Appendix C
Telecommunication Studies

Bowman Wind, LLC
March 2021

ENGINEERING REPORT
CONCERNING THE EFFECTS UPON
FCC LICENSED RF FACILITIES
DUE TO CONSTRUCTION OF THE
BOWMAN WIND ENERGY PROJECT
In
BOWMAN COUNTY, NORTH DAKOTA

Prepared for
Apex Clean Energy
Charlottesville, VA

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I. INTRODUCTION

This engineering report describes the results of a study and analysis to determine the locations of federally-licensed (FCC) microwave and fixed station radio frequency (RF) facilities that may be adversely impacted as a result of the construction of the Bowman Wind Energy Project in Bowman County, North Dakota. This document describes impact zones and any necessary mitigation procedures, along with recommendations concerning individual wind turbine siting. All illustrations, calculations and conclusions contained in this document are based on FCC database records[1].

Frequently, wind turbines located on land parcels near RF facilities can cause more than one mode of RF impact, and may require an iterative procedure to minimize adverse effects. This procedure is necessary in order to ensure that disruption of RF facilities either does not occur or, in the alternative, that mitigation procedures will be effective. The purpose of this study is to facilitate the siting of turbines to avoid such unacceptable impact.

The Bowman wind project as currently planned involves the construction of approximately 85 wind turbines just south of the City of Rhame and just west of the City of Bowman, in western Bowman County, North Dakota. Two models of wind turbines are being considered for construction, one with a hub height of 89 meters and a rotor diameter of 127 meters (152.5 meter maximum blade tip height) and the other with a 107.5 meter hub height and a 158 meter rotor diameter (186.5 meter blade tip height). For the purpose of this report, the taller turbine was modeled.

[1] The databases used in creating the attached tables and maps are generally accurate, but anomalies have been known to occur. Generally, for wind turbine siting, an on-site verification survey is often suggested as part of the due diligence process.

Using industry standard procedures and FCC databases, a search was conducted to determine the presence of any existing microwave paths crossing the subject property, land mobile and other RF facilities within or adjacent to the identified area and broadcast signals receivable in the area. A specific turbine layout has been submitted for analysis. Accordingly, this report will address the potential conflicts that may be caused by the proposed turbines.

The following tabulation and analysis consists of four sections:

1. Microwave point-to-point path analysis[2]
2. Land mobile, public safety and other communications tower sites
3. Broadcast AM, FM and TV
4. Radar and NTIA Notification

The attached figures were generated based upon the operating parameters of the FCC-licensed stations as contained in the FCC station databases, with corrections of the antenna locations if possible and as needed.

The following analysis examines the pertinent FCC licensed services in the area for impact. This analysis assumes that all licensed services have been designed and constructed according to FCC requirements and good engineering practice. If this is not the case, the impacted facility must share responsibility with the wind project developer for the costs of any mitigation measures[3].

Each of the RF analyses is described separately in the sections that follow.

II. ANALYSIS OF MICROWAVE LINKS

An extensive analysis was undertaken to determine the likely effect of the new wind turbine farm upon the existing microwave paths, consisting of a Fresnel x/y/z axis study. The microwave paths have been overlaid on Google Earth™ maps, and the images of the microwave paths and the proposed turbines are also available in a KMZ file.

Important Note: Microwave path studies are based upon third party and FCC databases that normally exhibit a high degree of accuracy and reliability. Although Evans performs due diligence to ensure that all existing microwave facilities are represented, we cannot be responsible for errors in FCC databases that may lead to incomplete results. However, should

[2] Only point-to point microwave facilities were considered (for instance, a study of earth station facilities is not included).

[3] For instance, some microwave paths may have insufficient ground clearances as they are presently configured.

such situations occur, Evans would perform an engineering analysis to determine how the additional facilities can be accommodated or, if wind turbine structures are already built, determine a method to re-direct an impacted beam path.

For this microwave study, the 100% *First Fresnel Zone* (FFZ) was calculated for each microwave path, with the K factor at 1.333. The mid-point of a microwave path is the location where the widest (or worst case) Fresnel zone occurs. The radius *R* of the First Fresnel Zone, in meters, at the midpoint of the path is calculated for each microwave link using the following formula:

$$R \cong 8.65\sqrt{\frac{D}{F_{GHz}}}$$

where D is the microwave path length in kilometers and F_{GHz} is the frequency in gigahertz.

In general, the FFZ is defined by the elliptical three-dimensional boundary that extends between the transmitting and receiving points and whose radius at the midpoint is *R* as calculated above. This is the zone where the siting of obstructions should be avoided. Evans Engineering Solutions has identified one unique licensed microwave path from the FCC database within one mile of the project area. This microwave path is listed in Table 1 and mapped in Figures 1 and 2.

Call Sign 1	Call Sign 2	Site 1 Name	Site 2 Name	Freq. (MHz)	WCFZ (m)	Licensee
WQKW716	WQKW717	Rhame	East Rainy	6004.5-6795	27.8	Basin Electric Power Cooperative

Table 1 – Active Microwave Links in and near Bowman Project Area

As can be seen in Figures 1 and 2, this one microwave path penetrates the turbine project area, but based on the latest turbine layout, no turbine would cause obstruction to the microwave FFZ. Thus, the Bowman wind project is not expected to cause interference with any FCC-licensed microwave links.

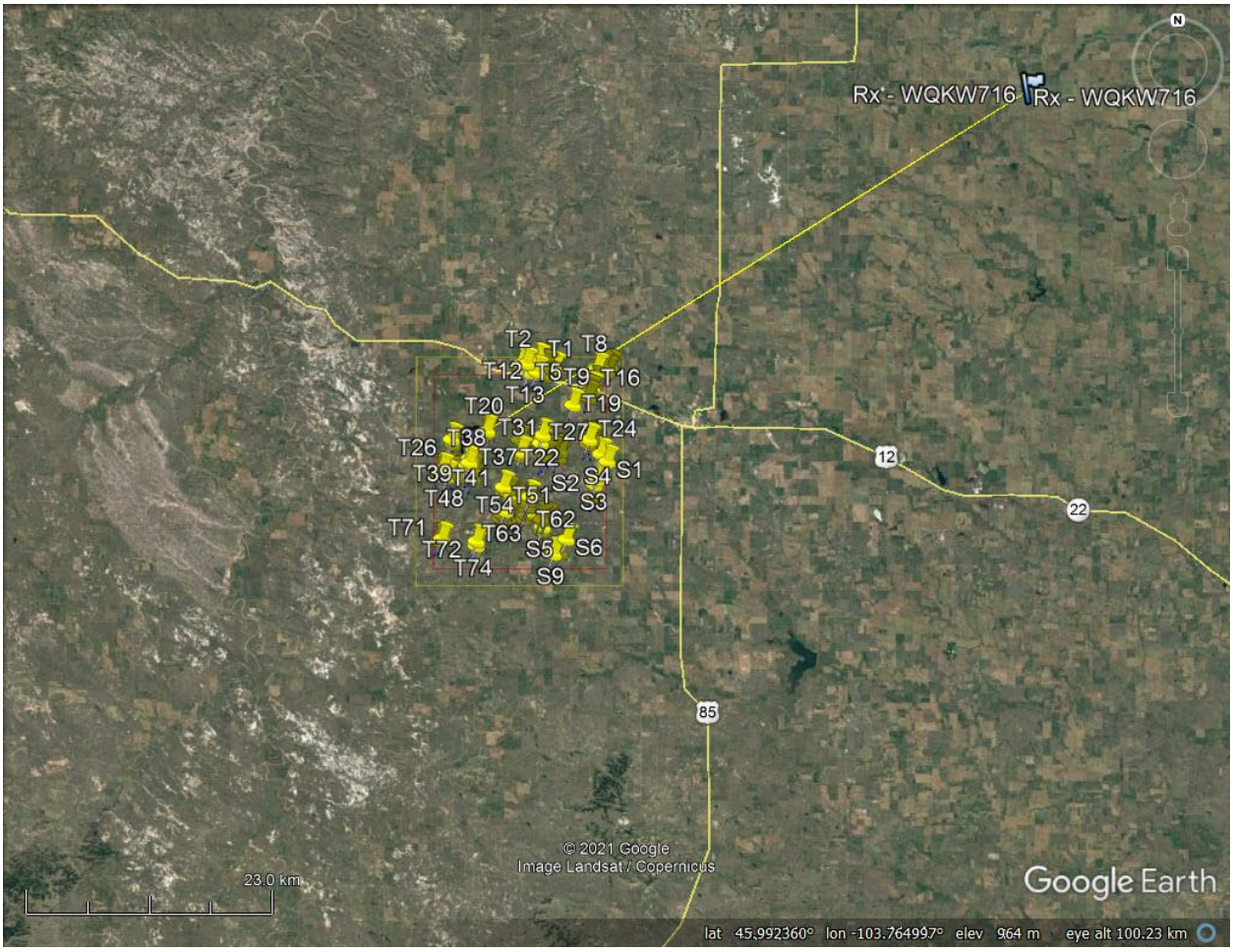

Figure 1 – Licensed Microwave Path near Bowman Project Area

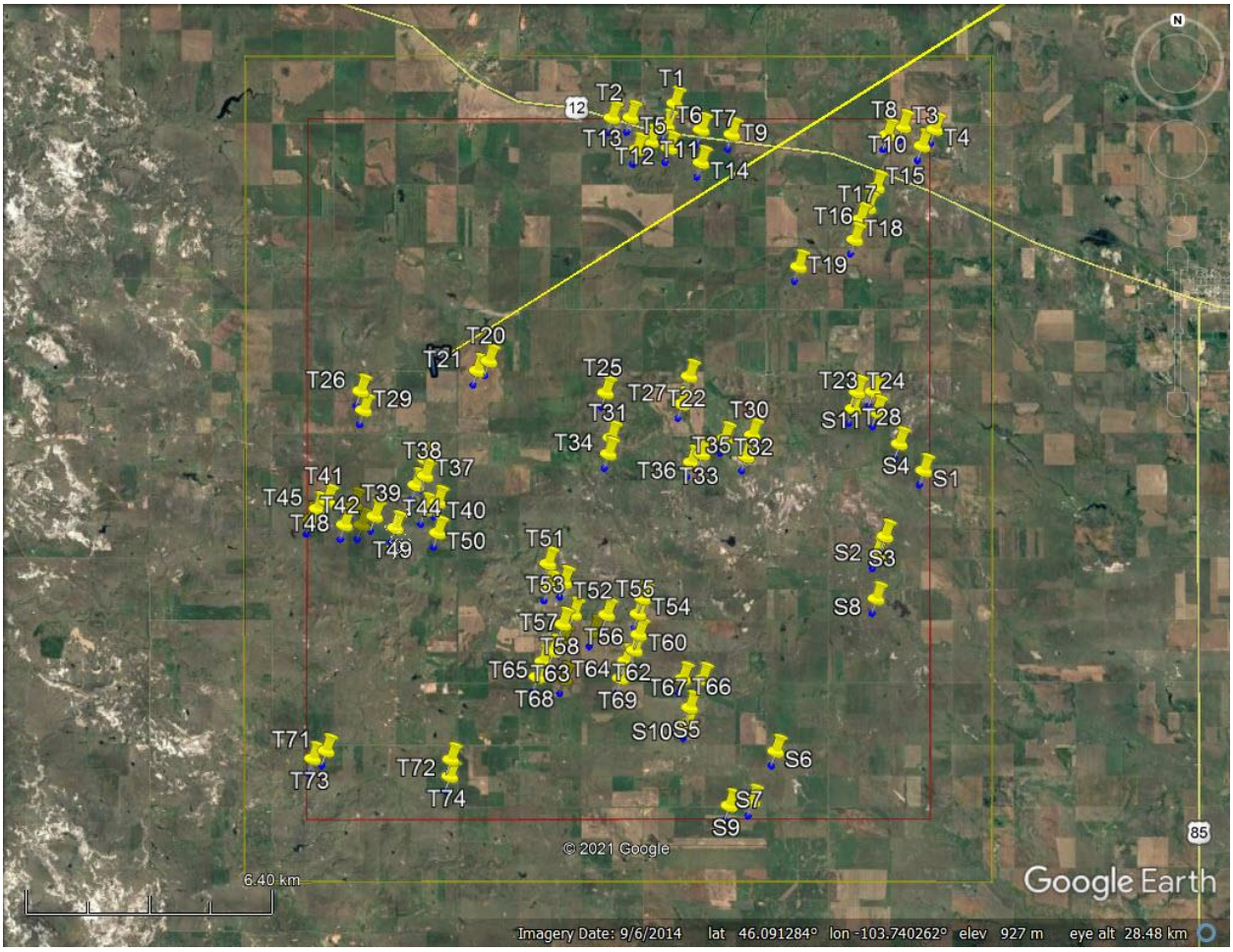

Figure 2 – Close-Up of Licensed Microwave Path near Bowman Project Area

III. ANALYSIS OF FIXED RADIO FACILITIES

3.1 Land Mobile & Public Safety Facilities

A search of the FCC's land mobile/public safety radio database revealed 12 land mobile transmitter stations that fall within the search area (about one mile beyond the project area). These land mobile stations are listed in Table 2 and mapped in Figure 3. The specifications on the land mobile stations can be found in the associated land mobile (LM) spreadsheet file.

For a wind energy project of this scope, multi-directional transmitting facilities, including land mobile stations, that are within 450 meters of a turbine site customarily should be further evaluated for the possibility of transmitter interference caused by wind turbines. Only two mobile stations, highlighted in yellow in Table 2 (both at a common antenna site), would be within this distance from a planned turbine. The turbine site nearest to these two stations, Turbine T5, is 377 meters away.

The reader is referred to the provided KMZ file for more magnification and closer inspection.

Call Sign	Location No.	Latitude (NAD-83)	Longitude (NAD-83)	Ant. Ht. (m AGL)	Freq. (MHz)	Licensee
KTN83	1	46.233611	-103.6475	6	153.98	Bowman, County of
KZN307	2	46.146667	-103.682139	9.7	151.58	Miller, Dallas
WPAP204	6	46.220445	-103.536074	9.1	453.975	Southwest Water Authority
WPKC870	5	46.233333	-103.653889	15	158.76	Bowman, County of
WPMC846	1	46.211667	-103.704639	10	153.11	Fischer, Jerome
WPMF816	1	46.234167	-103.652417	10	153.215	Fish, Allen T.
WQAC538	1	46.219861	-103.59975	3.2	160.92	BNSF Railway Company
WQJA861	1	46.219861	-103.59975	6.4	44.58	BNSF Railway Company
WQJT550	1	46.164882	-103.666315	47.9	452.4375	Basin Electric Power Cooperative
WQNK641	4	46.232611	-103.656667	14.3	44.58	BNSF Railway Company
WQPQ239	1	46.09	-103.658528	30	461.025	Continental Resources, Inc.
WQSX289	1	46.219583	-103.655944	9.1	152.3825	Bowman, Eric

Table 2 – Land Mobiles Stations within 1 Mile of Project Area

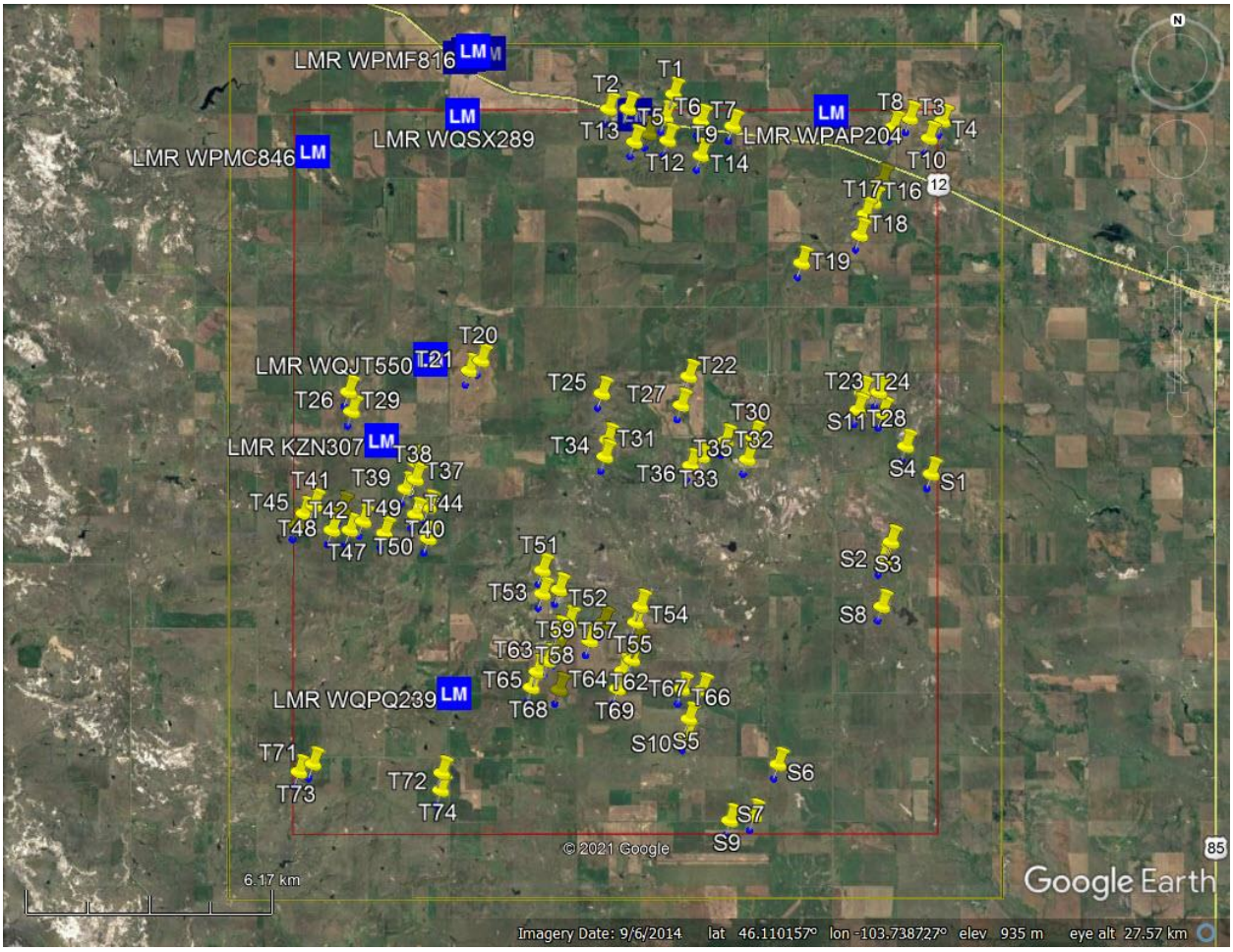

Figure 3 – Land Mobile Stations in or near Bowman Project Area

When recommending setback distances from land mobile stations, Evans Engineering Solutions makes use of the concept of the "far-field" region of a transmitting antenna. The far-field region is defined as the distance just far enough from the antenna such that the shape of the radiation pattern of the antenna doesn't change with increased distance from the antenna, unlike in the near-field (although the *strength* of the received signal in the far-field decreases with increased distance). An object near the antenna that has highly conductive properties, such as a wind turbine with a metal supporting tower, may cause distortion of the antenna's radiation pattern if it is located in the antenna's near-field. Thus, in general, a turbine should not be sited inside the edge of the far-field region of a land mobile transmitting antenna.

The distance R_{ff} to the edge of the far-field region of an antenna, also known as the Fraunhofer distance, can be calculated using the following equation:

$$R_{ff} = 2D^2/\lambda$$

where D is the length of the antenna and λ is the wavelength at the operating frequency.

Since the length of the antenna and the frequency are usually known, we can utilize this equation to establish setback distances from omni-directional[4] land mobile stations. Evans Engineering Solutions uses a modified form of the above equation, substituting "3" for "2" as the coefficient in the equation. This increases the setback 50% to provide additional protection by reducing the antenna aperture blockage presented by the wind turbine support towers.

By using worst-case assumptions of frequency and antenna length, we can arrive at a worst-case setback for the purpose of performing an initial "screening" for potential land mobile interference by wind turbines. Let us assume that a land mobile station, whether licensed or unlicensed, could operate on a frequency up to 965 MHz and utilize an antenna up to 20 feet in length (commercially available antennas that operate omni-directionally at this frequency are usually less than 10 feet long). The wavelength λ at 965 MHz is 1.02 feet. Thus, in the modified Fraunhofer equation, the turbine setback is calculated as follows:

$$R = 3(20)^2/1.02 = 1{,}176 \text{ feet}$$

Converting to metric, the worst-case setback R is 359 meters. One of the turbine models being considered for the Bowman project has rotor blades that extend out to 79 meters from the turbine tower (measured from the rotor hub to the tip of the blade). We add this length to R to get a recommended spacing from any land mobile antenna structure to the turbine tower, which

[4] "Omni-directional" transmitting stations operate with nearly equal levels of RF energy in all directions, unlike, for example, point-to-point microwave stations which transmit RF energy in one discrete direction.

becomes 438 meters. It is the practice of this firm to round up setback distances to the nearest number divisible by 25; thus, 450 meters is recommended as the setback distance between a land mobile tower and the nearest turbine. However, if a turbine is sited less than the recommended setback from a land mobile station and there are no acceptable options that would meet the setback, we then use the actual highest operating frequency and antenna length to calculate an alternative setback which, with rare exceptions, is less than the worst-case spacing.

If the locations of all the land mobile stations listed in Table 2 are positioned at the coordinates specified in their FCC licenses, only two of the land mobile stations listed are within 450 meters of any planned Bowman turbine site, based on the currently proposed layout (see Figures 3). The nearest planned turbine, T5, would be 377 meters from stations WQAC538 and WQJA861 which are located at a common site (see Figure 4). WQAC538 operates on 160.92 MHz and WQJA861 operates on 44.58 MHz.

Applying the modified Fraunhofer equation, the distances to the far-field regions of WQAC538 and WQJA861 are 63 meters and 18 meters, respectively. The larger region is distinctively seen in Figure 4 as a blue circle of 63 meters radius centered at the land mobile site. We add the maximum length of the turbine blades, 79 meters, to 63 meters to obtain a recommended spacing from the WQAC539/WQJA861 to the turbine tower, which becomes 142 meters, 150 meters when rounded to the next number divisible by 25. This is substantially less that the actual distance of 377 meters from the nearest turbine site, T5, to the land mobile site.

Therefore, based on the current project layout, and assuming that the land mobile stations in and near the project area are actually located at their licensed locations, or located farther away from turbines, no adverse impact is expected to be caused to the transmissions of land mobile or public safety stations that are licensed by the FCC.

Figure 4 – Close-Up of Land Mobile Stations WQAC538 & WQJA861 near Turbine T5

The nearest planned turbine, Turbine T5, is 377 meters from the WQAC538/WQJA861 transmitter, significantly less than the recommended setback of 150 meters.

3.2 Other Communications Sites

A search through the FCC-registered antenna structures database reveals communications towers located within 25 kilometers of the center of the proposed project area, which are listed in Table 3 and mapped in Figure 5. Many of these structures might be cellular base station towers. It is suggested, although not required, that these sites be investigated for microwave operations that are not in the FCC database, including unlicensed microwave facilities.

As mentioned previously, multi-directional transmitting facilities within 450 meters of a planned turbine customarily should be further evaluated for the possibility of turbine-related transmitter interference. The Bowman project is not expected to cause any turbine-related signal transmission problems to multi-directional transmitting facilities located at any of the tower sites listed in Table 3 and shown in Figure 5, since none are closer than 2.8 kilometers from any planned turbine[5].

Table 3 should not be considered as a complete list of antenna structures in the area, since most towers under 61 meters (200 feet) in height are not required to be registered with the FCC. An on-site visual survey is suggested to identify such towers.

FCC ASR Registr. #	Owner	Location	Latitude	Longitude	Height AGL (m)
1039982	North Dakota, State of	Bowman, ND	46-16-25.0N	103-21-04.0W	100.6
1040020	North Dakota, State of	Bowman, ND	46-10-38.0N	103-24-31.0W	15.5
1046458	BNSF Railway Co.	Bowman, ND	46-11-55.8N	103-28-23.3W	24.4
1057669	K2 Towers II, LLC	Bowman, ND	46-12-15.0N	103-23-32.0W	60.0
1057670	K2 Towers II, LLC	Bowman, ND	46-12-14.0N	103-23-33.0W	60.0
1238933	Bowman County Airport Authority	Bowman, ND	46-11-06.0N	103-25-43.6W	18.3
1264563	Bowman, County of	Bowman, ND	46-12-15.3N	103-23-34.0W	30.4
1268500	American Towers, LLC.	Bowman, ND	46-12-14.9N	103-23-31.1W	22.3
1282682	BNSF Railway Co.	Bowman, ND	46-11-39.7N	103-26-59.0W	15.2
1282683	BNSF Railway Co.	Bowman, ND	46-11-08.2N	103-24-07.6W	15.2
1285459	Bowman County	Bowman, ND	46-11-02.0N	103-23-50.0W	30.5
1286936	Bowman County	Rhame, ND	46-14-16.5N	103-39-35.6W	36.6
1292602	Bowman Regional Airport	Bowman, ND	46-09-56.1N	103-17-47.1W	9.1
1297302	State of North Dakota	Bowman, ND	46-10-17.3N	103-18-11.2W	16.8
1314954	Municipal Communications	Rhame, ND	46-13-53.1N	103-38-56.6W	60.7

The listed coordinates for the above structures are from documents filed with the FCC and have not been verified by this consultant.

Table 3 – FCC-Registered Antenna Structures within 25 KM of Center of Project Area

[5] The closest FCC-registered tower to a planned turbine is ASR 1046458, 2.83 kilometers from Turbine T4.

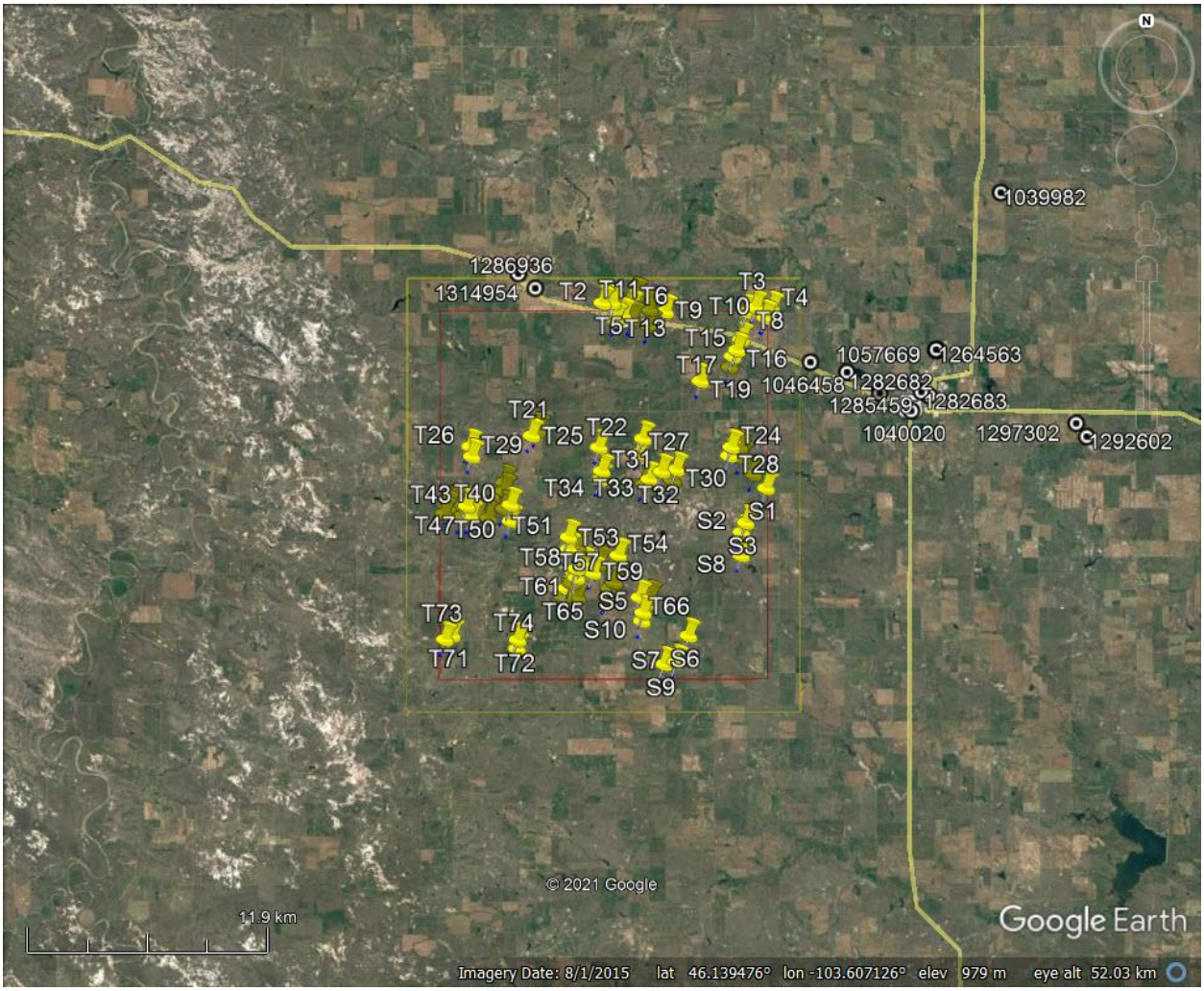

Figure 5 – FCC-Registered Antenna Structures within 25 KM of Center of Project Area

IV. ANALYSIS OF BROADCAST FACILITIES

4.1 TV Broadcast Facilities

The rotating blades of a wind turbine have the potential to disrupt off-the-air broadcast TV reception within a few miles of the turbine, especially when the direct path from the viewer's residence is obstructed by terrain. Interference is caused when signals reflected by the blades arrive at the viewer's TV antenna along with the direct signal. This is known as "multipath interference." However, as turbine manufacturers have replaced all-metal blades with blades constructed of mostly nonmetallic materials[6], this effect has been reduced. Also, the new generation of HDTV receivers is better equipped to deal with minor multipath interference (which is manifested by "pixilating" or "freezing" of the digital picture) than analog TV sets, as special circuitry is employed to suppress the reflected signal. Occasionally, however, multipath interference from one or more turbines can cause video failure in HDTV receivers, especially if the receiver location is in a valley or other place of low elevation.

There is some possibility of signal disruption for residences that have to point their outdoor antennas through the turbine area, or that utilize "rabbit ear" antennas and/or older HDTV receivers. Most of this effect should be dissipated for locations three or more miles from a turbine, but some residual problems could be noted for HDTV receivers that are located below the grade level at the turbine base. Usually, a rule of thumb is that approximately 10% of the receiver locations are affected to some extent within three miles of a large turbine when the turbine is between the TV station and the receiver. The usual effect is intermittent "pixilation" or freezing of the digital TV picture. This estimate is based upon Evans Engineering's experience with similar wind energy projects.

Bowman County is in the Minot-Bismarck-Dickinson, North Dakota Designated Market Area (DMA) as defined by Nielsen Media Research. TV stations that are predicted to serve any part of the Bowman wind project area or its adjacent areas with an off-the-air signal are listed in Table 4 below. The predicted service areas of these stations are shown in yellow in Figure 6.

[6] Modern turbine blades are usually constructed from glass-reinforced plastic (GRP), although they usually contain some metal for strengthening, balance and grounding.

Call Sign	Type of Station[7]	Network Affiliate	Displayed Channel	RF Channel	City of License	Power (KW)	Ant. Height (m HAAT)	Dist. km)	Azimuth (°T)
KQCD-TV	Conventional	NBC	7	7	Dickinson, ND	11.3	205	101.5	27.5
KDSE-DT	Conventional	PBS	9	9	Dickinson, ND	30.3	238	84.0	38.9

Table 4 - TV Stations Serving Bowman Project Area and Environs

If the Bowman wind project should cause disruptions to over-the-air TV viewing, methods to resolve them are available, and are as follows:

1. Relocation of the household antenna to receive a better signal
2. Installation of a better outside antenna, or one with a higher gain
3. Installation of satellite or cable TV

According to this engineer's calculations, and based on the 2019 U.S. Census Update, there are approximately 157 households within an area likely to be affected (approximately 200 square miles, shown in Figure 6). Based on the 10% criteria described previously, up to 16 TV receiving locations may be affected in the worst-case. Mitigation costs would be approximately $200 per location for an upgraded outdoor antenna, or $400 per year per location for a satellite or cable subscription.

It is the opinion of this consultant that any disruptions to over-the-air TV broadcast signals, if they occur, can be resolved satisfactorily.

[7] "Conventional" TV station is a station serving a wide geographic area which is often affiliate of a major broadcast network but also could be independent of a network.

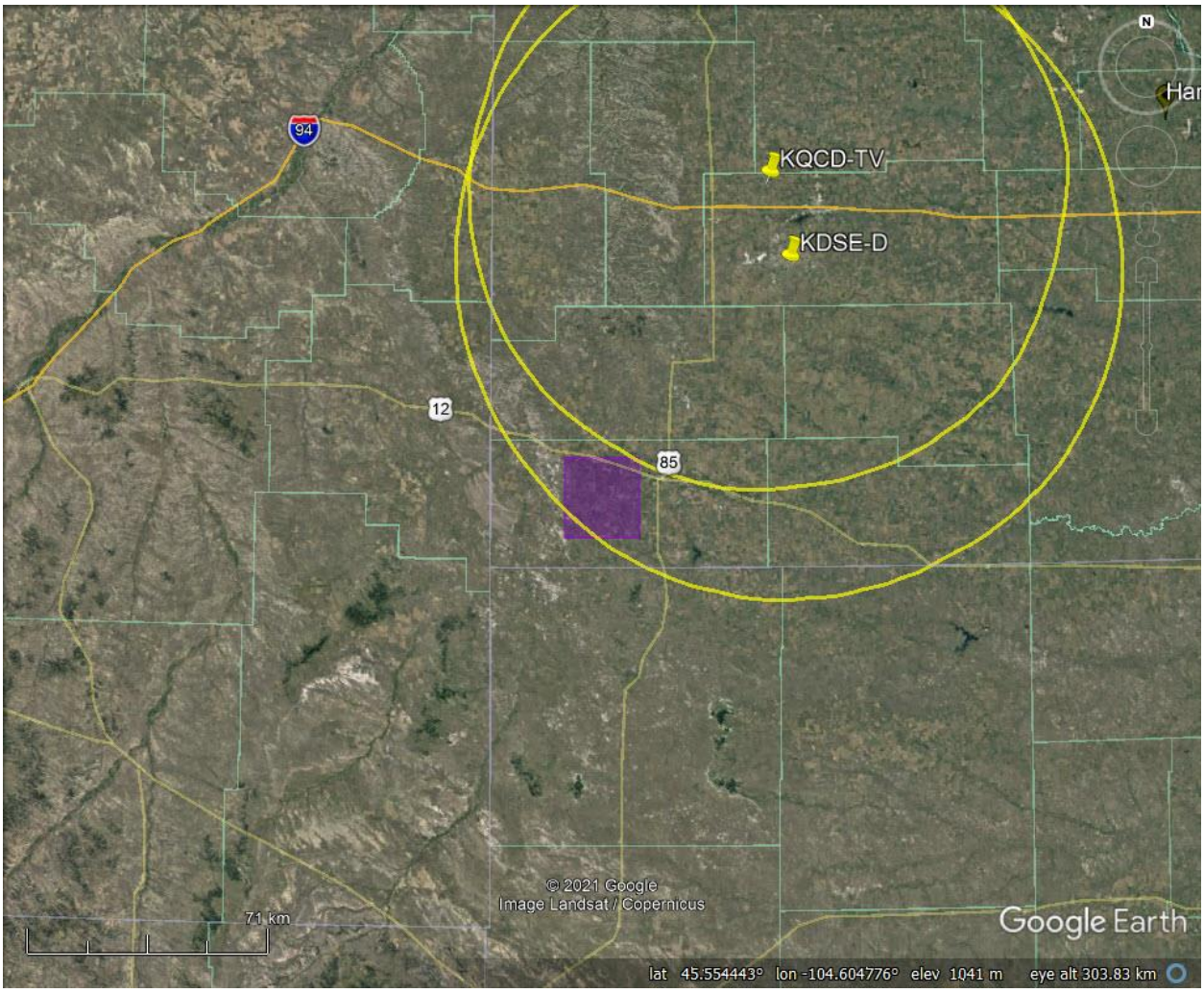

Figure 6 – Predicted Over-the-Air Television Coverage into Bowman Project Area

The yellow boundaries represent TV station coverages that extend into or near the Bowman wind energy project area. The purple square represents the predicted potential off-the-air TV reception interference area. According to the 2019 US Census Update, there are 157 households within the interference area.

4.2 FM Facilities

The full-service FM stations that place a predicted primary signal over at least part of the project area are listed in the following Table 6. The FM stations' service area boundaries are mapped in Figure 7.

Call Sign	Type of Station[8]	Freq. (MHz)	City of License	Power (KW)	Ant. Height (m HAAT)	Dist. (km)	Azimuth (°T)
K220FJ	Translator	91.9	Bowman, ND	0.008	34.9	17.1	72.8
K293BN	Translator	106.5	Bowman, ND	0.068	148	18.0	66.5

Table 6 – FM Stations Serving Bowman Project Area

Real-world experience with wind farms has shown that FM radio station signals (88 to 108 MHz) are fairly insensitive to wind turbine interference, even in cases where the FM transmitting antenna is surrounded by turbines that are higher than the FM antenna. Because of the "capture effect" supported by the "discriminator" in FM receivers, significant disruptions to the above facilities are not expected. Although the received signal may vary with the blade rotation at some receiver locations in the immediate area, good quality FM radios should factor out such time-varying signals.

The transmitting antennas of the two FM translators in Bowman and their respective predicted coverage areas are beyond the footprint of the proposed Bowman turbines (see Figure 7). In any case, as explained above, turbine interference to the reception of K220FJ or K293BN is not expected.

4.3 AM Facilities

Large metallic structures such as wind turbines can adversely affect the transmitted signals of AM broadcast stations up to three kilometers away. A search of the FCC's database revealed no AM facilities within the required notification distance of three kilometers from any planned turbine. There should therefore be no reasonable expectations of disruptions in transmitted radiations on the AM band due to the presence of the turbines. Occasionally, depending upon ground conditions, local AM receivers may experience slight signal changes due to local effects,

[8] An FM translator station is a low-power station that retransmits the signals of a full-power FM station on a different frequency for the purpose of filling in an uncovered area within the designated service area or extending the reach of a full-power FM station outside its designated service area.

but such anomalies are not recognized by the FCC or the standards of good engineering practice as having an unduly adverse effect.

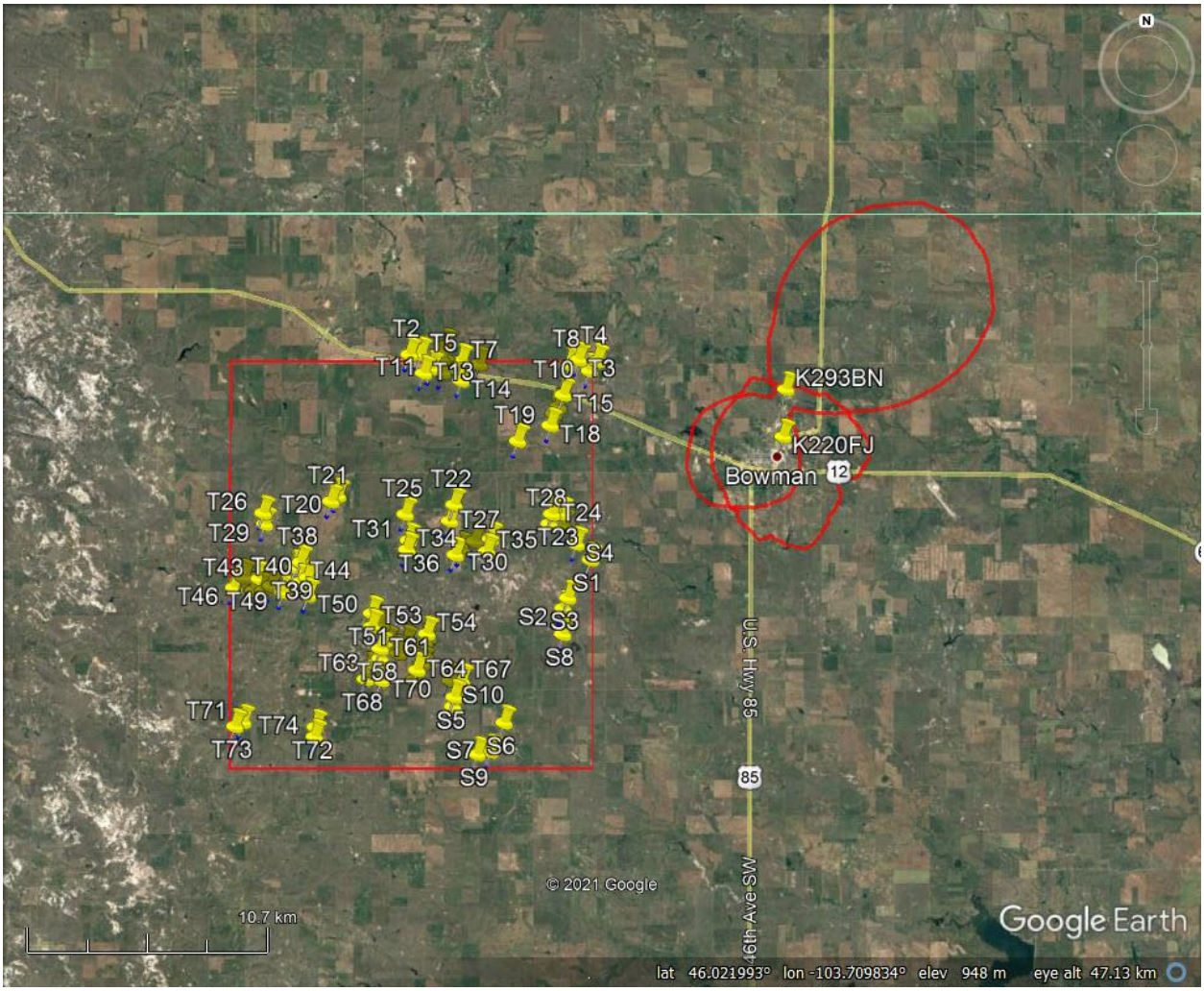

Figure 7 – FM Radio Station Locations & Coverage near Bowman Project Area

V. RADAR AND NTIA NOTIFICATION

5.1 DoD Radar Concerns

The Department of Defense (DoD) and the Department of Homeland Security *Long Range Radar Joint Program Office* "JPO" has adopted a "pre-screening tool" to evaluate the impact of wind turbines on air defense long-range radar. This tool was applied to the Bowman project area, and it returned a result of "no anticipated impact" (green) to Air Defense and Homeland Security radars (see Figure 8). However, a definitive determination is obtained only after formal study by the DoD, which is triggered by the FAA 7460-1 notification process.

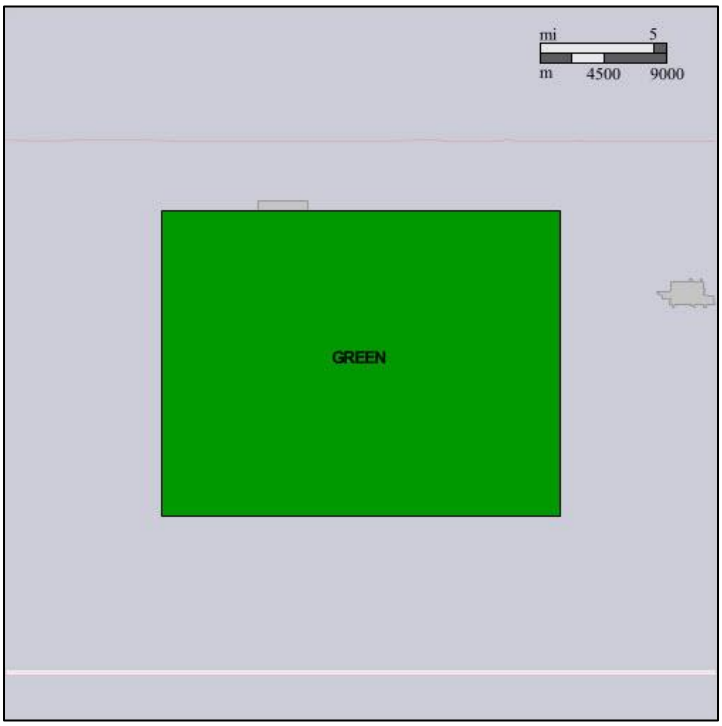

Figure 8 – DoD Long-Range Radar Screening

Map Legend:

- **Green:** No anticipated impact to Air Defense and Homeland Security radars. Aeronautical study required.

5.2 NEXRAD

A pre-screening tool has been developed to evaluate the potential impact of obstructions to the NEXRAD Weather Surveillance Doppler Radar Stations. This tool was applied to the Bowman project area, and it returned a result, shown in Figure 9, of "impacts not likely" to weather radar operations. However, a definitive determination is obtained only after the NTIA review process.

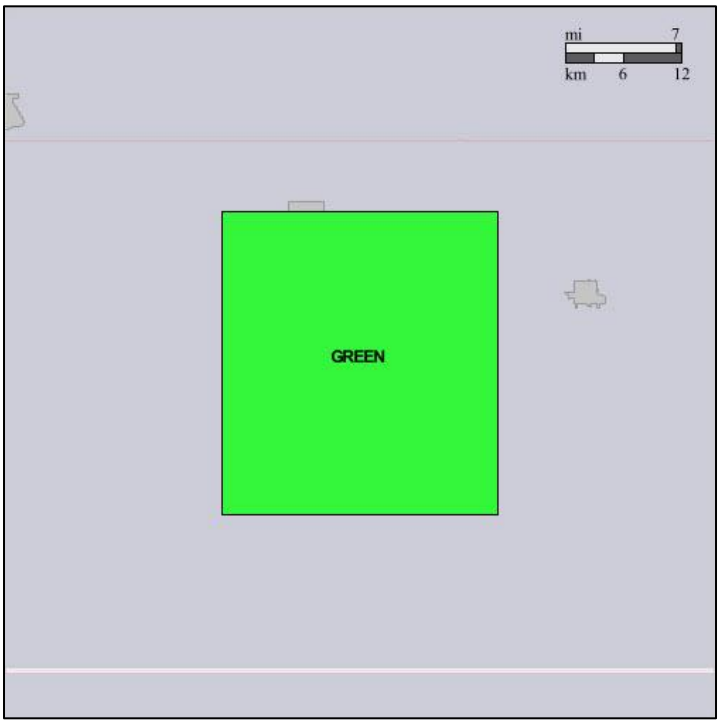

Figure 9 – NEXRAD Weather Radar Screening

Map Legend:

- **Green: No Impact Zone.** Impacts not likely. NOAA will not perform a detailed analysis, but would still like to know about the project.

5.3 NTIA NOTIFICATION

Operation of RF frequencies for federal government use is managed by the National Telecommunication Information Agency (NTIA), which is part of the U.S. Department of Commerce. The technical specifications for most government facilities are unavailable to the public. In order to avoid the derailment of the wind energy project due to late objections from a government agency, the NTIA should be notified of the proposed project during pre-construction planning. The NTIA has set in place a review process, wherein the Interdepartmental Radio Advisory Committee (IRAC), consisting of representatives from various government agencies, reviews new proposals for wind turbine projects for impact on government frequencies. In almost all cases, no adverse impact is found, and IRAC usually issues a determination in about 60 days.

On February 10, 2021, this office sent a notification of the Bowman wind project in its final configuration to the NTIA, and a determination is expected about the first full week of April 2021.

VI. CONCLUSIONS AND RECOMMENDATIONS

1. The only FCC-licensed microwave path found in the vicinity of the project does penetrate the project area but would not be impacted by any proposed turbine according to the current layout.

2. If an excessive amount of time goes by before the turbines are to be constructed (six months or more), it is recommended that the microwave study be updated in case new paths have been added to the FCC's database.

3. No land mobile transmitting stations are expected to be adversely affected, assuming that their transmitters are located exactly as per their FCC licenses. If any of the turbines are to be re-sited, it is recommended that no turbine be closer than 150 meters from land mobile stations WQAC538 and WQJA861.

4. Interference to off-the-air TV reception due to operating wind turbines is not expected to be a significant problem. Effective mitigation methods to resolve any interference that may occur are available, with satellite or cable service installation providing the worst-case solution. No radio broadcast facilities are likely to be affected.

Respectfully Submitted,

B. Benjamin Evans
RF Impact Consultant

February 15, 2021

UNITED STATES DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Washington, D.C. 20230

March 31, 2020

Mr. B. Benjamin Evans
EVANS ENGINEERING SOLUTIONS, LLC
524 Alta Loma Drive
Thiensville, WI 53092

Re: Bowman Project, Revision 1: Bowman County, ND

Dear Mr. Evans:

In response to your request on February 5, 2020, the National Telecommunications and Information Administration provided to the federal agencies represented in the Interdepartment Radio Advisory Committee (IRAC) the plans for the Bowman Wind Project, Revision 1, located in Bowman County, North Dakota.

After a 45+ day period of review, of the reviewing federal agencies, none had concerns with turbine construction in the designated areas.

While the other IRAC agencies did not identify any concerns regarding radio frequency blockage, this does not eliminate the need for the wind energy facilities to meet any other requirements specified by law related to these agencies. For example, this review by the IRAC does not eliminate any need that may exist to coordinate with the Federal Aviation Administration concerning flight obstruction.

Thank you for the opportunity to review these proposals.

Sincerely,

John R. McFall
Deputy Chief, Spectrum Services Division
Office of Spectrum Management