(a)(1) and 7(a)(2) of the Act and its implementing regulations (50 CFR 402 et seq.), Federal agencies are required to utilize their authorities to carry out programs for the conservation of threatened and endangered species and to determine whether projects may affect threatened and endangered species and/or designated critical habitat.
A Biological Assessment is required for construction projects (or other undertakings having similar physical impacts) that are major Federal actions significantly affecting the quality of the human environment as defined in the National Environmental Policy Act (42 U.S.C. 4332(2)(c)). For projects other than major construction activities, the Service suggests that a biological evaluation similar to a Biological Assessment be prepared to determine whether the project may affect listed or proposed species and/or designated or proposed critical habitat. Recommended contents of a Biological Assessment are described at 50 CFR 402.12.

If a Federal agency determines, based on the Biological Assessment or biological evaluation, that listed species and/or designated critical habitat may be affected by the proposed project, the agency is required to consult with the Service pursuant to 50 CFR 402. In addition, the Service recommends that candidate species, proposed species and proposed critical habitat be addressed within the consultation. More information on the regulations and procedures for section 7 consultation, including the role of permit or license applicants, can be found in the "Endangered Species Consultation Handbook" at:

http://www.fws.gov/endangered/esa-library/pdf/TOC-GLOS.PDF

Please be aware that bald and golden eagles are protected under the Bald and Golden Eagle Protection Act (16 U.S.C. 668 et seq.), and projects affecting these species may require development of an eagle conservation plan (http://www.fws.gov/windenergy/eagle_guidance.html). Additionally, wind energy projects should follow the wind energy guidelines (http://www.fws.gov/windenergy/) for minimizing impacts to migratory birds and bats.

Guidance for minimizing impacts to migratory birds for projects including communications towers (e.g., cellular, digital television, radio, and emergency broadcast) can be found at: http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/towers.htm; http://www.towerkill.com; and http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/comtow.html.

We appreciate your concern for threatened and endangered species. The Service encourages Federal agencies to include conservation of threatened and endangered species into their project planning to further the purposes of the Act. Please include the Consultation Tracking Number in the header of this letter with any request for consultation or correspondence about your project that you submit to our office.

Attachment(s):

- Official Species List
- USFWS National Wildlife Refuges and Fish Hatcheries
- Migratory Birds
Official Species List

This list is provided pursuant to Section 7 of the Endangered Species Act, and fulfills the requirement for Federal agencies to "request of the Secretary of the Interior information whether any species which is listed or proposed to be listed may be present in the area of a proposed action".

This species list is provided by:

South Carolina Ecological Services
176 Croghan Spur Road, Suite 200
Charleston, SC 29407-7558
(843) 727-4707
Project Summary

Consultation Code: 04ES1000-2019-SLI-0145

Event Code: 04ES1000-2019-E-00286

Project Name: KGSP WSR-88D Lower Scan Angle

Project Type: COMMUNICATIONS TOWER

Project Description: Lowering the minimum scan angle of the existing KGSP WSR-88D from +0.5 deg to +0.2 deg

Project Location:
Approximate location of the project can be viewed in Google Maps: https://www.google.com/maps/place/34.883237844328235N82.2197898797548W

Counties: Spartanburg, SC
Endangered Species Act Species

There is a total of 1 threatened, endangered, or candidate species on this species list.

Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species.

IPaC does not display listed species or critical habitats under the sole jurisdiction of NOAA Fisheries\(^1\), as USFWS does not have the authority to speak on behalf of NOAA and the Department of Commerce.

See the "Critical habitats" section below for those critical habitats that lie wholly or partially within your project area under this office's jurisdiction. Please contact the designated FWS office if you have questions.

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1. NOAA Fisheries, also known as the National Marine Fisheries Service (NMFS), is an office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

Flowering Plants

<table>
<thead>
<tr>
<th>NAME</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dwarf-flowered Heartleaf <em>Hexastylis naniflora</em></td>
<td>Threatened</td>
</tr>
</tbody>
</table>

No critical habitat has been designated for this species.
Species profile: [https://ecos.fws.gov/ecp/species/2458](https://ecos.fws.gov/ecp/species/2458)

Critical habitats

THERE ARE NO CRITICAL HABITATS WITHIN YOUR PROJECT AREA UNDER THIS OFFICE'S JURISDICTION.
USFWS National Wildlife Refuge Lands And Fish Hatcheries

Any activity proposed on lands managed by the National Wildlife Refuge system must undergo a 'Compatibility Determination' conducted by the Refuge. Please contact the individual Refuges to discuss any questions or concerns.

THERE ARE NO REFUGE LANDS OR FISH HATCHERIES WITHIN YOUR PROJECT AREA.
Migratory Birds

Certain birds are protected under the Migratory Bird Treaty Act\textsuperscript{1} and the Bald and Golden Eagle Protection Act\textsuperscript{2}.

Any person or organization who plans or conducts activities that may result in impacts to migratory birds, eagles, and their habitats should follow appropriate regulations and consider implementing appropriate conservation measures, as described below.

1. The \textit{Migratory Birds Treaty Act} of 1918.
2. The \textit{Bald and Golden Eagle Protection Act} of 1940.
3. 50 C.F.R. Sec. 10.12 and 16 U.S.C. Sec. 668(a)

The birds listed below are birds of particular concern either because they occur on the USFWS Birds of Conservation Concern (BCC) list or warrant special attention in your project location. To learn more about the levels of concern for birds on your list and how this list is generated, see the FAQ below. This is not a list of every bird you may find in this location, nor a guarantee that every bird on this list will be found in your project area. To see exact locations of where birders and the general public have sighted birds in and around your project area, visit the \textit{E-bird data mapping tool} (Tip: enter your location, desired date range and a species on your list). For projects that occur off the Atlantic Coast, additional maps and models detailing the relative occurrence and abundance of bird species on your list are available. Links to additional information about Atlantic Coast birds, and other important information about your migratory bird list, including how to properly interpret and use your migratory bird report, can be found below.

For guidance on when to schedule activities or implement avoidance and minimization measures to reduce impacts to migratory birds on your list, click on the PROBABILITY OF PRESENCE SUMMARY at the top of your list to see when these birds are most likely to be present and breeding in your project area.

<table>
<thead>
<tr>
<th>NAME</th>
<th>BREEDING SEASON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern Whip-poor-will \textit{Antrostomus vociferus}</td>
<td>Breeds May 1 to Aug 20</td>
</tr>
<tr>
<td>This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.</td>
<td></td>
</tr>
<tr>
<td>Prairie Warbler \textit{Dendroica discolor}</td>
<td>Breeds May 1 to Jul 31</td>
</tr>
<tr>
<td>This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.</td>
<td></td>
</tr>
<tr>
<td>Prothonotary Warbler \textit{Protonotaria citrea}</td>
<td>Breeds Apr 1 to Jul 31</td>
</tr>
<tr>
<td>This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.</td>
<td></td>
</tr>
</tbody>
</table>
NAME | BREEDING SEASON
---|---
Red-headed Woodpecker *Melanerpes erythrocephalus* | Breeds May 10 to Sep 10
This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.

Rusty Blackbird *Euphagus carolinus* | Breeds elsewhere
This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.

Wood Thrush *Hylocichla mustelina* | Breeds May 10 to Aug 31
This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.

### Probability Of Presence Summary

The graphs below provide our best understanding of when birds of concern are most likely to be present in your project area. This information can be used to tailor and schedule your project activities to avoid or minimize impacts to birds. Please make sure you read and understand the FAQ “Proper Interpretation and Use of Your Migratory Bird Report” before using or attempting to interpret this report.

**Probability of Presence (**)**

Each green bar represents the bird's relative probability of presence in the 10km grid cell(s) your project overlaps during a particular week of the year. (A year is represented as 12 4-week months.) A taller bar indicates a higher probability of species presence. The survey effort (see below) can be used to establish a level of confidence in the presence score. One can have higher confidence in the presence score if the corresponding survey effort is also high.

How is the probability of presence score calculated? The calculation is done in three steps:

1. The probability of presence for each week is calculated as the number of survey events in the week where the species was detected divided by the total number of survey events for that week. For example, if in week 12 there were 20 survey events and the Spotted Towhee was found in 5 of them, the probability of presence of the Spotted Towhee in week 12 is 0.25.

2. To properly present the pattern of presence across the year, the relative probability of presence is calculated. This is the probability of presence divided by the maximum probability of presence across all weeks. For example, imagine the probability of presence in week 20 for the Spotted Towhee is 0.05, and that the probability of presence at week 12 (0.25) is the maximum of any week of the year. The relative probability of presence on week 12 is 0.25/0.25 = 1; at week 20 it is 0.05/0.25 = 0.2.

3. The relative probability of presence calculated in the previous step undergoes a statistical conversion so that all possible values fall between 0 and 10, inclusive. This is the probability of presence score.

**Breeding Season (**

Yellow bars denote a very liberal estimate of the time-frame inside which the bird breeds across its entire range. If there are no yellow bars shown for a bird, it does not breed in your project area.

**Survey Effort** (!)
Vertical black lines superimposed on probability of presence bars indicate the number of surveys performed for that species in the 10km grid cell(s) your project area overlaps. The number of surveys is expressed as a range, for example, 33 to 64 surveys.

**No Data (−)**
A week is marked as having no data if there were no survey events for that week.

**Survey Timeframe**
Surveys from only the last 10 years are used in order to ensure delivery of currently relevant information. The exception to this is areas off the Atlantic coast, where bird returns are based on all years of available data, since data in these areas is currently much more sparse.

Additional information can be found using the following links:

Migratory Birds FAQ

Tell me more about conservation measures I can implement to avoid or minimize impacts to migratory birds.

Nationwide Conservation Measures describes measures that can help avoid and minimize impacts to all birds at any location year round. Implementation of these measures is particularly important when birds are most likely to occur in the project area. When birds may be breeding in the area, identifying the locations of any active nests and avoiding their destruction is a very helpful impact minimization measure. To see when birds are most likely to occur and be breeding in your project area, view the Probability of Presence Summary. Additional measures and/or permits may be advisable depending on the type of activity you are conducting and the type of infrastructure or bird species present on your project site.

What does IPaC use to generate the migratory birds potentially occurring in my specified location?
The Migratory Bird Resource List is comprised of USFWS Birds of Conservation Concern (BCC) and other species that may warrant special attention in your project location.

The migratory bird list generated for your project is derived from data provided by the Avian Knowledge Network (AKN). The AKN data is based on a growing collection of survey, banding, and citizen science datasets and is queried and filtered to return a list of those birds reported as occurring in the 10km grid cell(s) which your project intersects, and that have been identified as warranting special attention because they are a BCC species in that area, an eagle (Eagle Act requirements may apply), or a species that has a particular vulnerability to offshore activities or development.

Again, the Migratory Bird Resource list includes only a subset of birds that may occur in your project area. It is not representative of all birds that may occur in your project area. To get a list of all birds potentially present in your project area, please visit the E-bird Explore Data Tool.

What does IPaC use to generate the probability of presence graphs for the migratory birds potentially occurring in my specified location?
The probability of presence graphs associated with your migratory bird list are based on data provided by the Avian Knowledge Network (AKN). This data is derived from a growing collection of survey, banding, and citizen science datasets.

Probability of presence data is continuously being updated as new and better information becomes available. To learn more about how the probability of presence graphs are produced and how to interpret them, go the Probability of Presence Summary and then click on the "Tell me about these graphs" link.

How do I know if a bird is breeding, wintering, migrating or present year-round in my project area?
To see what part of a particular bird's range your project area falls within (i.e. breeding, wintering, migrating or year-round), you may refer to the following resources: The Cornell Lab of Ornithology All About Birds Bird Guide, or (if you are unsuccessful in locating the bird of
interest there), the Cornell Lab of Ornithology Neotropical Birds guide. If a bird on your migratory bird species list has a breeding season associated with it, if that bird does occur in your project area, there may be nests present at some point within the timeframe specified. If "Breeds elsewhere" is indicated, then the bird likely does not breed in your project area.

What are the levels of concern for migratory birds?
Migratory birds delivered through IPaC fall into the following distinct categories of concern:

1. "BCC Rangewide" birds are Birds of Conservation Concern (BCC) that are of concern throughout their range anywhere within the USA (including Hawaii, the Pacific Islands, Puerto Rico, and the Virgin Islands);
2. "BCC - BCR" birds are BCCs that are of concern only in particular Bird Conservation Regions (BCRs) in the continental USA; and
3. "Non-BCC - Vulnerable" birds are not BCC species in your project area, but appear on your list either because of the Eagle Act requirements (for eagles) or (for non-eagles) potential susceptibilities in offshore areas from certain types of development or activities (e.g. offshore energy development or longline fishing).

Although it is important to try to avoid and minimize impacts to all birds, efforts should be made, in particular, to avoid and minimize impacts to the birds on this list, especially eagles and BCC species of rangewide concern. For more information on conservation measures you can implement to help avoid and minimize migratory bird impacts and requirements for eagles, please see the FAQs for these topics.

Details about birds that are potentially affected by offshore projects
For additional details about the relative occurrence and abundance of both individual bird species and groups of bird species within your project area off the Atlantic Coast, please visit the Northeast Ocean Data Portal. The Portal also offers data and information about other taxa besides birds that may be helpful to you in your project review. Alternately, you may download the bird model results files underlying the portal maps through the NOAA NCCOS Integrative Statistical Modeling and Predictive Mapping of Marine Bird Distributions and Abundance on the Atlantic Outer Continental Shelf project webpage.

Bird tracking data can also provide additional details about occurrence and habitat use throughout the year, including migration. Models relying on survey data may not include this information. For additional information on marine bird tracking data, see the Diving Bird Study and the nanotag studies or contact Caleb Spiegel or Pam Loring.

What if I have eagles on my list?
If your project has the potential to disturb or kill eagles, you may need to obtain a permit to avoid violating the Eagle Act should such impacts occur.

Proper Interpretation and Use of Your Migratory Bird Report
The migratory bird list generated is not a list of all birds in your project area, only a subset of birds of priority concern. To learn more about how your list is generated, and see options for identifying what other birds may be in your project area, please see the FAQ “What does IPaC
use to generate the migratory birds potentially occurring in my specified location”. Please be aware this report provides the “probability of presence” of birds within the 10 km grid cell(s) that overlap your project; not your exact project footprint. On the graphs provided, please also look carefully at the survey effort (indicated by the black vertical bar) and for the existence of the “no data” indicator (a red horizontal bar). A high survey effort is the key component. If the survey effort is high, then the probability of presence score can be viewed as more dependable. In contrast, a low survey effort bar or no data bar means a lack of data and, therefore, a lack of certainty about presence of the species. This list is not perfect; it is simply a starting point for identifying what birds of concern have the potential to be in your project area, when they might be there, and if they might be breeding (which means nests might be present). The list helps you know what to look for to confirm presence, and helps guide you in knowing when to implement conservation measures to avoid or minimize potential impacts from your project activities, should presence be confirmed. To learn more about conservation measures, visit the FAQ “Tell me about conservation measures I can implement to avoid or minimize impacts to migratory birds” at the bottom of your migratory bird trust resources page.
APPENDIX C

PROTECTED SPECIES LIST FOR KCAE WSR-88D
In Reply Refer To:  
Consultation Code: 04ES1000-2019-SLI-0183  
Event Code: 04ES1000-2019-E-00351  
Project Name: KCAE WSR-88D Lower Scan Angle  

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project  

To Whom It May Concern:  

The enclosed species list identifies threatened, endangered, proposed and candidate species, as well as proposed and final designated critical habitat, that may occur within the boundary of your proposed project and/or may be affected by your proposed project. The species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under section 7(c) of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 et seq.).  

New information based on updated surveys, changes in the abundance and distribution of species, changed habitat conditions, or other factors could change this list. Please feel free to contact us if you need more current information or assistance regarding the potential impacts to federally proposed, listed, and candidate species and federally designated and proposed critical habitat. Please note that under 50 CFR 402.12(e) of the regulations implementing section 7 of the Act, the accuracy of this species list should be verified after 90 days. This verification can be completed formally or informally as desired. The Service recommends that verification be completed by visiting the ECOS-IPaC website at regular intervals during project planning and implementation for updates to species lists and information. An updated list may be requested through the ECOS-IPaC system by completing the same process used to receive the enclosed list.  

The purpose of the Act is to provide a means whereby threatened and endangered species and the ecosystems upon which they depend may be conserved. Under sections 7(a)(1) and 7(a)(2) of the Act and its implementing regulations (50 CFR 402 et seq.), Federal agencies are required to utilize their authorities to carry out programs for the conservation of threatened and endangered species and to determine whether projects may affect threatened and endangered species and/or designated critical habitat.
A Biological Assessment is required for construction projects (or other undertakings having similar physical impacts) that are major Federal actions significantly affecting the quality of the human environment as defined in the National Environmental Policy Act (42 U.S.C. 4332(2)(c)). For projects other than major construction activities, the Service suggests that a biological evaluation similar to a Biological Assessment be prepared to determine whether the project may affect listed or proposed species and/or designated or proposed critical habitat. Recommended contents of a Biological Assessment are described at 50 CFR 402.12.

If a Federal agency determines, based on the Biological Assessment or biological evaluation, that listed species and/or designated critical habitat may be affected by the proposed project, the agency is required to consult with the Service pursuant to 50 CFR 402. In addition, the Service recommends that candidate species, proposed species and proposed critical habitat be addressed within the consultation. More information on the regulations and procedures for section 7 consultation, including the role of permit or license applicants, can be found in the "Endangered Species Consultation Handbook" at:

http://www.fws.gov/endangered/esa-library/pdf/TOC-GLOS.PDF

Please be aware that bald and golden eagles are protected under the Bald and Golden Eagle Protection Act (16 U.S.C. 668 et seq.), and projects affecting these species may require development of an eagle conservation plan (http://www.fws.gov/windenergy/eagle_guidance.html). Additionally, wind energy projects should follow the wind energy guidelines (http://www.fws.gov/windenergy/) for minimizing impacts to migratory birds and bats.

Guidance for minimizing impacts to migratory birds for projects including communications towers (e.g., cellular, digital television, radio, and emergency broadcast) can be found at: http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/towers.htm; http://www.towerkill.com; and http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/comtow.html.

We appreciate your concern for threatened and endangered species. The Service encourages Federal agencies to include conservation of threatened and endangered species into their project planning to further the purposes of the Act. Please include the Consultation Tracking Number in the header of this letter with any request for consultation or correspondence about your project that you submit to our office.

Attachment(s):

- Official Species List
- USFWS National Wildlife Refuges and Fish Hatcheries
- Migratory Birds
Official Species List

This list is provided pursuant to Section 7 of the Endangered Species Act, and fulfills the requirement for Federal agencies to "request of the Secretary of the Interior information whether any species which is listed or proposed to be listed may be present in the area of a proposed action".

This species list is provided by:

South Carolina Ecological Services
176 Croghan Spur Road, Suite 200
Charleston, SC 29407-7558
(843) 727-4707
Project Summary

Consultation Code: 04ES1000-2019-SLI-0183

Project Name: KCAE WSR-88D Lower Scan Angle

Project Type: COMMUNICATIONS TOWER

Project Description: Lowering the minimum scan angle of the KCAE WSR-88D from +0.5 deg to +0.4 deg

Project Location: Approximate location of the project can be viewed in Google Maps: https://www.google.com/maps/place/33.94876462417834N81.118191877081W

Counties: Lexington, SC
Endangered Species Act Species

There is a total of 3 threatened, endangered, or candidate species on this species list.

Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species.

IPaC does not display listed species or critical habitats under the sole jurisdiction of NOAA Fisheries, as USFWS does not have the authority to speak on behalf of NOAA and the Department of Commerce.

See the "Critical habitats" section below for those critical habitats that lie wholly or partially within your project area under this office's jurisdiction. Please contact the designated FWS office if you have questions.

1. NOAA Fisheries, also known as the National Marine Fisheries Service (NMFS), is an office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

<table>
<thead>
<tr>
<th>NAME</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Red-cockaded Woodpecker</strong></td>
<td><strong>Endangered</strong></td>
</tr>
<tr>
<td>Picoides borealis</td>
<td></td>
</tr>
<tr>
<td>No critical habitat has been designated for this species.</td>
<td></td>
</tr>
<tr>
<td>Species profile: <a href="https://ecos.fws.gov/ecp/species/7614">https://ecos.fws.gov/ecp/species/7614</a></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NAME</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carolina Heelsplitter</strong></td>
<td><strong>Endangered</strong></td>
</tr>
<tr>
<td>Lasmigona decorata</td>
<td></td>
</tr>
<tr>
<td>There is final critical habitat for this species. Your location is outside the critical habitat.</td>
<td></td>
</tr>
<tr>
<td>Species profile: <a href="https://ecos.fws.gov/ecp/species/3534">https://ecos.fws.gov/ecp/species/3534</a></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NAME</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Smooth Coneflower</strong></td>
<td><strong>Endangered</strong></td>
</tr>
<tr>
<td>Echinacea laevigata</td>
<td></td>
</tr>
<tr>
<td>No critical habitat has been designated for this species.</td>
<td></td>
</tr>
<tr>
<td>Species profile: <a href="https://ecos.fws.gov/ecp/species/3473">https://ecos.fws.gov/ecp/species/3473</a></td>
<td></td>
</tr>
</tbody>
</table>
**Critical habitats**

THERE ARE NO CRITICAL HABITATS WITHIN YOUR PROJECT AREA UNDER THIS OFFICE’S JURISDICTION.
USFWS National Wildlife Refuge Lands And Fish Hatcheries

Any activity proposed on lands managed by the [National Wildlife Refuge](https://www.nature Conservancy.org) system must undergo a 'Compatibility Determination' conducted by the Refuge. Please contact the individual Refuges to discuss any questions or concerns.

THERE ARE NO REFUGE LANDS OR FISH HATCHERIES WITHIN YOUR PROJECT AREA.
Migratory Birds

Certain birds are protected under the Migratory Bird Treaty Act\(^1\) and the Bald and Golden Eagle Protection Act\(^2\).

Any person or organization who plans or conducts activities that may result in impacts to migratory birds, eagles, and their habitats should follow appropriate regulations and consider implementing appropriate conservation measures, as described below.

2. The [Bald and Golden Eagle Protection Act](https://www.northamericabirds.org/migration/eagle-protection-act) of 1940.
3. 50 C.F.R. Sec. 10.12 and 16 U.S.C. Sec. 668(a)

The birds listed below are birds of particular concern either because they occur on the [USFWS Birds of Conservation Concern](https://www.fws.gov/birds/conservation-concern) (BCC) list or warrant special attention in your project location. To learn more about the levels of concern for birds on your list and how this list is generated, see the FAQ below. This is not a list of every bird you may find in this location, nor a guarantee that every bird on this list will be found in your project area. To see exact locations of where birders and the general public have sighted birds in and around your project area, visit the [E-bird data mapping tool](https://ebird.org/tools/mapping) (Tip: enter your location, desired date range and a species on your list). For projects that occur off the Atlantic Coast, additional maps and models detailing the relative occurrence and abundance of bird species on your list are available. Links to additional information about Atlantic Coast birds, and other important information about your migratory bird list, including how to properly interpret and use your migratory bird report, can be found below.

For guidance on when to schedule activities or implement avoidance and minimization measures to reduce impacts to migratory birds on your list, click on the [PROBABILITY OF PRESENCE SUMMARY](#) at the top of your list to see when these birds are most likely to be present and breeding in your project area.

<table>
<thead>
<tr>
<th>NAME</th>
<th>BREEDING SEASON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Ground-dove <em>Columbina passerina exigua</em></td>
<td>Breeds Feb 1 to Dec 31</td>
</tr>
<tr>
<td>This is a Bird of Conservation Concern (BCC) only in particular Bird Conservation Regions (BCRs) in the continental USA</td>
<td></td>
</tr>
<tr>
<td>Le Conte's Sparrow <em>Ammodramus leconteii</em></td>
<td>Breeds elsewhere</td>
</tr>
<tr>
<td>This is a Bird of Conservation Concern (BCC) only in particular Bird Conservation Regions (BCRs) in the continental USA</td>
<td></td>
</tr>
<tr>
<td>Red-headed Woodpecker <em>Melanerpes erythrocephalus</em></td>
<td>Breeds May 10 to Sep 10</td>
</tr>
<tr>
<td>This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.</td>
<td></td>
</tr>
</tbody>
</table>
Probability Of Presence Summary

The graphs below provide our best understanding of when birds of concern are most likely to be present in your project area. This information can be used to tailor and schedule your project activities to avoid or minimize impacts to birds. Please make sure you read and understand the FAQ “Proper Interpretation and Use of Your Migratory Bird Report” before using or attempting to interpret this report.

Probability of Presence (■)

Each green bar represents the bird's relative probability of presence in the 10km grid cell(s) your project overlaps during a particular week of the year. (A year is represented as 12 4-week months.) A taller bar indicates a higher probability of species presence. The survey effort (see below) can be used to establish a level of confidence in the presence score. One can have higher confidence in the presence score if the corresponding survey effort is also high.

How is the probability of presence score calculated? The calculation is done in three steps:

1. The probability of presence for each week is calculated as the number of survey events in the week where the species was detected divided by the total number of survey events for that week. For example, if in week 12 there were 20 survey events and the Spotted Towhee was found in 5 of them, the probability of presence of the Spotted Towhee in week 12 is 0.25.

2. To properly present the pattern of presence across the year, the relative probability of presence is calculated. This is the probability of presence divided by the maximum probability of presence across all weeks. For example, imagine the probability of presence in week 20 for the Spotted Towhee is 0.05, and that the probability of presence at week 12 (0.25) is the maximum of any week of the year. The relative probability of presence on week 12 is 0.25/0.25 = 1; at week 20 it is 0.05/0.25 = 0.2.

3. The relative probability of presence calculated in the previous step undergoes a statistical conversion so that all possible values fall between 0 and 10, inclusive. This is the probability of presence score.

Breeding Season (■)

Yellow bars denote a very liberal estimate of the time-frame inside which the bird breeds across its entire range. If there are no yellow bars shown for a bird, it does not breed in your project area.

Survey Effort (□)

Vertical black lines superimposed on probability of presence bars indicate the number of surveys performed for that species in the 10km grid cell(s) your project area overlaps. The number of surveys is expressed as a range, for example, 33 to 64 surveys.

No Data (—)

A week is marked as having no data if there were no survey events for that week.

Survey Timeframe
Surveys from only the last 10 years are used in order to ensure delivery of currently relevant information. The exception to this is areas off the Atlantic coast, where bird returns are based on all years of available data, since data in these areas is currently much more sparse.

### SPECIES

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>JAN</th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
<th>OCT</th>
<th>NOV</th>
<th>DEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Ground-dove</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>BCC - BCR</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Le Conte's Sparrow</td>
<td></td>
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<tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red-headed Woodpecker</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BCC Rangewide (CON)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Additional information can be found using the following links:


### Migratory Birds FAQ

**Tell me more about conservation measures I can implement to avoid or minimize impacts to migratory birds.**

_Nationwide Conservation Measures_ describes measures that can help avoid and minimize impacts to all birds at any location year round. Implementation of these measures is particularly important when birds are most likely to occur in the project area. When birds may be breeding in the area, identifying the locations of any active nests and avoiding their destruction is a very helpful impact minimization measure. To see when birds are most likely to occur and be breeding in your project area, view the Probability of Presence Summary. _Additional measures_ and/or _permits_ may be advisable depending on the type of activity you are conducting and the type of infrastructure or bird species present on your project site.

**What does IPaC use to generate the migratory birds potentially occurring in my specified location?**

The Migratory Bird Resource List is comprised of USFWS _Birds of Conservation Concern (BCC)_ and other species that may warrant special attention in your project location.
The migratory bird list generated for your project is derived from data provided by the Avian Knowledge Network (AKN). The AKN data is based on a growing collection of survey, banding, and citizen science datasets and is queried and filtered to return a list of those birds reported as occurring in the 10km grid cell(s) which your project intersects, and that have been identified as warranting special attention because they are a BCC species in that area, an eagle (Eagle Act requirements may apply), or a species that has a particular vulnerability to offshore activities or development.

Again, the Migratory Bird Resource list includes only a subset of birds that may occur in your project area. It is not representative of all birds that may occur in your project area. To get a list of all birds potentially present in your project area, please visit the E-bird Explore Data Tool.

**What does IPaC use to generate the probability of presence graphs for the migratory birds potentially occurring in my specified location?**

The probability of presence graphs associated with your migratory bird list are based on data provided by the Avian Knowledge Network (AKN). This data is derived from a growing collection of survey, banding, and citizen science datasets. Probability of presence data is continuously being updated as new and better information becomes available. To learn more about how the probability of presence graphs are produced and how to interpret them, go the Probability of Presence Summary and then click on the "Tell me about these graphs" link.

**How do I know if a bird is breeding, wintering, migrating or present year-round in my project area?**

To see what part of a particular bird's range your project area falls within (i.e. breeding, wintering, migrating or year-round), you may refer to the following resources: The Cornell Lab of Ornithology All About Birds Bird Guide, or (if you are unsuccessful in locating the bird of interest there), the Cornell Lab of Ornithology Neotropical Birds guide. If a bird on your migratory bird species list has a breeding season associated with it, if that bird does occur in your project area, there may be nests present at some point within the timeframe specified. If "Breeds elsewhere" is indicated, then the bird likely does not breed in your project area.

**What are the levels of concern for migratory birds?**

Migratory birds delivered through IPaC fall into the following distinct categories of concern:

1. "BCC Rangewide" birds are Birds of Conservation Concern (BCC) that are of concern throughout their range anywhere within the USA (including Hawaii, the Pacific Islands, Puerto Rico, and the Virgin Islands);
2. "BCC - BCR" birds are BCCs that are of concern only in particular Bird Conservation Regions (BCRs) in the continental USA; and
3. "Non-BCC - Vulnerable" birds are not BCC species in your project area, but appear on your list either because of the Eagle Act requirements (for eagles) or (for non-eagles) potential susceptibilities in offshore areas from certain types of development or activities (e.g. offshore energy development or longline fishing).
Although it is important to try to avoid and minimize impacts to all birds, efforts should be made, in particular, to avoid and minimize impacts to the birds on this list, especially eagles and BCC species of rangewide concern. For more information on conservation measures you can implement to help avoid and minimize migratory bird impacts and requirements for eagles, please see the FAQs for these topics.

**Details about birds that are potentially affected by offshore projects**

For additional details about the relative occurrence and abundance of both individual bird species and groups of bird species within your project area off the Atlantic Coast, please visit the [Northeast Ocean Data Portal](https://www.nodc.noaa.gov). The Portal also offers data and information about other taxa besides birds that may be helpful to you in your project review. Alternately, you may download the bird model results files underlying the portal maps through the [NOAA NCCOS Integrative Statistical Modeling and Predictive Mapping of Marine Bird Distributions and Abundance on the Atlantic Outer Continental Shelf](https://www.nccos.noaa.gov/) project webpage.

Bird tracking data can also provide additional details about occurrence and habitat use throughout the year, including migration. Models relying on survey data may not include this information. For additional information on marine bird tracking data, see the [Diving Bird Study](https://www.nmfs.noaa.gov/pr/conservation/conservation-measures/marine-birds/diving-bird-study/) and the [nanotag studies](https://www.nmfs.noaa.gov/pr/conservation/conservation-measures/marine-birds/nanotag-studies/) or contact Caleb Spiegel or Pam Loring.

**What if I have eagles on my list?**

If your project has the potential to disturb or kill eagles, you may need to [obtain a permit](https://www.fws.gov/) to avoid violating the Eagle Act should such impacts occur.

**Proper Interpretation and Use of Your Migratory Bird Report**

The migratory bird list generated is not a list of all birds in your project area, only a subset of birds of priority concern. To learn more about how your list is generated, and see options for identifying what other birds may be in your project area, please see the FAQ “What does IPaC use to generate the migratory birds potentially occurring in my specified location”. Please be aware this report provides the “probability of presence” of birds within the 10 km grid cell(s) that overlap your project; not your exact project footprint. On the graphs provided, please also look carefully at the survey effort (indicated by the black vertical bar) and for the existence of the “no data” indicator (a red horizontal bar). A high survey effort is the key component. If the survey effort is high, then the probability of presence score can be viewed as more dependable. In contrast, a low survey effort bar or no data bar means a lack of data and, therefore, a lack of certainty about presence of the species. This list is not perfect; it is simply a starting point for identifying what birds of concern have the potential to be in your project area, when they might be there, and if they might be breeding (which means nests might be present). The list helps you know what to look for to confirm presence, and helps guide you in knowing when to implement conservation measures to avoid or minimize potential impacts from your project activities, should presence be confirmed. To learn more about conservation measures, visit the FAQ “Tell me about conservation measures I can implement to avoid or minimize impacts to migratory birds” at the bottom of your migratory bird trust resources page.
APPENDIX D

PROTECTED SPECIES LIST FOR KRAX WSR-88D
In Reply Refer To: November 26, 2018
Consultation Code: 04EN2000-2019-SLI-0163
Project Name: KRAX WSR-88D Lower Scan Angle

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The species list generated pursuant to the information you provided identifies threatened, endangered, proposed and candidate species, as well as proposed and final designated critical habitat, that may occur within the boundary of your proposed project and/or may be affected by your proposed project. The species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under section 7(c) of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 et seq.).

New information based on updated surveys, changes in the abundance and distribution of species, changed habitat conditions, or other factors could change this list. Please feel free to contact us if you need more current information or assistance regarding the potential impacts to federally proposed, listed, and candidate species and federally designated and proposed critical habitat. Please note that under 50 CFR 402.12(e) of the regulations implementing section 7 of the Act, the accuracy of this species list should be verified after 90 days. This verification can be completed formally or informally as desired. The Service recommends that verification be completed by visiting the ECOS-IPaC website at regular intervals during project planning and implementation for updates to species lists and information. An updated list may be requested through the ECOS-IPaC system by completing the same process used to receive the enclosed list.

Section 7 of the Act requires that all federal agencies (or their designated non-federal representative), in consultation with the Service, insure that any action federally authorized, funded, or carried out by such agencies is not likely to jeopardize the continued existence of any federally-listed endangered or threatened species. A biological assessment or evaluation may be prepared to fulfill that requirement and in determining whether additional consultation with the Service is necessary. In addition to the federally-protected species list, information on the species' life histories and habitats and information on completing a biological assessment or
evaluation and can be found on our web page at http://www.fws.gov/raleigh. Please check the web site often for updated information or changes.

If your project contains suitable habitat for any of the federally-listed species known to be present within the county where your project occurs, the proposed action has the potential to adversely affect those species. As such, we recommend that surveys be conducted to determine the species' presence or absence within the project area. The use of North Carolina Natural Heritage program data should not be substituted for actual field surveys.

If you determine that the proposed action may affect (i.e., likely to adversely affect or not likely to adversely affect) a federally-protected species, you should notify this office with your determination, the results of your surveys, survey methodologies, and an analysis of the effects of the action on listed species, including consideration of direct, indirect, and cumulative effects, before conducting any activities that might affect the species. If you determine that the proposed action will have no effect (i.e., no beneficial or adverse, direct or indirect effect) on federally listed species, then you are not required to contact our office for concurrence (unless an Environmental Impact Statement is prepared). However, you should maintain a complete record of the assessment, including steps leading to your determination of effect, the qualified personnel conducting the assessment, habitat conditions, site photographs, and any other related articles.

Please be aware that bald and golden eagles are protected under the Bald and Golden Eagle Protection Act (16 U.S.C. 668 et seq.), and projects affecting these species may require development of an eagle conservation plan (http://www.fws.gov/windenergy/eagle_guidance.html). Additionally, wind energy projects should follow the wind energy guidelines (http://www.fws.gov/windenergy/) for minimizing impacts to migratory birds and bats.

Guidance for minimizing impacts to migratory birds for projects including communications towers (e.g., cellular, digital television, radio, and emergency broadcast) can be found at: http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/towers.htm; http://www.towerkill.com; and http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/comtow.html.

Not all Threatened and Endangered Species that occur in North Carolina are subject to section 7 consultation with the U.S Fish and Wildlife Service. Atlantic and shortnose sturgeon, sea turtles, when in the water, and certain marine mammals are under purview of the National Marine Fisheries Service. If your project occurs in marine, estuarine, or coastal river systems you should also contact the National Marine Fisheries Service, http://www.nmfs.noaa.gov/

We appreciate your concern for threatened and endangered species. The Service encourages Federal agencies to include conservation of threatened and endangered species into their project planning to further the purposes of the Act. Please include the Consultation Tracking Number in the header of this letter with any request for consultation or correspondence about your project that you submit to our office. If you have any questions or comments, please contact John Ellis of this office at john_ellis@fws.gov.
Attachment(s):

- Official Species List
Official Species List

This list is provided pursuant to Section 7 of the Endangered Species Act, and fulfills the requirement for Federal agencies to "request of the Secretary of the Interior information whether any species which is listed or proposed to be listed may be present in the area of a proposed action".

This species list is provided by:

**Raleigh Ecological Services Field Office**
Post Office Box 33726
Raleigh, NC 27636-3726
(919) 856-4520
Project Summary

Consultation Code: 04EN2000-2019-SLI-0163


Project Name: KRAX WSR-88D Lower Scan Angle

Project Type: COMMUNICATIONS TOWER

Project Description: Lowering the minimum scan angle of the KRAX WSR-88D

Project Location:
Approximate location of the project can be viewed in Google Maps: https://www.google.com/maps/place/35.6654574726936N78.48995308679937W

Counties: Johnston, NC
**Endangered Species Act Species**

There is a total of 5 threatened, endangered, or candidate species on this species list.

Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species.

IPaC does not display listed species or critical habitats under the sole jurisdiction of NOAA Fisheries, as USFWS does not have the authority to speak on behalf of NOAA and the Department of Commerce.

See the "Critical habitats" section below for those critical habitats that lie wholly or partially within your project area under this office's jurisdiction. Please contact the designated FWS office if you have questions.

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1. [NOAA Fisheries](https://www.noaa.gov), also known as the National Marine Fisheries Service (NMFS), is an office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

**Birds**

<table>
<thead>
<tr>
<th>NAME</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red-cockaded Woodpecker <em>Picoides borealis</em></td>
<td>Endangered</td>
</tr>
<tr>
<td><em>No critical habitat has been designated for this species.</em></td>
<td></td>
</tr>
<tr>
<td>Species profile: <a href="https://ecos.fws.gov/ecp/species/7614">https://ecos.fws.gov/ecp/species/7614</a></td>
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</tr>
</tbody>
</table>

**Clams**

<table>
<thead>
<tr>
<th>NAME</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlantic Pigtoe <em>Fusconaia masoni</em></td>
<td>Proposed</td>
</tr>
<tr>
<td><em>No critical habitat has been designated for this species.</em></td>
<td></td>
</tr>
<tr>
<td>Species profile: <a href="https://ecos.fws.gov/ecp/species/5164">https://ecos.fws.gov/ecp/species/5164</a></td>
<td></td>
</tr>
<tr>
<td>Dwarf Wedgemussel <em>Alasmidonta heterodon</em></td>
<td>Threatened</td>
</tr>
<tr>
<td><em>No critical habitat has been designated for this species.</em></td>
<td></td>
</tr>
<tr>
<td>Species profile: <a href="https://ecos.fws.gov/ecp/species/784">https://ecos.fws.gov/ecp/species/784</a></td>
<td></td>
</tr>
<tr>
<td>Yellow Lance <em>Elliptio lanceolata</em></td>
<td>Threatened</td>
</tr>
<tr>
<td><em>No critical habitat has been designated for this species.</em></td>
<td></td>
</tr>
<tr>
<td>Species profile: <a href="https://ecos.fws.gov/ecp/species/4511">https://ecos.fws.gov/ecp/species/4511</a></td>
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</tr>
</tbody>
</table>
Flowering Plants

<table>
<thead>
<tr>
<th>NAME</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Michaux's Sumac <em>Rhus michauxii</em></td>
<td>Endangered</td>
</tr>
</tbody>
</table>

No critical habitat has been designated for this species.
Species profile: [https://ecos.fws.gov/ecp/species/5217](https://ecos.fws.gov/ecp/species/5217)

Critical habitats

THERE ARE NO CRITICAL HABITATS WITHIN YOUR PROJECT AREA UNDER THIS OFFICE'S JURISDICTION.
APPENDIX E

TECHNICAL MEMORANDUM / TRIP REPORT KGSP AND KCAE WSR-88DS
1. BACKGROUND AND NEED

The National Weather Service (NWS) proposes to reduce the minimum vertical scan angles used during normal operation of the WSR-88Ds serving the Greer and Columbia, South Carolina areas. Information on these two radars is shown in Tables 1A and 1B, respectively.

<table>
<thead>
<tr>
<th>Location</th>
<th>Greenville-Spartanburg International Airport, Greer, SC</th>
</tr>
</thead>
<tbody>
<tr>
<td>International Civil Aviation Organization designator</td>
<td>KGSP</td>
</tr>
<tr>
<td>Elevation, ground surface at tower base (mean sea level, MSL)</td>
<td>956 ft</td>
</tr>
<tr>
<td>Elevation, center of antenna (MSL)</td>
<td>1,070 ft</td>
</tr>
<tr>
<td>Tower Height (m)</td>
<td>30 m (98 ft)</td>
</tr>
<tr>
<td>Latitude (WGS84)</td>
<td>34° 52’ 59.9” N</td>
</tr>
<tr>
<td>Longitude (WGS84)</td>
<td>82° 13’ 11.4” W</td>
</tr>
<tr>
<td>Weather Forecast Office (WFO)</td>
<td>GSP International Airport, 1549 GSP Drive, Greer, SC 29651</td>
</tr>
<tr>
<td>Meteorologist-in-Charge (MIC)</td>
<td>Steve Wilkinson Email: <a href="mailto:stephen.wilkinson@noaa.gov">stephen.wilkinson@noaa.gov</a> Tel: (864)848-3859</td>
</tr>
<tr>
<td>Operating Frequency</td>
<td>2,780 megaHertz (MHz)</td>
</tr>
<tr>
<td>Spot Blanking or Sector Blanking used</td>
<td>No</td>
</tr>
</tbody>
</table>
TABLE 1B: Information On WSR-88D Serving The Columbia, SC, Area

<table>
<thead>
<tr>
<th>Location</th>
<th>Columbia Metropolitan Airport</th>
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</thead>
<tbody>
<tr>
<td>Location</td>
<td>KCAE</td>
</tr>
<tr>
<td>Location</td>
<td>231 ft</td>
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<td>Location</td>
<td>344 ft</td>
</tr>
<tr>
<td>Location</td>
<td>30 m (98 ft)</td>
</tr>
<tr>
<td>Location</td>
<td>33° 56' 55.4&quot; N</td>
</tr>
<tr>
<td>Location</td>
<td>81° 07' 05.8&quot; W</td>
</tr>
<tr>
<td>Location</td>
<td>2909 West Aviation Way</td>
</tr>
<tr>
<td>Location</td>
<td>West Columbia, SC 29170-2102</td>
</tr>
<tr>
<td>Location</td>
<td>Richard Okulski</td>
</tr>
<tr>
<td>Location</td>
<td>Email: <a href="mailto:richard.okulski@noaa.gov">richard.okulski@noaa.gov</a></td>
</tr>
<tr>
<td>Location</td>
<td>Tel: (803)822-8135</td>
</tr>
<tr>
<td>Location</td>
<td>2,890 megaHertz (MHz)</td>
</tr>
<tr>
<td>Location</td>
<td>No</td>
</tr>
</tbody>
</table>

The KGSP and KCAE WSR-88Ds were commissioned in March 1996 and June 1995, respectively. NWS currently operates the KGSP and KCAE WSR-88Ds at a minimum center-of-beam scan angle of +0.5 degree (deg). The WSR-88D main beam has a width of 1 deg to the half power points. Half of the beam (i.e., 0.5 deg) is below the axis, resulting in an essentially horizontal floor for existing radar coverage. As a result, the WSR-88Ds cannot provide radar coverage of the atmosphere below the elevation of the WSR-88D antenna. At considerable distance from the radar, earth curvature increases the height above the ground surface of the uncovered area. To increase the amount of radar coverage provided by the KGSP and KCAE WSR-88Ds, NWS proposes to operate the radar with an center-of-beam scan angle as low -0.2 deg, which would result in the lower half power point of the main beam at -0.7 deg.

2. INVESTIGATIONS PERFORMED

To analyze the benefits and potential impacts of lowering the scan angle of the KCAE WSR-88D, Sensor Environmental LLC and our subcontractor Alion Science and Technology Corporation performed the following tasks:

1. We visited the KGSP and KCAE WSR-88Ds with NWS staff from the Greer and Columbia, SC, Weather Forecast Offices (WFOs) to ascertain site conditions and activities in the vicinity (see Attachment A, Trip Report).
2. We obtained 360-degree calibrated panoramic photograph taken at 25-m level of each WSR-88D tower, which is about 28 ft lower than the KGSP and KCAE WSR-88D center of antenna heights.

3. For each WSR-88D, we prepared maps showing the extent of WSR-88D coverage at 2,000 ft above site level for each (center of beam) scan angle from the current minimum of +0.5 degree to -0.2 degree.

4. We identified areas of terrain and potentially sensitive activities in proximity to the KGSP and KCAE WSR-88Ds that would be directly illuminated by the main beam at each lower scan angle under consideration by NWS.

3. WSR-88D COVERAGE

The Project team used Alion Integrated Target Acquisition System (ITAS) terrain-based computer model with GIS-based interface to project the terrain-dependent radar coverage for the KGSP and KCAE WSR-88D at 2,000 ft above site level (ASL). The radar coverages shown in Attachment B are based on Digital Terrain Elevation Data (DTED) Level 2 topographic data and 4/3 earth radius to account for atmospheric refraction of the WSR-88D main beam. The lower half-power point of the unobstructed WSR-88D main beam is considered the minimum elevation of WSR-88D coverage. Tables 2A and 2B show coverage areas for KGSP and KCAE WSR-88Ds, respectively, for the range of minimum scan angles under consideration by NWS.

KGSP WSR-88D is located at Greenville-Spartanburg International Airport. As shown in Attachment B1, when operating at the current minimum center of beam minimum scan angle of +0.5 deg, the KGSP WSR-88D is subject to terrain blockage from southwest through north-northeast; therefore lowering the minimum scan angle would not improve coverage in those directions. Lowering the minimum scan angle to +0.2 deg would improve radar coverage to the northeast, east, southeast, south, and southwest. Table 2A shows radar coverage area at an elevation of 2,000 ft above site level (ASL) for minimum scan angles from +0.5 to -0.2 deg. Lowering the minimum scan angle to +0.2 deg would increase coverage area by 69.7%. Lowering the minimum scan angle below +0.2 deg would not increase coverage area.

| TABLE 2A: KGSP WSR-88D Radar Coverage Areas For Minimum Scan Angles Between +0.5 deg And -0.2 deg |
|---|---|---|---|---|
| Coverage Altitude Above Site Level (ft) | Minimum Center of Beam Scan Angle (deg) | Lower Half-power Point (deg) | Area in Lambert Projection (sq mi) | Change from Existing Minimum Scan Angle |
| 2,000 | +0.5 | 0.0 | 8,359 | n/a |
| 2,000 | +0.4 | -0.1 | 10,575 | +26.5% |
| 2,000 | +0.3 | -0.2 | 12,959 | +50.7% |
| 2,000 | +0.2, +0.1, 0.0, -0.1, -0.2 | -0.3 to -0.7 | 14,185 | +69.7% |
KCAE WSR-88D is located at Columbia Metropolitan Airport. As shown in Attachment B2, when operating at the current minimum center of beam minimum scan angle of +0.5 deg, the KCAE WSR-88D is subject to terrain blockage from south-southeast through north-northwest; therefore lowering the minimum scan angle would not improve coverage in those directions. Lowering the minimum scan angle to +0.4 deg would improve radar coverage to the north, northeast, east, and southeast. Further lowering the minimum scan angle to +0.3 deg or +0.2 deg would increase coverage area to the east and east-southeast. Table 2B shows radar coverage area at an elevation of 2,000 ft ASL for minimum scan angles from +0.5 to -0.2 deg. Lowering the minimum scan angle to +0.2 deg would increase coverage area by 15.2%. Lowering the minimum scan angle below +0.2 deg would not increase coverage area.

TABLE 2B: KCAE WSR-88D Radar Coverage Areas For Minimum Scan Angles Between +0.5 deg And -0.2 deg

<table>
<thead>
<tr>
<th>Coverage Altitude Above Site Level (ft)</th>
<th>Minimum Center of Beam Scan Angle (deg)</th>
<th>Lower Half-power Point (deg)</th>
<th>Area in Lambert Projection (sq mi)</th>
<th>Change from Existing Minimum Scan Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,000</td>
<td>+0.5</td>
<td>0.0</td>
<td>8,915</td>
<td>n/a</td>
</tr>
<tr>
<td>2,000</td>
<td>+0.4</td>
<td>-0.1</td>
<td>9,794</td>
<td>+9.9%</td>
</tr>
<tr>
<td>2,000</td>
<td>+0.3</td>
<td>-0.2</td>
<td>10,200</td>
<td>+14.4%</td>
</tr>
<tr>
<td>2,000</td>
<td>+0.2, +0.1, 0.0, -0.1, -0.2</td>
<td>-0.3 to -0.7</td>
<td>10,271</td>
<td>+15.2%</td>
</tr>
</tbody>
</table>

Charlotte, NC is located at elevation 740 ft MSL about 77 miles east-northeast of the KGSP WSR-88D at azimuth 67 (0 = true north, 90 = east, 180 = south, 70 = west) and 86 miles north of the KCAE WSR-88D at azimuth 04. Table 3 shows the existing height of the center of the WSR-88D beam and the radar coverage floor over Charlotte, NC for the KGSP and KCAE WSR-88Ds. Table 3 also shows the center of beam height and the radar coverage floor for minimum scan angles of +0.4 to +0.2 deg for each radar. For the KGSP WSR-88D, the altitude of radar coverage over Charlotte would be reduced with each lower scan angle down to +0.2 deg. At a scan angle of +0.2 deg, the center of the KGSP WSR-88D beam would have an altitude of 4,700 ft above ground level (AGL) over Charlotte and the radar coverage floor would be at 1,200 ft AGL.

Terrain blockage between the KCAE WSR-88D and Charlotte would prevent any reduction in beam height or coverage floor altitude for minimum scan angles lower than +0.4 deg, although the lower scan angles would improve radar coverage in other directions. At +0.4 deg, the center of the KCAE WSR-88D main beam would have an altitude of 6,500 ft AGL over Charlotte and the radar coverage floor would be at 2,500 ft AGL.
### TABLE 3: Altitude over Charlotte, NC, of KGSP and KCAE WSR-88D Radar Coverage

<table>
<thead>
<tr>
<th>WSR-88D</th>
<th>Minimum Scan Angle (deg)</th>
<th>Center of Beam Altitude Over Charlotte, NC (ft AGL)</th>
<th>Radar Coverage Floor Altitude over Charlotte, NC (ft AGL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KGSP</td>
<td>+0.5</td>
<td>7,000</td>
<td>3,300</td>
</tr>
<tr>
<td></td>
<td>+0.4</td>
<td>6,100</td>
<td>2,500</td>
</tr>
<tr>
<td></td>
<td>+0.3</td>
<td>5,400</td>
<td>1,900</td>
</tr>
<tr>
<td></td>
<td>+0.2</td>
<td>4,700</td>
<td>1,200</td>
</tr>
<tr>
<td>KCAE</td>
<td>+0.5</td>
<td>7,300</td>
<td>3,300</td>
</tr>
<tr>
<td></td>
<td>+0.4, +0.3, +0.2</td>
<td>6,500</td>
<td>2,500</td>
</tr>
</tbody>
</table>

4. HUMAN EXPOSURE AND POTENTIALLY RADIOFREQUENCY (RF)-SENSITIVE ACTIVITIES

Exposure to the WSR-88D main beam could represent a hazard to persons and certain sensitive activities. Table 4 presents the safe setback distances from the WSR-88D for human exposure, implantable medical devices, fuel handling, and EEDs (Sensor Environmental LLC, 2011). Safety standards for implantable medical devices, fuel handling, and EEDs are based on instantaneous exposure.

Safety Standards for human exposure are based on time-averaged exposure; therefore exposure during both rotating antenna and stationary-antenna operation are considered.

### TABLE 4: Safe Setback Distances For Human Exposure And Potentially Sensitive Activities Directly Illuminated By The WSR-88D Main Beam

<table>
<thead>
<tr>
<th>Activity</th>
<th>Safe Setback Distance (ft)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Exposure</td>
<td>Rotating Antenna</td>
<td>20 American National Standards Institute/Institute of Electrical and Electronic Engineers (ANSI/IEEE) and International Council for Non-Ionizing Radiation Protection (ICNIRP)</td>
</tr>
<tr>
<td></td>
<td>Stationary Antenna</td>
<td>1,700</td>
</tr>
<tr>
<td>Implantable Medical devices</td>
<td></td>
<td>2,060 ANSI/Association for the Advancement of Medical Instrumentation (AAMI)</td>
</tr>
<tr>
<td>EEDs</td>
<td></td>
<td>6,030 U.S. Air Force</td>
</tr>
<tr>
<td>Fuel Handling</td>
<td></td>
<td>537 Naval Sea Systems Command</td>
</tr>
</tbody>
</table>

5. DIRECTLY ILLUMINATED TERRAIN AND STRUCTURES

Exposure to radiofrequency (RF) radiation can potentially be harmful to humans and RF-sensitive activities. The safe setback distances from the WSR-88D for human exposure, implantable medical
devices, fuel handling, and electro-explosive devices (EEDs), are given in section 4 of this memorandum. The greatest safe setback distance for human exposure or any of these activities is 6,030 ft for exposure of EEDs, which include blasting caps, some types of ordnance, and equipment used in and aviation systems (e.g. ejection seats and separation systems for air-launched missiles).

5.1 KGSP WSR-88D

Attachment C1 shows terrain within 3 miles of the KGSP WSR-88D that would be directly illuminated by the WSR-88D main beam at each lower center of beam scan angle under consideration. There would be no directly illuminated terrain within 3 miles at scan angles of +0.5 deg, 0+0.4 deg, or +0.3 deg. For a minimum scan angle of +0.2 deg, the nearest directly illuminated terrain is a hilltop 2.7 miles (14,300 ft) north-northwest of the WSR-88D, which is farther from the WSR-88D than the applicable setback distances.

The Federal Aviation Administration Airport Surveillance Radar, Model 8 (ASR-8) serving Greenville-Spartanburg International Airport is located 4,200 ft east-northeast of the KGSP WSR-88D at azimuth 60. The ASR is obscured by trees and does not appear in the panoramic photograph 2A in Attachment A because the photograph was taken about 31 ft below the WSR-88D center of antenna. Both the ASR-8 and the WSR-88D antennas are elevated above the tops of nearby trees, thus there is unobstructed line of sight between the two antennas. The primary and secondary operating frequencies of the ASR-8 are 2,890 MHz and 2,845 MHz, respectively (Atkinson, 2018). The WSR-88D operating frequency is separated from the ASR-8 primary frequency by 110 MHz and from the secondary by 65 MHz.

The center of the primary ASR-8 antenna is at elevation 1,035 ft MSL (Atkinson, 2018), or about 21 ft lower than the lower edge of the WSR-88D antenna which is at 1,056 ft MSL. In addition, a secondary antenna is mounted on top of the ASR-8 primary and rises about 20 ft above the center of the primary antenna. Thus, the top of the ASR-8 secondary antenna is at almost identical elevation as the lower edge of the WSR-88D antenna. There have been reports of mutual electromagnetic interference and NWS plans to install an RF filter on the WSR-88D to prevent future EMI (EMI) (Schultz, 2018). The planned NWS filter would attenuate signals that are separated by 25 to 100 MHz from the WSR-88D frequency by a minimum of 20 decibels (dB) and signals separated by over 100 decibels (dB) by a minimum of 20 dB (Ciardi, 2018). FAA installed filters on the ASR-8 to attenuate the WSR-88D signal received by the ASR-8 (Atkinson, 2018). Although the detailed specifications of the FAA RF filters are not known, it is likely they provide similar attenuation as the NWS filter.

Lowering the WSR-88D minimum scan angle would require adding two additional antenna rotations below +0.5 deg to the 12.4-minute volume scan pattern. During each of the added rotations, the WSR-88D antenna would point at the ASR-8 as it sweeps past azimuth 60. Currently this occurs twice during the volume scan pattern and that would increase to four times per each 12.4 minute volume scan pattern. The next scan level above +0.5 deg is +1.5 deg, during which the lower half-power point of the WSR-88D main beam would be about 70 ft above the ASR-8 antenna and only the first sidelobe would impinge on the ASR-8. Per the WSR-88D specification, the power level of the first sidelobe is 25 decibels.
Scans at +1.5 deg or above are unlikely to cause EMI with the ASR-8. The WSR-88D antenna gain and operating frequency would not change from the existing condition and the RF filters installed by the FAA and planned by NWS should be effective at preventing mutual EMI during the added lower elevation scans.

The only elevated structure rising above the horizon within 6,000 ft of the WSR-88D is the FAA ASR-8. The ASR-8 is outside all setbacks distances, except for EEDs, which would not be in use on the ASR tower. Other than the potential for EMI with the FAA ASR-8 (discussed above), lowering the KGSP WSR-88D minimum scan angle would not result in hazards to persons or RF-sensitive activities at structures in the vicinity.

### 5.2 KCAE WSR-88D

Attachment C2 shows terrain within 3 miles of the KCAE WSR-88D that would be directly illuminated by the WSR-88D main beam at each lower center of beam scan angle under consideration. For the current minimum scan angle of +0.5 deg, the nearest directly illuminated terrain is 2.4 miles (12,800 ft) to the northwest. A minimum scan angle of +0.4 deg would directly illuminate ground 1.5 miles (7,900 ft) northwest of the WSR-88D. A minimum scan angle of +0.3 or +0.2 deg would directly illuminate ground 1.3 miles (6,900 ft) to the northwest, and also additional terrain to the west and north located at farther distances. All of the directly illuminated terrain is farther from the WSR-88D than the applicable setback distances listed and no hazards to persons or potentially sensitive activities would result from lowering the minimum scan angle down to +0.2 deg.

Photographs 4A through 4D in the Trip Report (Attachment A) show structures and terrain in all directions around the KCAE WSR-88D. Two structures rise above the horizon: a water tank located 1,700 ft to the north-northwest at azimuth 340 and the Federal Aviation Administration Airport Surveillance Radar, Model 11 (ASR-11) located 3,600 ft to the west at azimuth 279 (see Photograph 4D in Attachment A). The water tower is outside all setback distances for all activities except for human exposure to the main beam in stationary antenna operation and active implantable medical devices and EEDs. Since the water tower is not an occupied structure, the potential for human exposure is very low. Nonetheless, to avoid RF levels exceeding safety levels, the WSR-88D should not be directed at the water tower (azimuth 340) during infrequent stationary antenna operation. The ASR-11 rises to elevation 396.5 ft MSL (LPA Group Aviation Consultants, 2012) and is directly illuminated by the WSR-88D main beam when scanning at +0.5 deg. However, the ASR-11 is outside all setback distances except for EEDs. It is very unlikely that EEDs would be used at upper portions of the ASR-11. RF exposure levels at the ASR-11 do not currently represent a hazard to persons and activities at the ASR-11 and lowering the WSR-88D minimum scan angle would not result in RF exposure hazards.

The Airport Traffic Control Tower (ATCT) serving Columbia Metropolitan Airport is located 1,600 ft south (azimuth 188) of the WSR-88D. The antennas on the roof of the ATCT cab rise to elevation 354 ft MSL (LPA Group Aviation Consultants, 2012). The roof of the ATCT cab is an estimated 30 ft lower at 324 ft MSL, or 6 ft below the lower half-power point of the WSR-88D main beam (330 ft MSL) operating at the...
current minimum scan angle of +0.5 deg. Lowering the WSR-88D minimum scan angle to +0.4 would reduce the elevation of the lower half-power point of the main beam by 3 ft to 327 ft MSL at the ATCT, which is still above the ATCT cab. A lower scan angle of +0.3 deg would result in the main beam impinging on the ATCT cab, which is an occupied structure. The ATCT is closer to the WSR-88D than the safe setback distances for stationary antenna operation, active implantable medical devices, and EEDs and direct illumination by the WSR-88D main beam, which would occur at scan angles of +0.3 deg or less. A minimum scan angle of +0.3 or lower could result in RF exposure at the ATCT exceeding safety levels. To avoid potential RF hazards to persons at the ATCT, the WSR-88D main beam should spot-blanked in the direction of the ATCT (azimuth 188) if the minimum scan angle is lowered to +0.3 deg or lower.

6. ASTRONOMICAL OBSERVATORIES

The WSR-88D can potentially cause harmful electromagnetic interference (EMI) with charge-couple devices (CCDs) which electronically record data collected by astronomical telescopes (NEXRAD JSPO), 1993). Due to the sensitivity of astronomical equipment which is designed to detect very faint signals from space, this equipment is vulnerable to EMI. The potential for harmful EMI would arise if the WSR-88D main beam would directly illuminate an astronomical observatory during low angle scanning.

Tables 5A and 5B list astronomical observatories located within 150 miles of the KGSP and KCAE WSR-88Ds, respectively. The two tables also provide distances and azimuths to the observatories from the WSR-88D based on true north, observatory elevation, and whether or not the observatory would be directly illuminated by the WSR-88D main beam at scan angles of +0.5 deg or lower. Direct illumination would not occur if terrain blockage is present between the observatory and WSR-88D or if the elevation of the lower half-power point of the main beam at the observatory location would be higher than the observatory elevation.

### TABLE 5A: Astronomical Observatories within 150 Miles of the KGSP WSR-88D

<table>
<thead>
<tr>
<th>Observatory</th>
<th>Location</th>
<th>Distance from WSR-88D / azimuth</th>
<th>Observatory elevation (ft MSL)</th>
<th>Directly illuminated by KGSP WSR-88D main beam at 0.5 deg or below?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charles, E. Daniel</td>
<td>Greenville, SC</td>
<td>5.8 mi / 240 deg</td>
<td>1,220</td>
<td>Yes</td>
</tr>
<tr>
<td>Dark Sky</td>
<td>Boone, NC</td>
<td>105 mi / 25 deg</td>
<td>3,090</td>
<td>No</td>
</tr>
<tr>
<td>Hard Labor Creek</td>
<td>Rutledge, GA</td>
<td>115 mi / 225 deg</td>
<td>760</td>
<td>No</td>
</tr>
<tr>
<td>Lucille Miller</td>
<td>Maiden, NC</td>
<td>74 mi / 50 deg</td>
<td>910</td>
<td>No</td>
</tr>
<tr>
<td>Melton Memorial, University of South Carolina</td>
<td>Columbia, SC</td>
<td>91 mi / 1245 deg</td>
<td>350</td>
<td>No</td>
</tr>
<tr>
<td>North Georgia College</td>
<td>Dahlonega, GA</td>
<td>107 mi / 255 deg</td>
<td>1,490</td>
<td>No</td>
</tr>
</tbody>
</table>
TABLE 5A: Astronomical Observatories within 150 Miles of the KGSP WSR-88D

<table>
<thead>
<tr>
<th>Observatory</th>
<th>Location</th>
<th>Distance from WSR-88D / azimuth</th>
<th>Observatory elevation (ft MSL)</th>
<th>Directly illuminated by KGSP WSR-88D main beam at 0.5 deg or below?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pisgah</td>
<td>Balsam Grove, NC</td>
<td>40 mi / 305 deg</td>
<td>3,040</td>
<td>No</td>
</tr>
<tr>
<td>University of Georgia</td>
<td>Athens, GA</td>
<td>92 mi, 225 deg</td>
<td>760</td>
<td>No</td>
</tr>
</tbody>
</table>

The KGSP WSR-88D has direct line of sight to the Charles Daniel Observatory, located about 5.8 miles northwest of the WSR-88D in Greenville, SC. The observatory telescopes are about 150 ft higher in elevation than the WSR-88D antenna and there is no higher terrain located between the observatory and WSR-88D. At the current minimum scan angle of +0.5 deg, the KGSP WSR-88D main beam directly illuminates the observatory, as would be the case for scan angles of +0.4 deg or lower.

TABLE 5B: ASTRONOMICAL OBSERVATORIES WITHIN 150 MILES OF THE KCAE WSR-88D

<table>
<thead>
<tr>
<th>Observatory</th>
<th>Location</th>
<th>Distance from WSR-88D / azimuth</th>
<th>Observatory elevation (ft MSL)</th>
<th>Directly illuminated by KCAE WSR-88D at 0.5 deg or below?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charles, E. Daniel</td>
<td>Greenville, SC</td>
<td>91 mi / 310 deg</td>
<td>1,220</td>
<td>No</td>
</tr>
<tr>
<td>Francis Marion University</td>
<td>Florence, SC</td>
<td>86 mi / 85 deg</td>
<td>120</td>
<td>No</td>
</tr>
<tr>
<td>Hard Labor Creek</td>
<td>Rutledge, GA</td>
<td>143 mi / 265 deg</td>
<td>760</td>
<td>No</td>
</tr>
<tr>
<td>Lucille Miller</td>
<td>Maiden, NC</td>
<td>113 mi / 357 deg</td>
<td>910</td>
<td>No</td>
</tr>
<tr>
<td>Melton Memorial, University of South Carolina</td>
<td>Columbia, SC</td>
<td>6.5 mi / 60 deg</td>
<td>350</td>
<td>No at 0.5 deg Yes at 0.4 deg or lower</td>
</tr>
<tr>
<td>Pisgah</td>
<td>Balsam Grove, NC</td>
<td>132 mi / 315 deg</td>
<td>3,040</td>
<td>No</td>
</tr>
<tr>
<td>University of Georgia</td>
<td>Athens, GA</td>
<td>130 mi, 270 deg</td>
<td>710</td>
<td>No</td>
</tr>
</tbody>
</table>

At the current minimum scan angle of +0.5 deg, the KCAE WSR-88D main beam does not impinge on the Melton Memorial Observatory at the University of South Carolina. However, at scan angles of +0.4 deg or lower, the Melton Memorial Observatory would be directly illuminated by the WSR-88D main beam.
7. RECOMMENDATION

Lowering the KGSP minimum scan angle to +0.2 deg would increase coverage area at 2,000 ft ASL by 69.7% and reduce the height of radar coverage floor over Charlotte, NC, area from 3,300 ft AGL to 1,200 ft AGL. No increase in hazards to RF-sensitive activities would result. The potential for mutual EMI with the FAA ASR at GSP can be mitigated through continued use of RF filters. Lowering the minimum scan angle below +0.2 deg would result in no increase in radar coverage or additional lowering of the radar coverage floor over Charlotte, NC, area. Therefore, lowering the KGSP minimum scan angle to +0.2 deg is recommended.

Lowering the KCAE WSR-88D minimum scan angle to +0.4 deg would increase coverage area at 2,000 ft ASL by 9.9% and reduce the height of radar coverage floor over Charlotte, NC, area from 3,300 ft AGL to 2,500 ft AGL. Reducing the KCAE WSR-88D minimum scan angle to +0.3 deg or lower would not result in additional lowering of the coverage floor over the Charlotte, NC, area. The ATCT at Columbia Metropolitan Airport and a nearby water tank are located 1,600 ft and 1,700 ft, respectively from the KCAE WSR-88D and within safe setback distances for the WSR-88D when operating with a stationary antenna. The WSR-88D main beam scanning at the current minimum angle of +0.5 deg impinges on the nearby water tank, but not the ATCT cab. The main beam scanning at +0.4 deg would also impinge on the water tank but not the ATCT cab. The WSR-88D main beam scanning at +0.4 deg or lower would also impinge the Melton Memorial observatory at the University of South Carolina, about 6.5 miles east-northeast of the WSR-88D. NWS consultation with the observatory staff is recommended to determine the risk of electromagnetic interference with observatory operations. With the following measures in place, lowering the KCAE minimum scan angle to +0.4 deg is recommended.

1) The WSR-88D main beam should not be directed at the water tank at azimuth 340 during stationary antenna operation.
2) NWS should consult with Melton Memorial Observatory staff to determine the potential for electromagnetic interference with observatory operations if the WSR-88D minimum scan angle is lowered. If significant interference is expected, operational changes, such as spot blanking in the direction of the observatory (azimuth 60 deg, should be considered.

8. MEMORANDUM AUTHORS

This memorandum was prepared by Sensor Environmental LLC under contract to Centuria Corporation, which is a support contractor to the National Weather Radar Operations Center. Mr. James Manitakos, CEO, served as Sensor’s Project Manager. Alion Science and Technology Corporation prepared radar coverage maps and calculated coverage areas under subcontract to Sensor. Mr. Andre Tarpinian, Radio Frequency Engineer, served as Alion’s Project Manager.
9. REFERENCES


Atkinson, Jennifer, NEXRAD FAA Liaison, AJW-144. Email to James Manitakos, Sensor Environmental LLC (November 2, 2018).

Ciardi, Ed, Program Manager, EVP Weather Systems, Centuria Corporation. Email to James Manitakos, Sensor Environmental LLC (November 6, 2018).


Jessica Shultz, NWS Radar Focal Point. Email to James Manitakos, Sensor Environmental (September 13, 2018).


NEXRAD JSPO. *Final Supplemental Environmental Assessment (SEA) of the Effects of Electromagnetic Radiation from the WSR-88D Radar* (April 1993).

Schultz, Jessica, NWS Radar Focal Point, email to James Manitakos, Sensor Environmental LLC. September 13, 2018.


ATTACHMENT A

TRIP REPORT, KGSP AND KCAE WSR-88Ds
TRIP REPORT

Traveler: James Manitakos, Sensor Environmental LLC

Destination: Greer and Columbia, SC Weather Forecast Offices (WFO) and KGSP and KCAE Weather Surveillance Radars, Model 1988 Doppler (WSR-88Ds)

Dates: October 14 - 16, 2018

Purpose: Field Inspection of KGSP and KCAE WSR-88Ds serving Greer and Columbia, SC areas, respectively

Summary: October 14, 2018: Mr. Manitakos flew from San Jose, CA to Atlanta, GA and drove to Greer, SC.

October 15, 2018: In the morning, Mr. Manitakos met at the KGSP WFO with Meteorologist-in-Charge Steve Wilkinson and Electronics Supervisor Lee Huber. The group reviewed preliminary KGSP WSR-88D coverage charts for lower scan angles ranging from +0.4 to -0.2 deg. The charts showed coverage area improved with each lower scan angle down to -0.2 deg, however terrain blockage from mountains to the northwest through northeast would mostly prevent improved radar coverage in those directions. Mr. Manitakos then proceeded to take a photograph of the KGSP WSR-88D (Photograph 1) and panoramic photographs (Photograph 2) from the 25-m level of the KGSP WSR-88D, which is 31 ft below the center of the WSR-88D antenna.

In the afternoon, Mr. Manitakos drove to Columbia, SC and met at the KCAE WFO with Meteorologist-in-Charge Richard Okulski and Electronics Supervisor Tony Stalcup. The group reviewed preliminary KGSP WSR-88D coverage charts for lower scan angles ranging from +0.4 to -0.2 deg. The charts showed minimal improvement in coverage area, primarily to the southeast. Mr. Manitakos then proceeded to take a photograph of the KCAE WSR-88D (Photograph 3) and panoramic photographs (Photograph 4) from the 25-m level of the KCAE WSR-88D, which is 31 ft below the center of the WSR-88D antenna.

October 16, 2018: Mr. Manitakos drove to Raleigh, NC.

Weather: Partly cloudy, 65°F at KGSP and 83°F at KCAE.
Photograph 1: KGSP WSR-88D serving Greenville-Spartanburg, area viewed from the northwest
Photograph 2A: Panoramic photograph from KGSP WSR-88D tower [—— 0 deg]

Photograph 2B: Panoramic photograph from KGSP WSR-88D tower [—— 0 deg]
**Photograph 2C:** Panoramic photograph from KGSP WSR-88D tower [0 deg]

**Photograph 2D:** Panoramic photograph from KGSP WSR-88D tower [0 deg]
Photograph 3: KCAE WSR-88D serving Columbia, SC, area viewed from the north
Photograph 4A: Panoramic photograph from KCAE WSR-88D tower [0 deg]

Photograph 4B: Panoramic photograph from KCAE WSR-88D tower [0 deg]
Photograph 4C: Panoramic photograph KCAE WSR-88D tower [0 deg]

Photograph 4D: Panoramic photograph from KCAE WSR-88D tower [0 deg]
ATTACHMENT B1

KGSP WSR-88D COVERAGE MAP

MINIMUM SCAN ANGLES +0.5 deg to -0.2 deg
ATTACHMENT B2

KCAE WSR-88D COVERAGE MAP

MINIMUM SCAN ANGLES +0.5 deg to -0.2 deg
ATTACHMENT C1

KGSP WSR-88D NEARBY DIRECTLY ILLUMINATED TERRAIN

AT SCAN ANGLE OF +0.2 deg
ATTACHMENT C2

KCAE WSR-88D NEARBY DIRECTLY ILLUMINATED TERRAIN

AT SCAN ANGLES OF +0.5 to +0.2 deg
Environmental Assessment - Lowering the Minimum Scan Angles of the KGSP, KCAE, and KRAX WSR-88Ds

APPENDIX F

TECHNICAL MEMORANDUM / TRIP REPORT KRAX WSR-88D
TECHNICAL MEMORANDUM

TO: Edward Ciardi, Program Manager, EVP Weather Systems, Centuria Corporation
FROM: James Manitakos, CEO, Sensor Environmental LLC
CC: Jessica Schultz, Radar Focal Point, National Weather Service
Andre Tarpinian, Senior RF Engineer, Alion Science and Technology Corp.

SUBJECT: Analysis of Lower Scan Angles For Weather Surveillance Radar, Model 1988 Doppler (WSR-88D) Serving the Raleigh, North Carolina, Area
DATE: November 16, 2018

1. BACKGROUND AND NEED

The National Weather Service (NWS) proposes to reduce the minimum vertical scan angle used during normal operation of the WSR-88D serving the Raleigh, North Carolina area. The WSR-88D’s designator is KRAX and the radar is located at an agricultural research facility in Clayton, Johnston County, operated by North Carolina State University (NCSU). The KRAX WSR-88D is 11.1 miles southeast of downtown Raleigh and 22.4 miles southeast of Raleigh-Durham International Airport (see Table 1).

<table>
<thead>
<tr>
<th>TABLE 1A: INFORMATION ON WSR-88D SERVING THE RALEIGH, NC, AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
</tr>
<tr>
<td><strong>International Civil Aviation Organization designator</strong></td>
</tr>
<tr>
<td><strong>Elevation, ground surface at tower base (mean sea level, MSL)</strong></td>
</tr>
<tr>
<td><strong>Elevation, center of antenna (MSL)</strong></td>
</tr>
<tr>
<td><strong>Tower Height (m)</strong></td>
</tr>
<tr>
<td><strong>Latitude (WGS84)</strong></td>
</tr>
<tr>
<td><strong>Longitude (WGS84)</strong></td>
</tr>
<tr>
<td><strong>Weather Forecast Office (WFO)</strong></td>
</tr>
<tr>
<td><strong>Meteorologist-in-Charge (MIC)</strong></td>
</tr>
<tr>
<td><strong>Operating Frequency</strong></td>
</tr>
<tr>
<td><strong>Spot Blanking or Sector Blanking used</strong></td>
</tr>
</tbody>
</table>
NWS currently operates the KRAX WSR-88D at a minimum center-of-beam scan angle of +0.5 degree (deg). The WSR-88D main beam has a width of 1 deg to the half power points. Half of the beam (i.e., 0.5 deg) is below the axis, resulting in an essentially horizontal floor for existing radar coverage. As a result, the WSR-88Ds cannot provide radar coverage of the atmosphere below the elevation of the WSR-88D antenna. At considerable distance from the radar, earth curvature increases the height above the ground surface of the uncovered area. To increase the amount of radar coverage provided by the KRAX WSR-88D, NWS proposes to operate the radar with an center-of-beam scan angle as low -0.2 deg, which would result in the lower half power point of the main beam at -0.7 deg.

2. INVESTIGATIONS PERFORMED

To analyze the benefits and potential impacts of lowering the scan angle of the KRAX WSR-88D, Sensor Environmental LLC and subcontractor Alion Science and Technology Corporation performed the following tasks:

1. We visited the KRAX WSR-88D with NWS staff from the Raleigh, NC, Weather Forecast Office (WFO) to ascertain site conditions and activities in the vicinity (see Attachment A, Trip Report).
2. We obtained 360-degree calibrated panoramic photograph taken at 25-m level of the KRAX WSR-88D tower, which is about 28 ft lower than the WSR-88D center of antenna height.
3. We prepared maps showing the extent of WSR-88D coverage at 2,000 ft above site level for each (center of beam) scan angle from the current minimum of +0.5 degree to -0.2 degree.
4. We identified areas of terrain and potentially sensitive activities in proximity to the KRAX WSR-88D that would be directly illuminated by the main beam at each lower scan angle under consideration by NWS.

3. WSR-88D COVERAGE

The Project team used Alion Integrated Target Acquisition System (ITAS) terrain-based computer model with GIS-based interface to project the terrain-dependent radar coverage for the KRAX WSR-88D at 2,000 ft above site level (ASL). The radar coverages shown in Attachment B are based on Digital Terrain Elevation Data (DTED) Level 2 topographic data and 4/3 earth radius to account for atmospheric refraction of the WSR-88D main beam. The lower half-power point of the unobstructed WSR-88D main beam is considered the minimum elevation of WSR-88D coverage. Table 2 shows coverage areas for KRAX WSR-88D, for the range of minimum scan angles under consideration by NWS.

As shown in Attachment B, when operating at the current minimum center of beam minimum scan angle of +0.5 deg, the KRAX WSR-88D is not subject to terrain blockage. A minimum scan angle of +0.4 deg would improve radar coverage in all directions except to the west and northwest where terrain blockage would occur (azimuths 272 to 312, where 0 = true north, 90 = east, 180 = south, 270 = west). A minimum scan angle of +0.3 would further improve coverage in all directions, except to the west and northwest (azimuths 272 to 332). A minimum scan angle of +0.2 would further increase coverage to the
northeast through south (azimuths 65 through 193). No additional improvement in coverage area would be achieved by lowering the KRAX WSR-88D minimum scan angle below +0.2 deg.

Table 2 shows the area of radar coverage at 2,000 ft above site level (ASL), for each minimum scan angle under consideration. Compare to the current minimum scan angle of +0.5 deg, lowering the WSR-88D minimum scan angle to +0.4, +0.3, or +0.2 deg would increase coverage area by 34.1, 63.5%, and 74.5%, respectively. Lowering the minimum scan angle below +0.2 deg would not yield any additional increase in coverage area.

<table>
<thead>
<tr>
<th>Coverage Altitude Above Site Level (ft)</th>
<th>Minimum Center of Beam Scan Angle (deg)</th>
<th>Lower Half-power Point (deg)</th>
<th>Area in Lambert Projection (sq mi)</th>
<th>Change from Existing Minimum Scan Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,000</td>
<td>+0.5</td>
<td>0.0</td>
<td>10,548</td>
<td>n/a</td>
</tr>
<tr>
<td>2,000</td>
<td>+0.4</td>
<td>-0.1</td>
<td>14,143</td>
<td>+34.1%</td>
</tr>
<tr>
<td>2,000</td>
<td>+0.3</td>
<td>-0.2</td>
<td>17,250</td>
<td>+63.5%</td>
</tr>
<tr>
<td>2,000</td>
<td>+0.2, +0.1, 0.0, -0.1, -0.2</td>
<td>-0.3 to -0.7</td>
<td>18,410</td>
<td>+74.5%</td>
</tr>
</tbody>
</table>

Charlotte, NC is located at azimuth 258 about 140 miles west-southwest of the KRAX WSR-88D. Downtown Charlotte is at elevation 740 ft MSL. Table 3 shows the existing height of the center of the KRAX WSR-88D beam and the radar coverage floor over Charlotte, NC. The altitude of radar coverage over Charlotte would be reduced with each lower scan angle down to +0.3 deg. At +0.3 deg, the lower WSR-88D main beam would be partially blocked in the direction of Charlotte, which would prevent any reduction in beam height or coverage floor altitude for minimum scan angles lower than +0.3 deg, although radar coverage would improve in other directions.

<table>
<thead>
<tr>
<th>Minimum Scan Angle (deg)</th>
<th>Center of Beam Altitude (ft AGL)*</th>
<th>Radar Coverage Floor Altitude (ft AGL)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>+0.5</td>
<td>16,100</td>
<td>9,500</td>
</tr>
<tr>
<td>+0.4</td>
<td>14,700</td>
<td>8,200</td>
</tr>
<tr>
<td>+0.3 or lower</td>
<td>13,400</td>
<td>7,600</td>
</tr>
</tbody>
</table>

* rounded to nearest 100 ft

The Cities of Greensboro, Winston-Salem and High Point, NC are called the Triad. They are located 78, 102, and 87 miles west-northwest of the KRAX WSR-88D, respectively. The city center elevations of the cities are: Greensboro = 830 ft MSL, Winston-Salem = 920 ft MSL, and High Point = 920 ft MSL. Table 4 shows the existing height of the center of the KRAX WSR-88D beam and the radar coverage floor over...
the center of the Triad, which is assumed to be 90 miles at azimuth 290 from the WSR-88D with ground elevation of 875 ft MSL. The altitude of radar coverage over the Triad would be reduced by lowering the minimum scan angle to +0.4 deg. At +0.4 deg, the KRAX WSR-88D center of beam would have an altitude of 7,000 ft AGL over the Triad and the radar coverage floor altitude would be 2,800 ft AGL. Terrain blockage between the KRAX WSR-88D and the Triad would prevent any reduction in beam height or coverage floor altitude for minimum scan angles lower than +0.4 deg; although the lower scan angles would improve radar coverage in other directions.

<table>
<thead>
<tr>
<th>Minimum Scan Angle (deg)</th>
<th>Center of Beam Altitude (ft AGL)*</th>
<th>Radar Coverage Floor Altitude (ft AGL)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>+0.5</td>
<td>7,800</td>
<td>3,600</td>
</tr>
<tr>
<td>+0.4 or lower</td>
<td>7,000</td>
<td>2,800</td>
</tr>
</tbody>
</table>

* rounded to nearest 100 ft

4. HUMAN EXPOSURE AND POTENTIALLY RADIOFREQUENCY (RF)-SENSITIVE ACTIVITIES

Exposure to the WSR-88D main beam could represent a hazard to persons and certain sensitive activities. Table 4 presents the safe setback distances from the WSR-88D for human exposure, implantable medical devices, fuel handling, and EEDs (Sensor Environmental LLC, 2011). Safety standards for implantable medical devices, fuel handling, and EEDs are based on instantaneous exposure. Safety Standards for human exposure are based on time-averaged exposure; therefore exposure during both rotating antenna and stationary-antenna operation are considered.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Safe Setback Distance (ft)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Exposure</td>
<td>Rotating Antenna</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Stationary Antenna</td>
<td>1,700</td>
</tr>
<tr>
<td>Implantable Medical devices</td>
<td></td>
<td>2,060</td>
</tr>
<tr>
<td>EEDs</td>
<td></td>
<td>6,030</td>
</tr>
<tr>
<td>Fuel Handling</td>
<td></td>
<td>537</td>
</tr>
</tbody>
</table>
5. DIRECTLY ILLUMINATED TERRAIN

Exposure to radiofrequency (RF) radiation can potentially be harmful to humans and RF-sensitive activities. The safe setback distances from the WSR-88D for human exposure, implantable medical devices, fuel handling, and electro-explosive devices (EEDs), are given in section 4 of this memorandum. The greatest safe setback distance for human exposure or any of these activities is 6,030 ft for exposure of EEDs, which include blasting caps, some types of ordnance, and equipment used in and aviation systems (e.g. ejection seats and separation systems for air-launched missiles).

Attachment C shows terrain within 3 miles of the KRAX WSR-88D that would be directly illuminated by the WSR-88D main beam at each lower center of beam scan angle under consideration. There would be no directly illuminated terrain within 3 miles at scan angles of +0.5 deg, 0+0.4 deg, or +0.3 deg. For a minimum scan angle of +0.2 deg, the nearest directly illuminated terrain is a hilltop 2.9 miles (15,200 ft) northwest of the WSR-88D, which is farther from the WSR-88D than the applicable setback distances.

Four elevated structures rise above the horizon in the vicinity of the KRAX WSR-88D. Table 5 shows the distance and the azimuth from the WSR-88D. These also shown in the panoramic photographs in the trip Report (see Attachment A). All of these structures are farther from the WSR-88D than the safety setback distances for all potentially RF-sensitive activities, except for use of EEDs, which is very unlikely to occur at the upper portion of a water tank or communications tower.

<table>
<thead>
<tr>
<th>Structure</th>
<th>Distance (ft)</th>
<th>Azimuth from WSR-88D</th>
<th>Trip Report Photograph</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Tank</td>
<td>3,800 ft</td>
<td>76 deg</td>
<td>2A</td>
<td>SW corner of Shotwell Rd/Old US Hwy 70 W</td>
</tr>
<tr>
<td>Comm Tower 1</td>
<td>12,700</td>
<td>276 deg</td>
<td>2C</td>
<td>WTVGD TV Tower</td>
</tr>
<tr>
<td>Comm Towers 2</td>
<td>11,800, 14,000</td>
<td>289, 288</td>
<td>2C</td>
<td>2 towers on same azimuth, farthest one is WRAL TV</td>
</tr>
<tr>
<td>Comm Tower 3</td>
<td>3,900 ft</td>
<td>355</td>
<td>2D</td>
<td>Red and white striped, East of Old Harmony Court</td>
</tr>
</tbody>
</table>

6. ASTRONOMICAL OBSERVATORIES

The WSR-88D can potentially cause harmful electromagnetic interference (EMI) with charge-couple devices (CCDs) which electronically record data collected by astronomical telescopes (NEXRAD JSPO), 1993). Due to the sensitivity of astronomical equipment which is designed to detect very faint signals from space, this equipment is vulnerable to EMI. The potential for harmful EMI would arise if the WSR-88D main beam would directly illuminate an astronomical observatory during low angle scanning. Table 6 lists astronomical observatories located within 150 miles of the KRAX WSR-88D and provides distances
and azimuths to the observatories from the WSR-88D based on true north, observatory elevation, and whether or not the observatory would be directly illuminated by the WSR-88D main beam at scan angles of +0.5 deg or lower. Direct illumination would not occur if terrain blockage is present between the observatory and WSR-88D or if the elevation of the lower half-power point of the main beam at the observatory location would be higher than the observatory elevation.

<table>
<thead>
<tr>
<th>Observatory</th>
<th>Location</th>
<th>Distance from WSR-88D / azimuth</th>
<th>Observatory elevation (ft MSL)</th>
<th>Directly illuminated by KRAX WSR-88D at 0.5 deg or below?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Francis Marion University</td>
<td>Florence, SC</td>
<td>121 mi / 212 deg</td>
<td>120</td>
<td>No</td>
</tr>
<tr>
<td>Three College</td>
<td>Graham, NC</td>
<td>55 mi / 290 deg</td>
<td>880</td>
<td>No</td>
</tr>
<tr>
<td>Winfree</td>
<td>Lynchburg, VA</td>
<td>126 mi / 347 deg</td>
<td>765</td>
<td>No</td>
</tr>
</tbody>
</table>

7. RECOMMENDATION

Lowering the KRAX minimum scan angle to +0.2 deg would increase coverage area at 2,000 ft ASL by 74.5% and reduce the height of radar coverage floor over Charlotte, NC, area from 9,500 ft to 7,600 ft AGL and over the Triad, NC, area from 3,600 to 2,800 ft AGL. No increase in hazards to RF-sensitive activities would result. Lowering the minimum scan angle below +0.2 deg would not further increase radar coverage or achieve additional lowering of the radar coverage floor over Charlotte or the Triad, NC, areas, but would have the adverse effect of increasing ground clutter returns. Therefore, lowering the KRAX minimum scan angle to +0.2 deg is recommended.

8. MEMORANDUM AUTHORS

This memorandum was prepared by Sensor Environmental LLC under contract to Centuria Corporation, which is a support contractor to the National Weather Radar Operations Center. Mr. James Manitakos, CEO, served as Sensor’s Project Manager. Alion Science and Technology Corporation prepared radar coverage maps and calculated coverage areas under subcontract to Sensor. Mr. Andre Tarpinian, Radio Frequency Engineer, served as Alion’s Project Manager.

9. REFERENCES


NEXRAD JSPO. *Final Supplemental Environmental Assessment (SEA) of the Effects of Electromagnetic Radiation from the WSR-88D Radar* (April 1993).


Schultz, Jessica, NWS Radar Focal Point, email to James Manitakos, Sensor Environmental LLC. (September 13, 2018).


ATTACHMENT A

TRIP REPORT, KRAX WSR-88D
TRIP REPORT

Traveler: James Manitakos, Sensor Environmental LLC

Destination: Raleigh, NC, Weather Forecast Offices (WFO) and Weather Surveillance Radar, Model 1988 Doppler (WSR-88D)

Dates: October 16, 2018

Purpose: Field Inspection of KRAX WSR-88D serving Raleigh, NC, area

Summary: October 16, 2018: Mr. Manitakos drove from Columbia, SC to Raleigh, NC, in the morning. Mr. Manitakos met at the Raleigh WFO with Meteorologist-in-Charge Jonathan Blaes and Electronics Supervisor JL Winthrop. MIC Blaes expressed a desire to improve radar coverage over the Charlotte, NC, and the Triad (Greensboro, Winston-Salem, Hypoint) area. Tornadoes are severe weather phenomena of particular concern. He also discussed the potential for structural blockage of the radar beam by multi-story hotels under construction in the White Oak area, about 2 miles west of the KRAX WSR-88D. Mr. Manitakos then proceeded to the KRAX WSR-88D and took a photograph of the KRAX WSR-88D (Photograph 1) and panoramic photographs (Photograph 2) from the 25-m level of the KRAX WSR-88D, which is 31 ft below the center of the WSR-88D antenna. In the evening, Mr. Manitakos flew to Boston, MA.

Weather: Partly cloudy, 85°F.
Photograph 1: KRAX WSR-88D serving Raleigh, NC, area viewed from the southwest.
Photograph 2A: Panoramic photograph from KRAX WSR-88D tower [0 deg]

Photograph 2B: Panoramic photograph from KRAX WSR-88D tower [0 deg]
**Photograph 2C:** Panoramic photograph from KRAX WSR-88D tower [0 deg]

**Photograph 2D:** Panoramic photograph from KRAX WSR-88D tower [0 deg]
ATTACHMENT B

KRAX WSR-88D COVERAGE MAP

MINIMUM SCAN ANGLES +0.5 deg to -0.2 deg
ATTACHMENT C

KRAX WSR-88D NEARBY DIRECTLY ILLUMINATED TERRAIN

AT SCAN ANGLE OF +0.2 deg
Terrain Illuminated by WSR-88D
Minimum Center of Beam Elevation Angle

+0.2 deg