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Navigational Telex (NAVTEX) Modeling

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16. Abstract (MAXIMUM 200 WORDS) The Coast Guard (CG) currently maintains 12 Navigational Telex (NAVTEX) broadcast transmitters. These transmitters are part of the International Maritime Organization's (IMO) Global Maritime Distress Safety System (GMDSS) and provide essential Marine Safety Information (MSI) to mariners. The CG Telecommunication and Information Systems Command (TISCOM) and Command, Control, and Communications Engineering Center (C3CEN) are working to improve the Coast Guard's NAVTEX system by recapitalizing the NAVTEX transmitters with power levels optimized for the published coverage area. They also plan to add additional monitoring capability. In this report, RDC provides transmitter power recommendations along with candidate locations for NAVTEX monitoring sites.					
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EXECUTIVE SUMMARY

The U.S. Coast Guard (CG) currently maintains 12 Navigational Telex (NAVTEX) broadcast transmitters. These transmitters are part of the International Maritime Organization's (IMO) Global Maritime Distress Safety System (GMDSS) and provide essential Marine Safety Information (MSI) to mariners. The USCG's NAVTEX stations provide coverage on the east and west coast of CONUS, Hawaii, and Alaska.

The CG Telecommunication and Information Systems Command (TISCOM) and Command, Control, and Communications Engineering Center (C3CEN) are working to improve the Coast Guard's NAVTEX system by recapitalizing the NAVTEX transmitters with power levels optimized for the published coverage area. They also plan to add additional monitoring capability.

This report uses modeling to show that a reduction of transmitter power is appropriate for most CG NAVTEX transmitters. The report also provides recommendations for candidate NAVTEX monitoring sites.

Additional work is required prior to moving forward with the transmit power reduction. Actual measurements in the user area, preferably open-ocean, are recommended. This should be done with current transmit power levels and also by decreasing the transmit power of the current transmitters to the power levels calculated by the model. This is necessary as each transmitter/antenna pair will have different numbers as the antennas can vary at each site.



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LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS

dB	decibel
dBuV/m	field strength in dB with the signal referenced to a microvolt
C3CEN	Command, Control, and Communications Engineering Center
COTS	Commercial off-the-shelf
DGPS	Differential Global Positioning System
ET2	Coast Guard Electronics Technician - second class
GMDSS	Global Maritime Distress and Safety System
IMO	International Maritime Organization
ITU	International Telecommunication Union
kHz	frequency expressed in thousands of Hertz
NAVTEX	Navigational Telex
MF	Medium Frequency
MSI	Marine Safety Information
RDC	Coast Guard Research and Development Center
SOLAS	Safety of Life at Sea
Telex	Teleprinter network
TISCOM	USCG Telecommunications and Information Systems Command
USCG	United States Coast Guard
uV/m	field strength expressed in microvolts per meter



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1 INTRODUCTION

On the 1st of October 2015 the EL FARO, a United States flagged cargo ship, sank about 40 miles north of Acklins & Crooked Island, Bahamas. A causative factor was lack of situational awareness. EL FARO had unknowingly steered directly into Hurricane Joaquin. The ship was battered by this category 3 hurricane, lost propulsion, and ultimately sank with the loss of all hands.

The United States Coast Guard (USCG) maintains a network of Navigational Telex (NAVTEX) transmitters for the automated dissemination of Maritime Safety Information (MSI). These transmitters serve as an early warning system for mariners, identifying the location of storms such as Hurricane Joaquin and other navigational and safety items for the mariner. NAVTEX is part of a larger international system and an important component of the Global Maritime Distress Safety System (GMDSS).

Currently, the USCG maintains 12 shore-side transmitting stations. All operate at a low frequency of 518 kHz with a broadcast power of 2500 W. Transmissions are rotated on a 4 hour schedule to prevent interference between CG and international NAVTEX stations. The data are sent using binary frequency-shift keying at a rate of 100 bits per second. This relatively slow system, by modern standards, is still viable with several manufacturers offering products for the mariner. These range from small self contained units for the recreational boater to computer-based units for integration into the electronic charting systems of SOLAS class vessels.

The Coast Guard Telecommunications and Information Systems Command (TISCOM) and Command, Control, and Communications Engineering Center (C3CEN) are currently working to improve the NAVTEX system by recapitalizing the NAVTEX transmitters and adding additional monitoring capability. In this report, RDC provides an independent recommendation supporting the change in transmitter power. A list of candidate NAVTEX monitoring sites is also included.

2 NAVTEX GROUND WAVE MODELING

To develop a NAVTEX forecast, RDC used the latest ITU-RP368-9 ground wave path loss tool as implemented in ATDI's commercially available Spectrum-E tool. To use this forecasting tool, the operator must enter the NAVTEX station location, transmitter power, antenna efficiency, and desired field strength for a user at the edge of the published coverage boundary.

Station locations and coverage boundaries are identified in the (International Marine Organization) IMO GMDSS.1/Circ.16 Master Plan of Shore-Based Facilities for the Global Maritime Distress and Safety System (GMDSS Master Plan). TISCOM provided the desired reduced transmitter power for each station and tower types. Together, this information is captured in Table 1. Half of the stations broadcast from 300 feet towers as shown in Photo 1. The remainder use either long wire or shorter towers.



The edge-user field strength is assumed to be 40 dBuV/m (100 uV/m). This conservative number is taken from a series of calculations described in an RTCM paper¹ submitted by Nautel. Other literature^{2, 3} suggests that NAVTEX is usable with a field strength of 25 dBuV/m (18 uV/m) or lower. The 40 dBuV/m (100 uV/m) threshold chosen for this paper is the same field strength used in the USCG DGPS site operational assessments. As will be demonstrated, the chosen 40 dBuV/m (100 uV/m) threshold is a good match with published NAVTEX coverage requirements.

The NAVTEX antenna efficiency number was derived from recent USCG DGPS site operations assessments. The empirical procedure is described in Appendix A. Based on this method, RDC determined a 7db loss (20% conversion efficiency from transmitter output to radiated signal) is appropriate for NAVTEX modeling. Future work is recommended as RDC's method does not account for the wide variety of transmitting antennas used by the USCG NAVTEX sites.



Figure 1. Half of the CG NAVTEX broadcast towers are similar to this CG DGPS tower.

¹ RTCM Paper 293-2010-SC123-083 “Technical Report Prediction of Necessary Field Strength for NAVTEX Operation in Indian Coastal Waters.

² Report ITU-R M.910-1 “Sharing Between the Maritime Mobile Service and the Aeronautical Radionavigational Service in the Band 415-526.5 kHz”

³ John Pumford-Green “518 kHz NAVTEX Reception in Shetland”



Table 1. Location of the USCG maintained NAVTEX broadcast facilities.

Station	Location	Antenna Type	Modeled Transmitter Power (W)
Astoria, WA	46° 12' 14.308" N 123° 57' 22.248" W	400' longwire	750
Boston, MA	41° 42' 35.580" N 70° 29' 54.120" W	300' tower	750
Cambria, CA	35° 31' 5.086" N 121° 3' 37.179" W	315' longwire	1500
Charleston, SC	32° 50' 43.560" N 79° 57' 0.354" W	300' tower	750
Guam	13° 28' 27.948" N 144° 50' 39.840" E	199' tower	750
Honolulu, HI	21° 26' 14.400" N 158° 08' 36.000" W	300' tower	1500
Isabella, Puerto Rico	18° 27' 59.921" N 67° 04' 18.658" W	300' tower	750
Kodiak, AK	57° 46' 53.655" N 152° 32' 15.145" W	600' longwire	750
Miami, FL	25° 37' 25.620" N 80° 23' 20.700" W	300' tower	1500
New Orleans, LA	29° 53' 4.980" N 89° 56' 44.220" W	300' tower	750
Portsmouth, VA	36° 42' 57.395" N 76° 00' 28.800" W	300' tower	750
San Francisco, CA	37° 55' 32.420" N 122° 43' 58.631" W	173' tower	1500

3 NAVTEX REDUCED POWER COVERAGE

This section presents an approximation of the NAVTEX coverage based on the modeling assumptions identified in the previous section. The ITU-RP368-9 ground wave path loss tool was configured using the station locations and transmitter power data from Table 1. A conservative 40 dBuV/m (100 uV/m) field strength requirement for edge-users was assumed. Each broadcast station is assumed to have a 7 dB loss (20 % efficiency) in the transmitter plus antenna path. Take note, this is not the status quo. Instead, it is a model based on a reduction of transmitter power. The status quo model with all transmitters operating at 2500W is not included, as this reduced power model is an excellent fit with the published coverage area.

The reduced power forecast is contained in Figures 1 through 3. The edge of the green band represents the established 40 dBuV/m limit. The additional bands for 30 and 35 dBuV/m are included, as these areas are expected to have spotty coverage that may change based on time of day and seasons.

Based on these status quo forecasts, RDC measured the limits of the ground wave coverage. Recall that NAVTEX propagates primarily via ground wave. For an open-ocean signal path the signal strength drops as a function of distance. Unlike HF modeling, there are no skywave skip zones in this NAVTEX modeling.



NAXTEX Modeling

Coverage is the distance between a transmitting station and the edge of the corresponding green band as seen in Figures 2 through 4. The forecast coverage results are tabulated in Table 3 closely-aligned with the published values also included in the table.

Readers should note that NAVTEX will propagate via Skywave, especially at night. It is desirable to optimize transmitter power to reduce interference between the international NAVTEX transmitters. This excerpt from the GMDSS.1/Circ.16⁴ is particularly relevant “Experience has indicated that the required range of 250 to 400 nautical miles can generally be attained by transmitter power in the range between 100 and 1,000 W during daylight with a 60% reduction at night.”

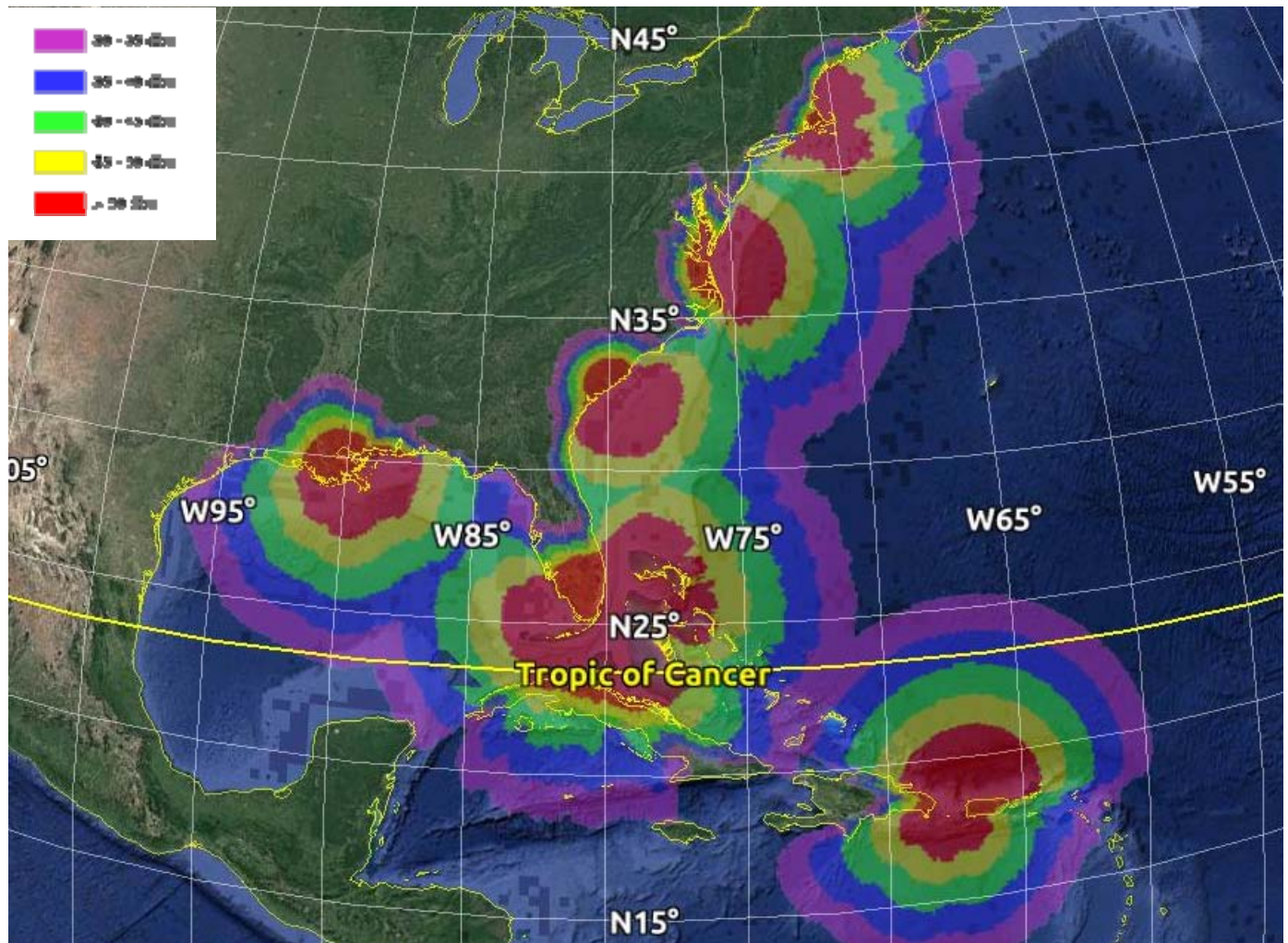


Figure 2. Reduced power forecast for the east coast CG maintained NAVTEX stations.

⁴ IMO GMDSS.1/Circ.16 Master Plan of Shore-Based Facilities for the Global Maritime Distress and Safety System (GMDSS Master Plan) 05 Feb 2014 https://www.navcen.uscg.gov/pdf/gmdss/GMDSS_1_Circ_16.pdf



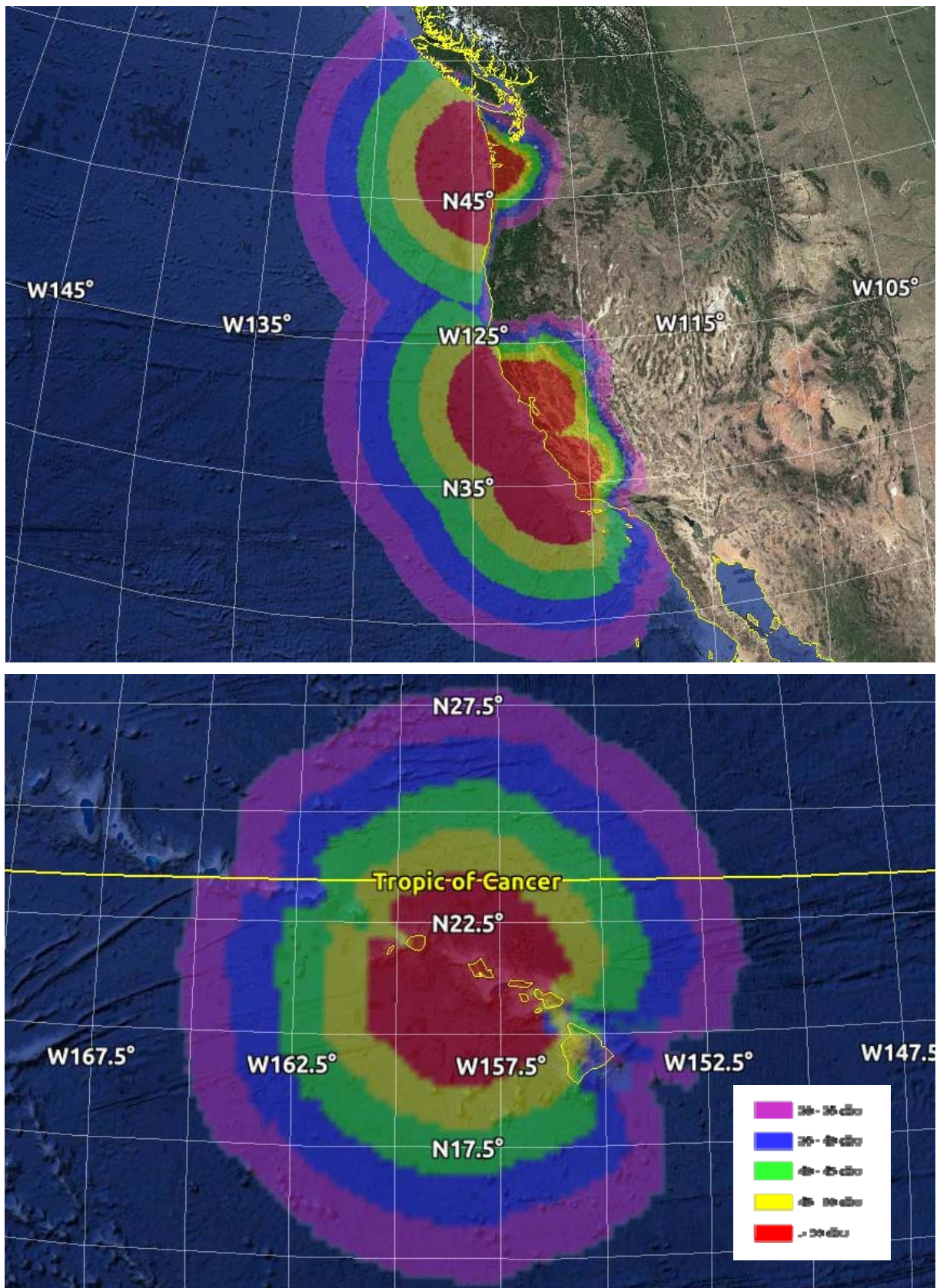


Figure 3. Reduced power forecast for the west coast and Hawaii NAVTEX stations.



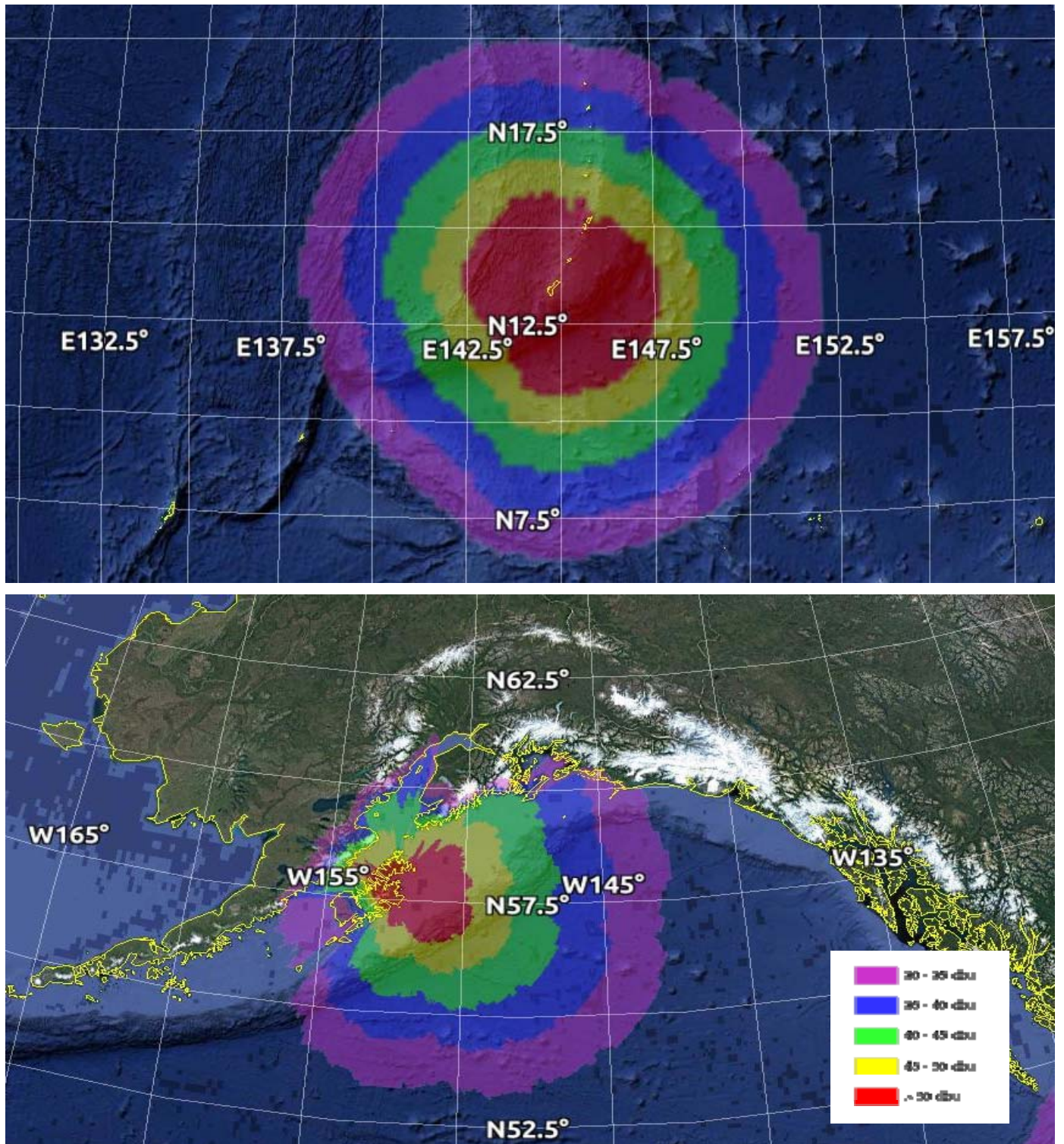


Figure 4. Reduced power forecast for the Guam and Kodiak NAVTEX stations.

Table 2. Comparison of published NAVTEX to modeled coverage area. The yellow highlights identify stations with a forecast below the published specification.

NAVTEX Station	Published Distance ⁵ (nautical miles)	Modeled Distance (nautical miles)	XMTR power (Watts)
Astoria, WA	300	300	750
Boston, MA	200	230	750
Cambria, CA	350	300	1500
Charleston, SC	200	275	750
Guam	250	275	750
Honolulu, HI	350	275	1500
Isabella, Puerto Rico	200	275	750
Kodiak, AK	200	200	750
Miami, FL	240	325	1500
New Orleans, LA	200	300	750
Portsmouth, VA	280	275	750
San Francisco, CA	350	300	1500

4 TRANSMITTER RECAP

Commercial off-the-Shelf (COTS) NAVTEX transmitters rated at 750, 1500, and 3000 W are available. Based on this assessment, RDC recommends the transmitter power be configured for the 750 and 1500W levels as identified in Table 3. The stations highlighted in yellow will require additional attention. These stations may require the larger 3000W transmitter.

As part of the recap, RDC recommends before and after operational assessments be conducted on all NAVTEX sites. Actual measurements in the user area, preferably open-ocean, are recommended. The pre assessment would provide verification of the transmitter power and antenna efficiency numbers upon which this model is constructed. The post assessment would allow transmitter power to be adjusted to nominally cover the published user areas in accordance with ITU recommendations⁵. This would minimize interference with other CG and international NAVTEX transmitters plus reduce energy costs.

5 MONITORING PLACEMENT

In this section, candidate locations are identified for installation of NAVTEX field monitors. These locations are chosen based on the NAVTEX coverage models developed in the previous section.

Candidate locations for NAVTEX field monitors were selected based on:

- Distance to the transmitting site. Ideally the monitor would be in a location in a zone with a 40 to 50 dBuV/m field strength. This should provide a representative sample of the signal as seen by the edge user.

⁵ IMO GMDSS.1/Circ.16 Master Plan of Shore-Based Facilities for the Global Maritime Distress and Safety System (GMDSS Master Plan) 05 Feb 2014 https://www.navcen.uscg.gov/pdf/gmdss/GMDSS_1_Circ_16.pdf



- Collocation with existing CG units or other military bases when possible. This will leverage existing CG land and infrastructure, such as power and computer networks. Collocation with other CG units is also desirable for maintenance. This repair and maintenance of the NAVTEX field equipment is expected to be an easy task for an independent Coast Guard Electronics Technician (ET2).

The expected space requirement for a NAVTEX field monitor is minimal. The antenna may take the form of a loop, H-field, or possibly a whip. The loop and H-field antenna may be mounted nearly anywhere as they are relatively small. A location on the roof of a main building or outbuilding would likely be acceptable. A whip, depending on size, could require additional space. In all cases, the antenna locations should be as far as possible from electrical and office equipment.

Table 3. Candidate NAVTEX field monitor locations.

NAVTEX Station	Recommended Field Monitor Location	Approximate Distance (nautical miles)
Astoria, WA	Sector North Bend North Bend, OR	170
Boston, MA	CG Station Boothbay Harbor Boothbay Harbor, ME	130
Cambria, CA	TRACEN Petaluma Petaluma, CA	180
Charleston, SC	CG Station Mayport Atlantic Beach, FL	170
Guam	Saipan Island recommended	110
Honolulu, HI	Station Maui Wailuku, Hawaii	100
Isabella, Puerto Rico	MSD St. Thomas St. Thomas, Virgin Islands	130
Kodiak, AK	CGC Hickory berthing Homer, AK	120
Miami, FL	ANT Fort Pierce Fort Pierce, FL	100
New Orleans, LA	CG Station Dauphin Island Dauphin Island, AL	100
Portsmouth, VA	TRACEN Cape May Cape May, NJ	150
San Francisco, CA	Sector Humboldt Bay McKinleyville, CA	190



APPENDIX A. ANTENNA EFFICIENCY BASED ON DGPS OPERATIONAL ASSESSMENTS

The United States Coast Guard (USCG) maintains a network of Differential Global Positioning System (DGPS) Medium Frequency (MF) transmitting sites. These MF sites are similar to the MF NAVTEX sites in power, broadcast frequency, and edge-user field signal strength requirements. Most importantly, many of the DGPS sites use the same transmitting towers as the NAVTEX sites. Consequently, lessons learned from the DGPS systems may be applied to the NAVTEX system.

The critical NAVTEX antenna efficiency number, as used in this report, was derived from the DGPS system. Specifically, it was derived from the readily available and detailed DGPS site operational assessments. These DGPS reports include actual signal strength readings taken over large geographical areas. For this analysis, RDC chose four stations as identified in Table A-1. These particular DGPS stations share the same 300 foot antenna as the majority of the NAVTEX stations.

The pertinent DGPS information from the operational assessments is shown graphically in Figures A-1, A-3, A-5, and A-7. Here, the measured signal strength is shown in units of dBuV/m. Colored boxes were added to group the measured field strength using the same colors previously used in the main document's Figures 1 through 3.

On the facing pages (Figure A-2, A-4, A-6, and A-8), the DGPS signal is modeled using a 7 dB loss. Here, the field strength is graduated in 5 dBuV/m increments with rainbow-colored bands for easy viewing. This allows the forecast to be compared with the actual DGPS measurements.

It took several iterations for RDC to select 7 dB to represent the antenna loss. Overall, this is a good fit for the four chosen stations. Unfortunately, it did not fit all stations. For example, the Appleton, WA DGPS site appears to have significantly less power than the 2000 W stated in the 13 Jul 2015 operational assessment.

Additional work is recommended to refine this 7 db loss estimation. Calibrated equipment designed for NAVTEX reception should be used. Also, measurements should be performed on the different types of NAVTEX antennas, preferably in the end user area (open-ocean).

Table A-1. Representative DGPS station featuring 300 foot towers.

DGPS Station	Location	Frequency, Transmitter Power
Annapolis, MD	39 00.67 N, 076 36.35 W	301 kHz, 900 W
Driver, VA	36 57.48 N, 076 33.44 W	289 kHz, 900 W
Kodiak, AK	57 37.1413 N, 152 11.6164 W	313 kHz, 500 W
Level Island, AK	56 28.01 N, 133 05.58 W	295 kHz, 550 W



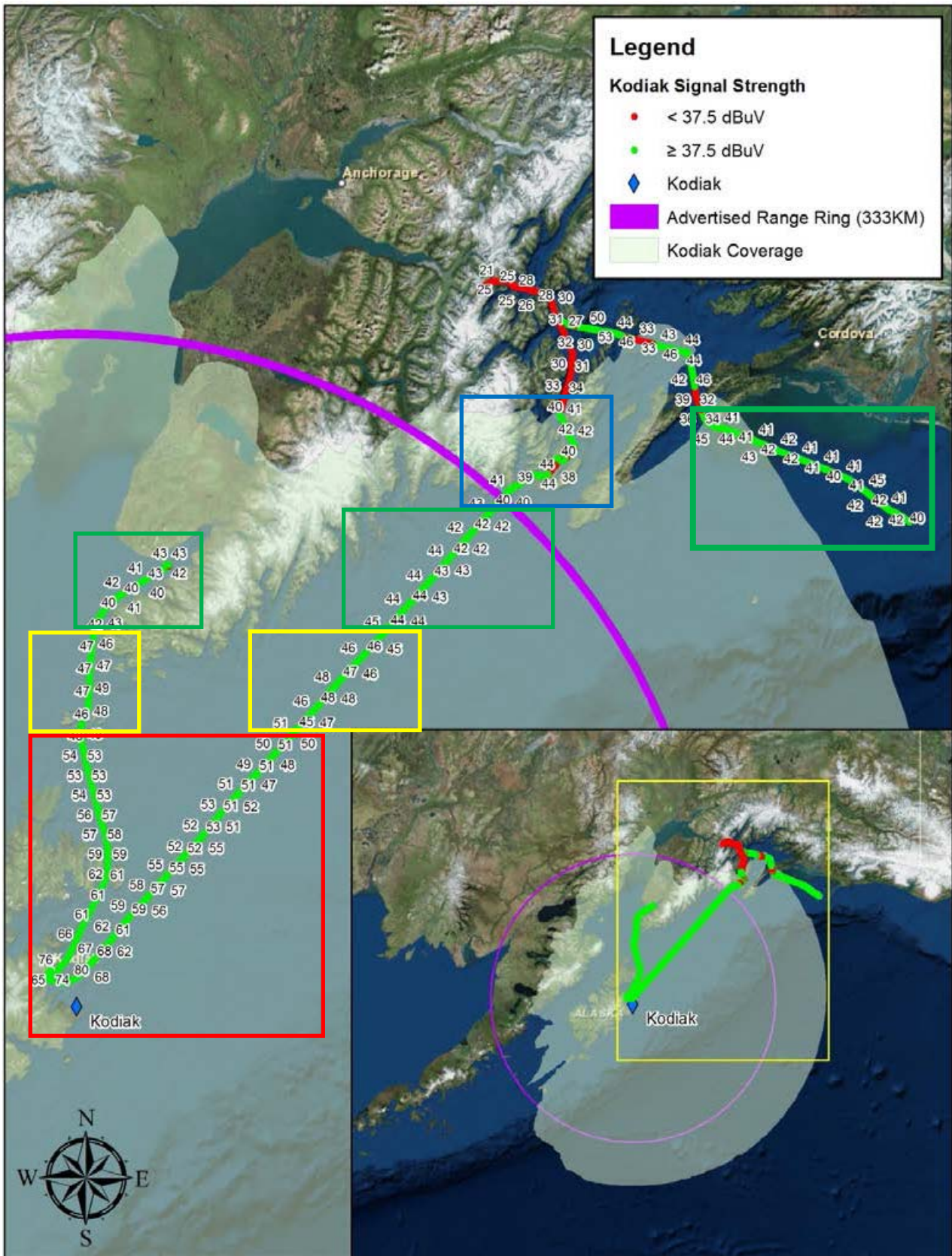


Figure A-1. Excerpt from the July 2014 Kodiak, AK GPS (DGPS) site operations assessment.



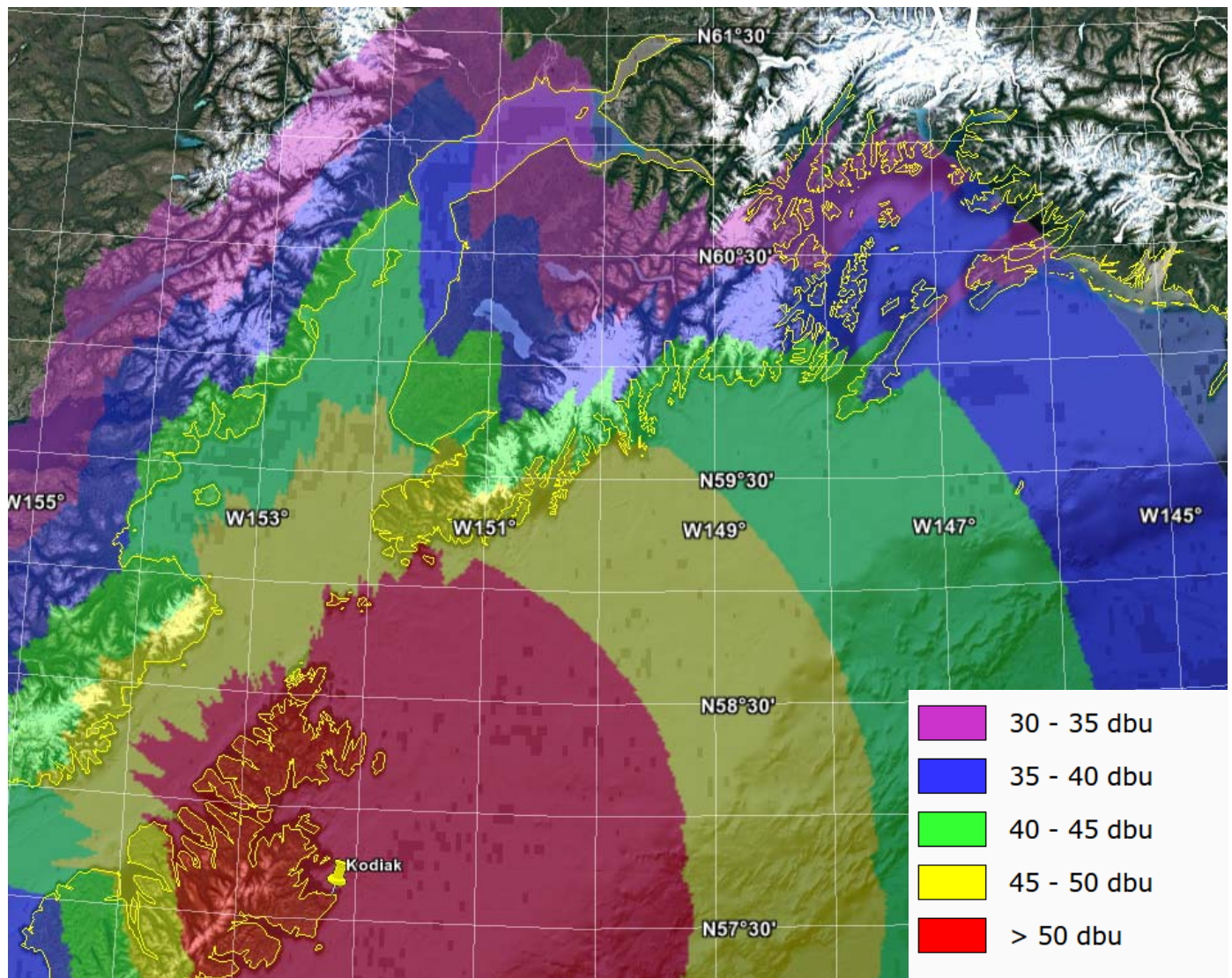


Figure A-2. Kodiak, AK DGPS coverage forecast assuming a 7 dB antenn loss.



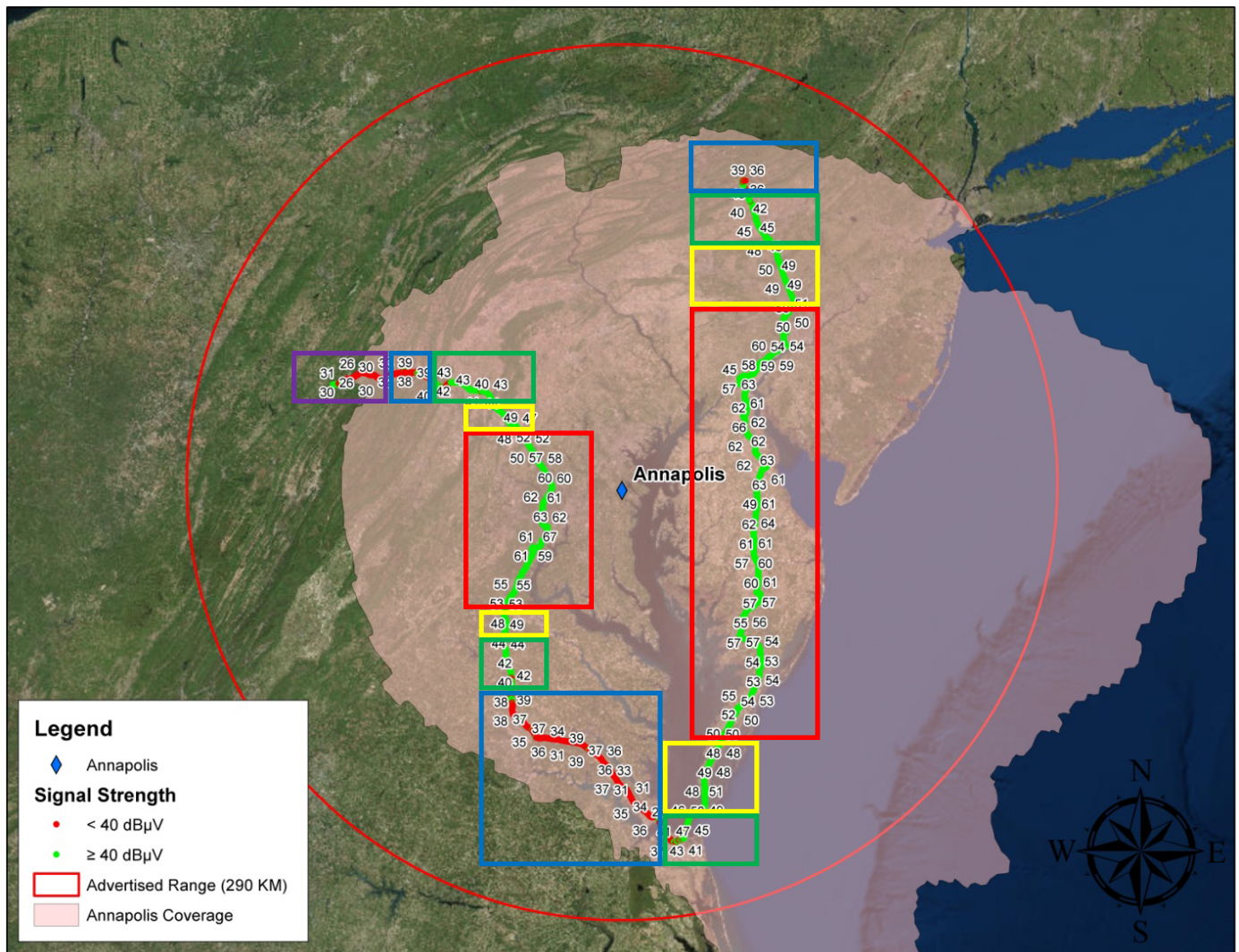


Figure A-3. Excerpt from the March 2015 Annapolis, MD DGPS site operations assessment.



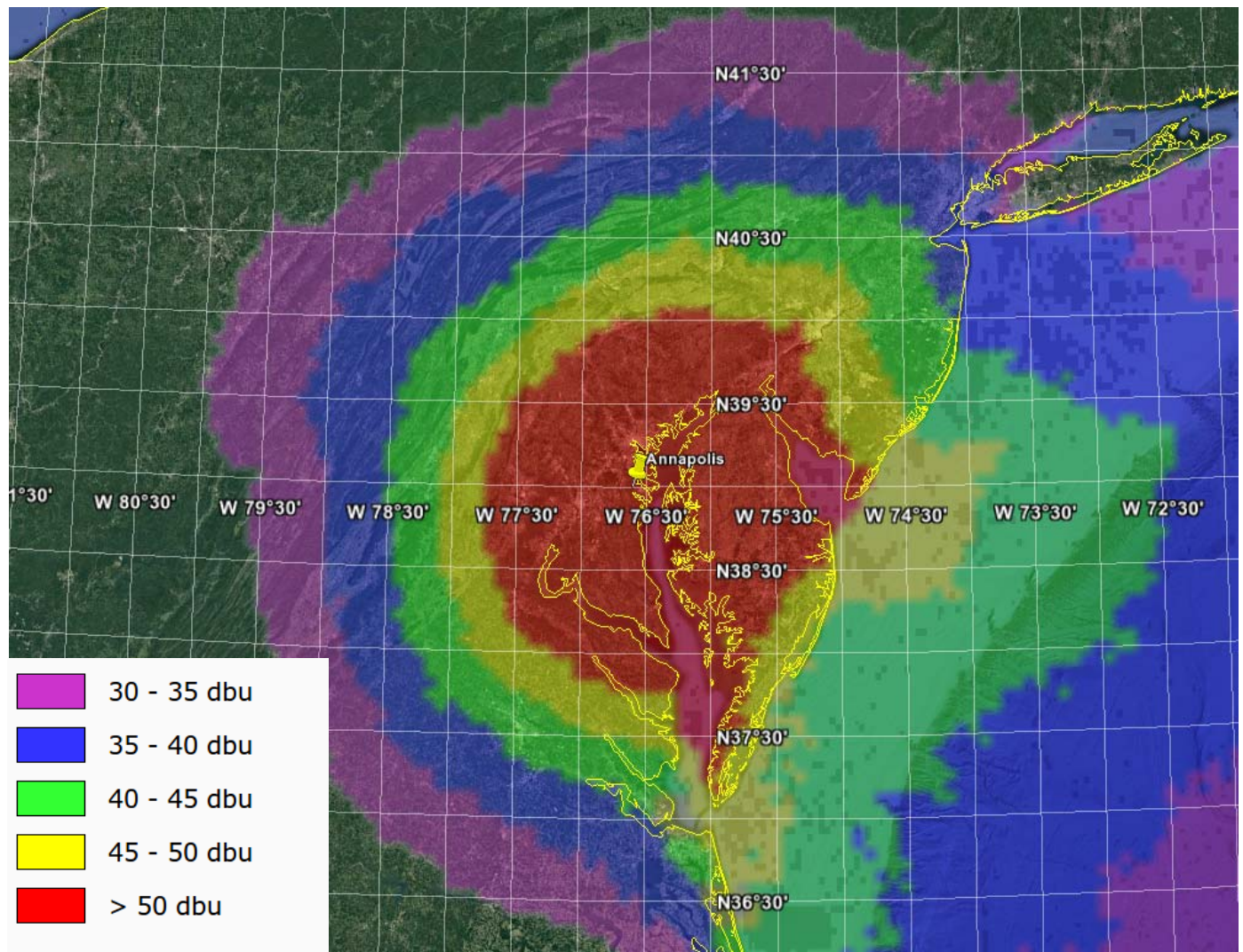


Figure A-4. Annapolis, MD DGPS coverage forecast assuming a 7 dB antenna loss.



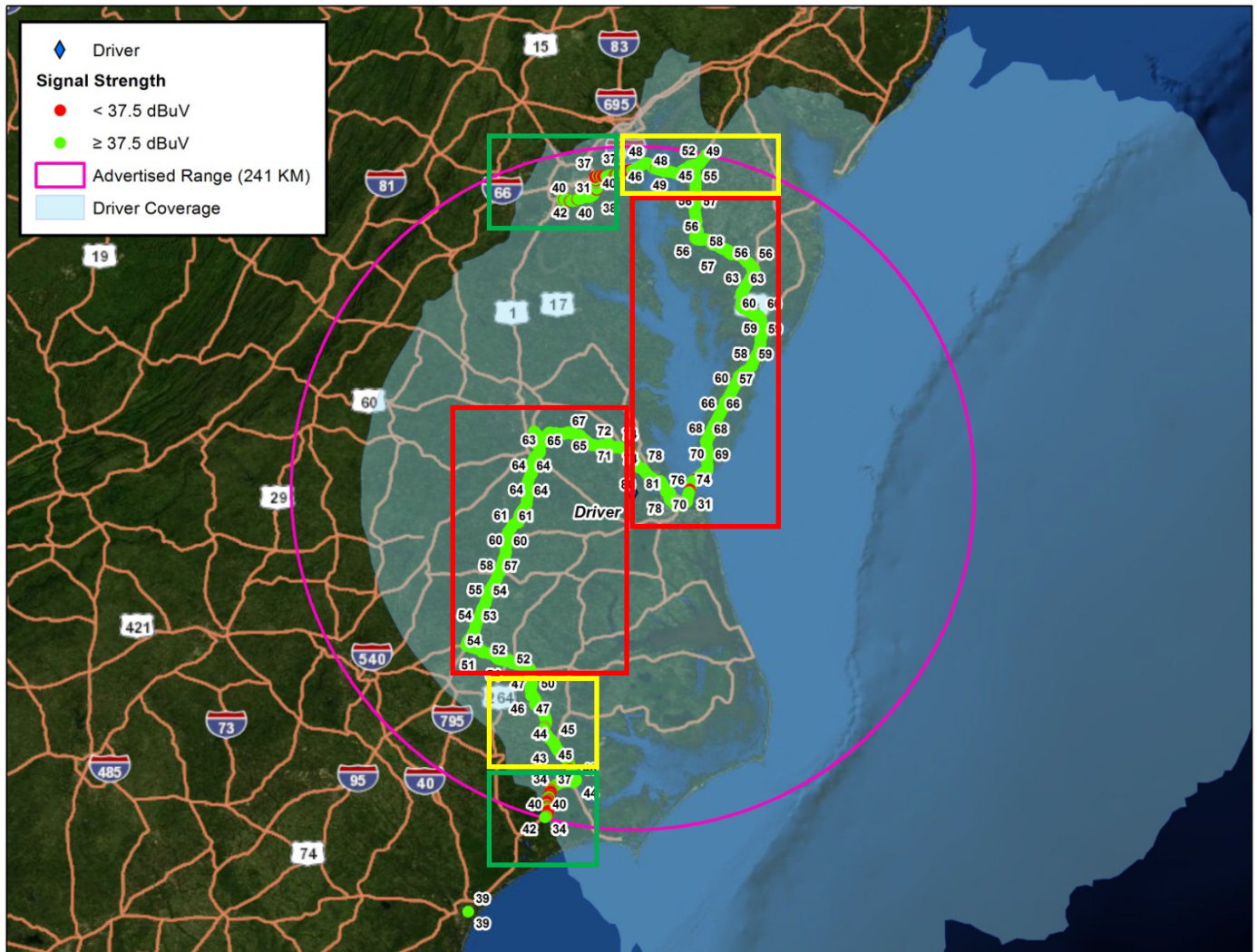


Figure A-5. Excerpt from the July 2013 Driver, VA DGPS site operations assessment.

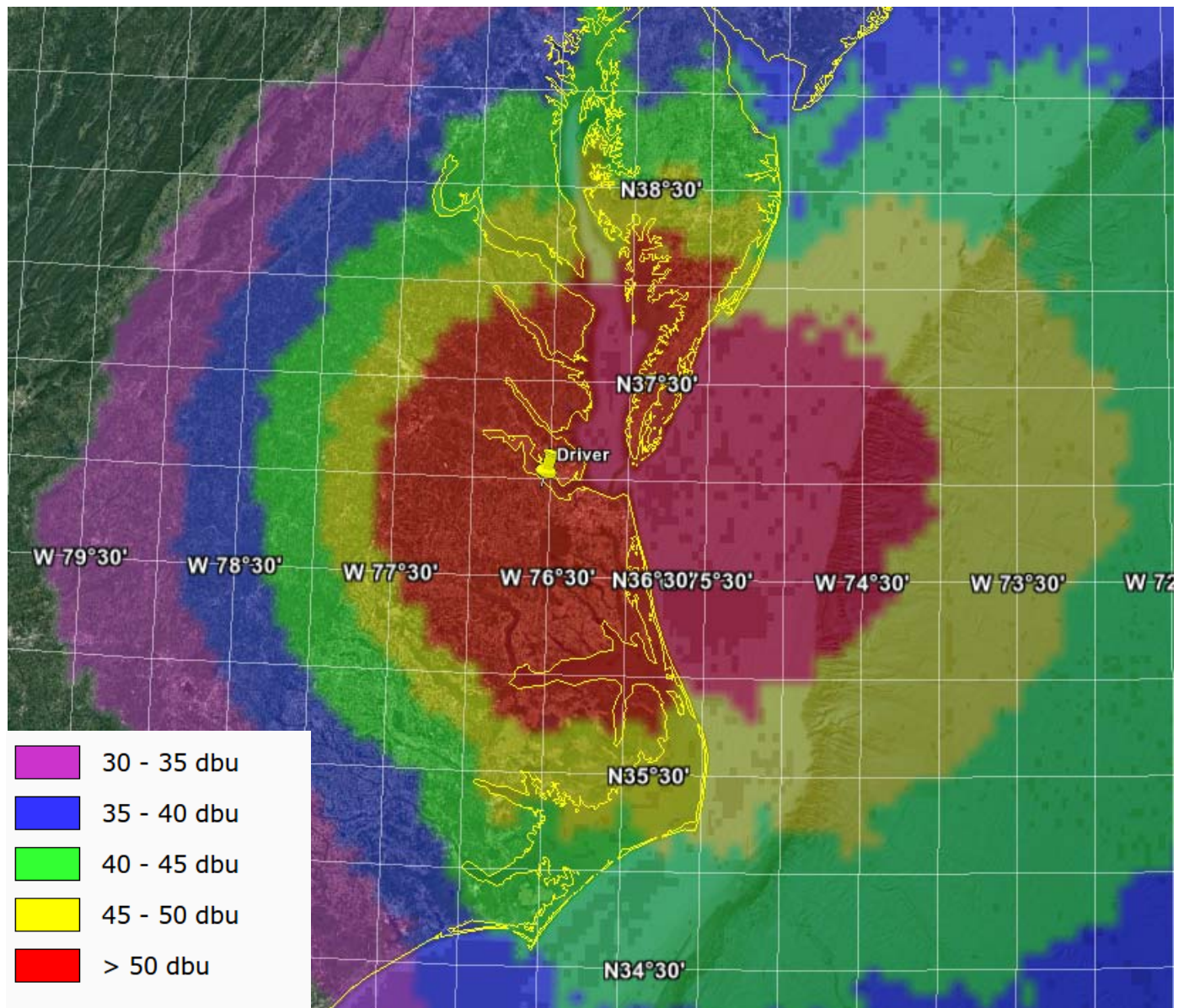


Figure A-6. Driver, VA DGPS coverage forecast assuming a 7 dB loss.



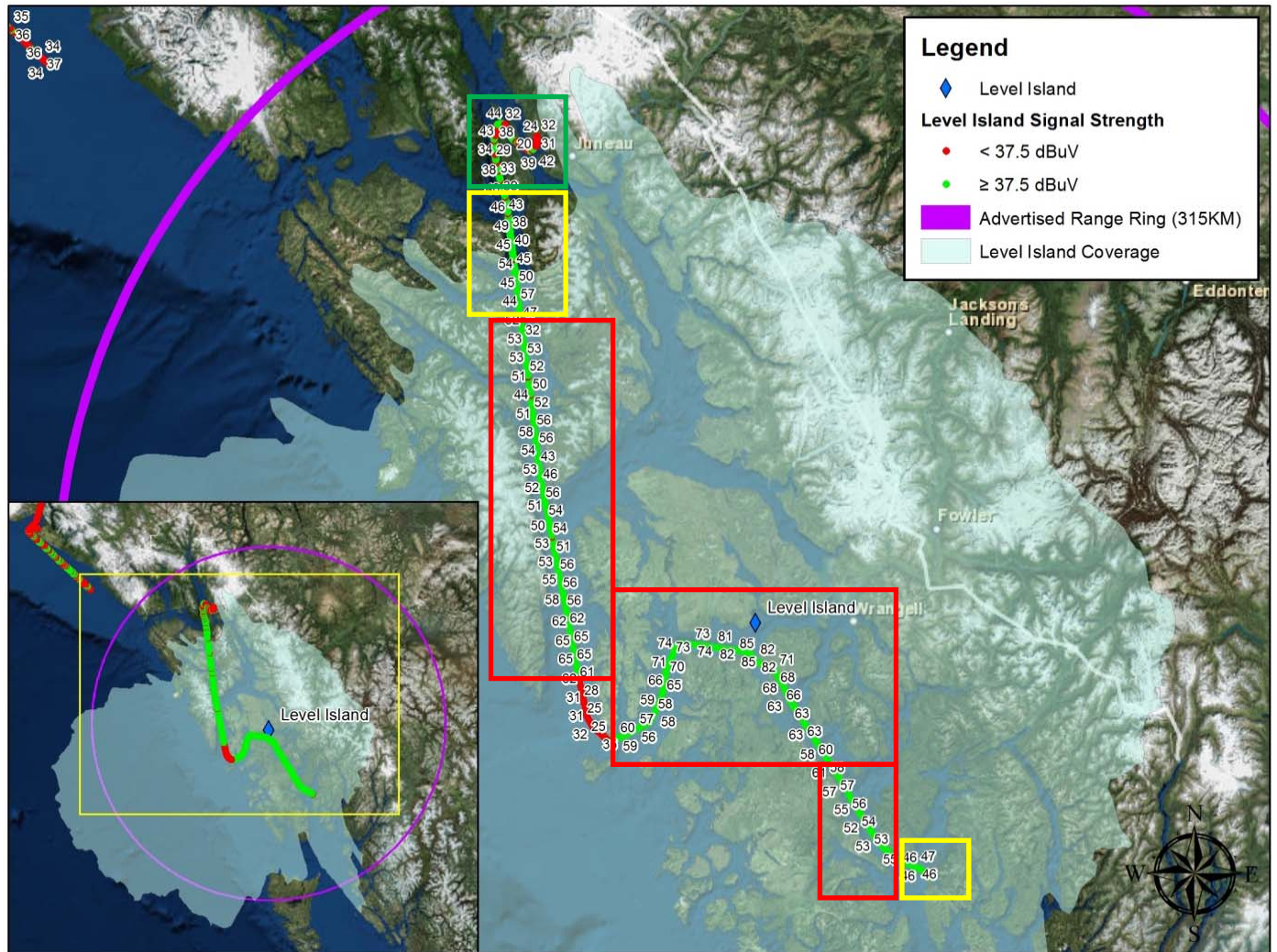


Figure A-7. Excerpt from the July 2014 Level Island, AK DGPS site operations assessment.

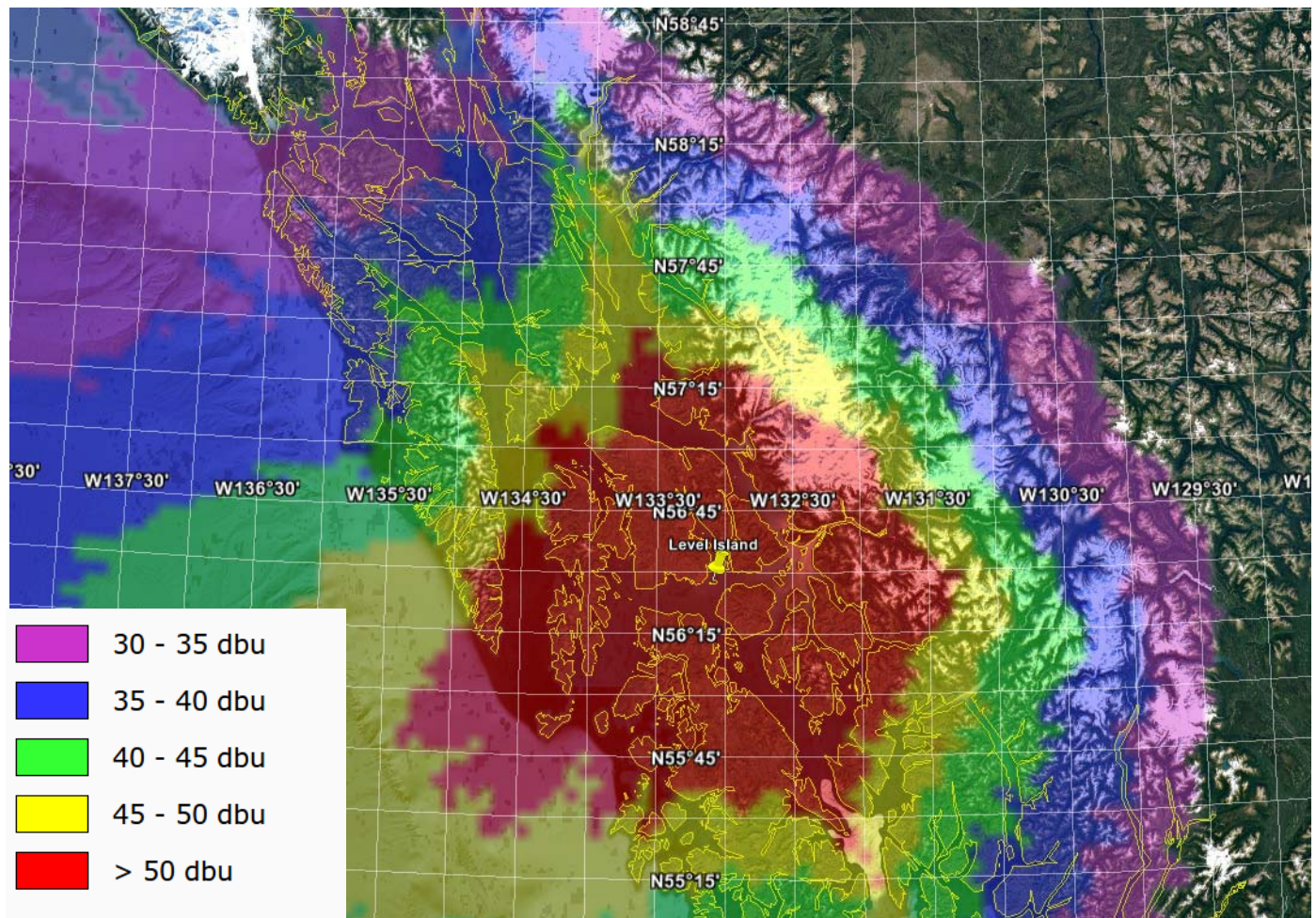


Figure A-8. Level Island , AK DGPS coverage forecast assuming a 7 dB loss.



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