The background of the slide is a complex collage. On the left, a tall radio tower with multiple antennas is shown in a golden-yellow hue. On the right, a close-up of a woman's face is visible, looking slightly to the side, with a soft, warm glow. The bottom right corner features a dark background with glowing binary code (0s and 1s) in a golden-yellow color. The entire composition is framed by a thin black border.

# Wyoming Radio Coverage Analysis

Presented to:  
**Federal Engineering,  
Inc.**

Prepared by:  
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Corporation**

## **TABLE OF CONTENTS**

<b>I.</b>	<b>INTRODUCTION</b>	<b>3</b>
<b>II.</b>	<b>DEFINITIONS AND ACRONYMS</b>	<b>5</b>
<b>III.</b>	<b>EVALUATION TOOLS</b>	<b>7</b>
	<b><u>A. EDX Signal Pro Software</u></b>	<b>7</b>
	<b><u>B. Grayson Invex 3G</u></b>	<b>9</b>
<b>IV.</b>	<b>EVALUATION THEORY</b>	<b>10</b>
	<b><u>A. Developing the Groupings for Analysis</u></b>	<b>10</b>
	<b><u>B. Coverage Analysis</u></b>	<b>12</b>
<b>V.</b>	<b>TASK 4.1 RESULTS AND RECOMMENDATIONS</b>	<b>13</b>
	<b><u>A. Specific State Agencies</u></b>	<b>14</b>
	<b><u>B. State Mutual Aid</u></b>	<b>14</b>
	<b><u>C. Fire</u></b>	<b>15</b>
	<b><u>D. Law Enforcement</u></b>	<b>15</b>
	<b><u>E. Local Government</u></b>	<b>16</b>
	<b><u>F. Medical and Special Emergency</u></b>	<b>16</b>
	<b><u>G. Road and Bridge</u></b>	<b>17</b>
	<b><u>H. BLM and DOI</u></b>	<b>18</b>
<b>VI.</b>	<b>TASK 4.1.1 RESULTS</b>	<b>18</b>
<b>VII.</b>	<b>TASK 4.2 RESULTS AND RECOMMENDATIONS</b>	<b>20</b>
<b>VIII.</b>	<b>INDEX OF EXHIBITS</b>	<b>22</b>

## I. INTRODUCTION

Composite analysis of approximately 555 existing Wyoming radio communications sites was performed to provide estimated statewide mobile talk-out and mobile talk-in coverage maps. Science Applications International Corporation (SAIC) utilized the Anderson 2D algorithm in the EDX Signal Pro 3.2 Propagation Model to generate the resulting maps. The TIA/EIA Telecommunications System Bulletin TSB88-A (Wireless Communications Systems - Performance in Noise and Interference-Limited Situations - Recommended Methods for Technology - Independent Modeling, Simulation, and Verification) was used as a guide for applying appropriate losses and determining signal strength values to obtain specific audio quality levels. At the request of the customer, the results were displayed in the following groupings:

Specific State Agencies	Local Government
State Mutual Aid	Medical and Special Emergency
Fire	Road and Bridge
Law Enforcement	BLM and DOI

Exhibit 1 (Wyoming Radio Communications Analysis, Groupings Analyzed) contains a list of agencies that had base/repeater sites that were utilized to determine statewide composite coverage. For each site, data was provided by Federal Engineering or entities within the State of Wyoming. When data was missing or inaccurate, the data was verified and/or corrected. When verification and correction was unachievable or impractical, sound engineering assumptions were applied to the data sets. Specific assumptions will be described later.

Results indicate that each grouping had overall coverage throughout the state with the exception of specific areas. No grouping had excellent coverage in 95% of the mass area of Wyoming. The specific areas with deficiencies in coverage area are described in Section V. (Tasks 4.1 Results and Recommendations). The summarized results are as follows:

- Every grouping had significant deficiencies in Park County, Teton County, the northern and/or western portion of Lincoln County, Sheridan County, the northern portion of Johnson County (Law Enforcement, Medical and Special Emergency, and Road & Bridge were not as significant), the northern portion of Sublette County (Fire had particular deficiencies in the entire County), and Campbell County (Law Enforcement and Road and Bridge groups were not as significant).
- All groupings except Special State Agencies showed limited deficiencies in coverage, with the Fire grouping showing significant coverage deficiencies in Sweetwater County.
- The State Mutual Aid system had limited deficiencies in Uinta County.
- The State Mutual Aid, Fire, Medical and Special Emergency, and Road and Bridge groupings had limited deficiencies in Big Horn County.

- The State Mutual Aid, Fire, Local Government, Medical and Special Emergency, Road and Bridge, and BLM and DOI groupings had limited deficiencies in Fremont County, with the Fire, Medical and Special Emergency and BLM and DOI groupings showing significant deficiencies.
- The State Mutual Aid, Fire, Law Enforcement, Local Government, Medical and Special Emergency, and BLM and DOI groupings had limited deficiencies in Natrona County, with the Fire, Local Government, and BLM and DOI groupings showing significant deficiencies.
- All groupings showed limited deficiencies in coverage, with the Fire, and Medical and Special Emergency groupings showing significant coverage deficiencies in Carbon County.
- The Special State Agency, Law Enforcement, Road and Bridge, and BLM and DOI groupings had limited deficiencies in Converse County. The State Mutual Aid, Fire, Local Government, and Medical and Special Emergency groupings had significant deficiencies in Converse County.
- The Special State Agency, State Mutual Aid, Fire, Medical and Special Emergency, and Road and Bridge groupings had limited deficiencies in Hot Springs County.
- The Special State Agency, State Mutual Aid, Fire, Road and Bridge, and BLM and DOI groupings had limited deficiencies in Hot Springs County. The Medical and Special Emergency grouping had significant deficiencies in Hot Springs County.
- The State Mutual Aid, Fire, Law Enforcement, and Road and Bridge groupings had limited deficiencies in Albany County. The Medical and Special Emergency, BLM and DOI groupings had significant deficiencies in Albany County.
- The State Mutual Aid, Fire, Law Enforcement, Medical and Special Emergency and Road and Bridge groupings had limited deficiencies in Laramie County. The BLM and DOI grouping had significant deficiencies in Laramie County.
- The State Mutual Aid, Fire, Law Enforcement, and BLM and DOI groupings had limited deficiencies in Goshen County. The Medical and Special Emergency grouping had significant deficiencies in Goshen County.
- The State Mutual Aid, Fire, and Law Enforcement groupings had limited deficiencies in Platte County. The Medical and Special Emergency grouping had significant deficiencies in Platte County.
- The State Mutual Aid, and Medical and Special Emergency groupings had limited deficiencies in Niobrara County. The Fire, Local Government, BLM and DOI grouping had significant deficiencies in Niobrara County.
- The Local Government, and Medical and Special Emergency groupings had limited deficiencies in Weston County. The Fire, and BLM and DOI groupings had significant deficiencies in Weston County.
- The State Mutual Aid, Local Government, and BLM and DOI groupings had significant deficiencies in Crook County.
- Overall, when all sites were combined to evaluate coverage performance statewide, significant deficiencies occurred in Park, Teton, Lincoln, Sheridan, and the northern portion of Sublette Counties. Limited coverage performance deficiencies occurred in Fremont, Sweetwater, Johnson, Natrona, Carbon, Campbell, Converse, Albany, Crook, Weston, and Niobrara Counties.

## II. DEFINITIONS AND ACRONYMS

- A. **AMSL - Above Mean Sea Level**
- B. **BAPC - Bounded Area Percent Coverage** - “The number of tiles within a bounded area which contain a tile margin equal or greater than that specified above the CPC requirement, divided by the total number of candidate tiles within the bounded area.”<sup>1</sup>
- C. **BLM - Federal Bureau of Land Management**
- D. **CPC - Channel Performance Criteria** - “A ratio of the minimum Rayleigh faded carrier magnitude to the sum of all the appropriate static or faded distortion sources. It is the signal strength value that correlates to a specific Delivered Audio Quality.”<sup>1</sup> The CPC should be in the form of  $C_r/(\Sigma I + \Sigma N)$  and is referenced to the receiver sensitivity at 12 SINAD.
- E. **DAQ - Delivered Audio Quality** - “A reference similar to Circuit Merit with additional definitions for digitized voice and a static SINAD equivalent intelligibility when subjected to multipath fading.”<sup>1</sup>
- F. **DOI - Federal Department of Interior**
- G. **EIA - Electronics Industry Alliance**
- H. **ERP - Effective Radiated Power** - The output power radiating from the antenna of a transmitting device, which typically includes the output power of the transmitter itself, the losses of cables and connectors, and the gain or loss of an antenna.
- I. **FCC - Federal Communications Commission** - the Federal agency which governs local and state government public safety frequency pools and the rules that must be followed when using the spectrum.
- J. **FE - Federal Engineering, Incorporated**
- K. **HP - Wyoming Highway Patrol**
- L. **Receiver** - the portion of a mobile radio, portable radio, or base/repeater station that listens for information sent out from another piece of equipment.

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<sup>1</sup> TIA/EIA Telecommunications Systems Bulletin, *Wireless Communication Systems – Performance in Noise and Interference-Limited Situations – Recommended Methods for Technology-Independent Modeling, Simulation, and Verification*, June 1999), Page 16.



- M. **RSS - Receiver Signal Strength** - is a measurement of signal strength received in a mobile radio, portable radio, base/repeater station or even a piece of test equipment from a given transmitter, referenced to a known value.
- N. **SAIC - Science Applications International Corporation**
- O. **SALECS - State Agency Law Enforcement Communications System**
- P. **Talk-In** - refers to the communications path from the mobile and portable radios back to the base/repeater station.
- Q. **Talk-Out** - refers to the communications path from the base/repeater station to the mobiles and portables.
- R. **TIA - Telecommunications Industry Association**
- S. **Transmitter** - the portion of a mobile radio, portable radio, or base/repeater station that sends out information to another piece of equipment.

### III. EVALUATION TOOLS

#### A. EDX Signal Pro Software

SAIC used the Anderson 2-D algorithm in the EDX SignalPro software to produce the complete set of projected communications coverage maps for the various systems coverage area within the State of Wyoming. These coverage maps indicate 95% tile reliability, (~500-m-square tiles), and minimum 98% Bounded Area Percent Coverage (BAPC).

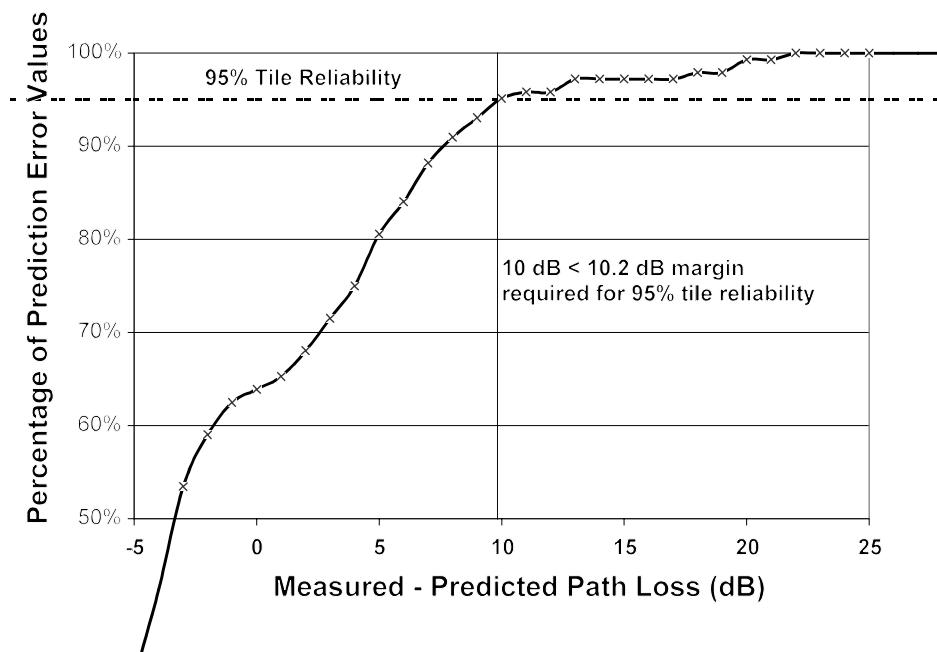
A key reason that the Anderson 2D algorithm in the EDX SignalPro® Propagation Model was judged most applicable for Wyoming coverage projections was because it was recommended for LMR applications after extensive study by Working Group 8.8 (WG 8.8) of the Land Mobile and Private Radio Section (TR-8) of the Telecommunications Industry Association (TIA). This recommendation was based on the TR-8 WG 8.8 objective to develop a single propagation prediction tool recommended for use by system designers and frequency coordinators in planning land mobile radio (LMR) systems like the various Wyoming radio systems. TR-8 WG 8.8 published their recommendation in *Wireless Communication Systems – Performance in Noise and Interference-Limited Situations – Recommended Methods for Technology-Independent Modeling, Simulation, and Verification*, also known as “TSB-88-A” (a TIA/EIA Telecommunications Systems Bulletin, June 1999).

Anderson 2D algorithm validation was performed by calculating the difference (prediction error) between path-loss values predicted by the Anderson 2D algorithm in the EDX SignalPro® Propagation Model for specific radio propagation links and the corresponding measured values of path loss for test links. A total of 144 measurements were used for this purpose. The probability distribution of the prediction error for these 144 measurements was plotted to show that 95% of this error was less than the 10.2 dB margin added to the median path-loss predictions from the Anderson 2D algorithm in the EDX SignalPro® Propagation Model. In this way, SAIC demonstrated that 95% tile reliability was achieved with coverage projections for 156.8 MHz at a 3.4 Delivered Audio Quality (DAQ) as defined in TSB-88-A.

Data chosen for validation included results of measurements at 173 MHz by the Institute of Telecommunications Sciences (ITS) made in the 1960’s and 1970’s. The radio path lengths of these measurement links were approximately 20 km (12 mi) and 50 km (31 mi). These paths had from zero to eight obstacles (ridges, mountains, and hills) between the transmitter and receiver, with at most, three obstacles at the 20-km distance. Median measured path-loss values were provided for these

links by the NTIA [<sup>2</sup>, <sup>3</sup>, <sup>4</sup>].

**Figure 1** shows a plot of the cumulative distribution of prediction error in median path loss for a total of 144 radio paths – many obstructed - for various antenna heights at frequencies of 150.9, 161.3, 171.3, and 173 MHz and propagation path lengths between 20 and 50 km. (Similar measured data is available for model validation in other frequency bands as can be seen by the references below.) The figure shows that 95% of the prediction error values were less than 10 dB above the predicted value. In other words, 95% of the measured median path-loss values were less than 10 dB more than the corresponding path-loss values predicted by the Anderson 2D algorithm in the EDX SignalPro® Propagation Model.



*Figure 1. Cumulative Distribution of Median Path Loss Prediction Error*

Since SAIC adds the TSB-88A-recommended margin of 10.2 dB to account for clutter and prediction uncertainty, the resulting path-loss predictions should exceed the expected measured path-loss on 95% of LMR links like those used by NTIA. This result validates the use of the Anderson 2D

<sup>2</sup> McQuate, P. L. et al, *Tabulations of Propagation Data Over Irregular Terrain in the 230- to 9200-MHz Frequency Range, Part I: Gunbarrel Hill Receiver Site*, Environmental Science Service Administration (ESSA), ESSA Research laboratories ERL 65-ITS 58, US Department of Commerce, Boulder, CO, March 1968.

<sup>3</sup> McQuate, P. L. et al, *Tabulations of Propagation Data Over Irregular Terrain in the 230- to 9200-MHz Frequency Range, Part III: Ohio Data*, Institutes for Environmental Research IER 38-ITSA 38-3, Environmental Science Service Administration, US Department of Commerce, Boulder, CO, December 1967.

<sup>4</sup> Hufford, G., *Tabulations of Propagation Data Over Irregular Terrain in the 75- to 8400-MHz Frequency Range, Part V: Virginia Data*, NTIA Report 91-282, December 1991.



algorithm in the EDX SignalPro® Propagation Model plus the 10.2 dB margin for coverage projections to meet the 95% tile reliability requirement.

An additional 10.2 dB margin (9.2 dB clutter margin and 1 dB uncertainty margin) was added to median path loss values predicted by EDX SignalPro® for Windows® 98/NT/2000. This added margin was specified by subclause 6.8 of TSB 88-A to account for clutter margin and uncertainty margin in a faded environment.

**B. Grayson Invex 3G**

The Grayson Invex 3G test equipment (produced by Grayson Wireless Corp.) used for testing was configured with internal software for analysis, an analog VHF highband receiver, and a GPS unit with two magnetic mount antennas. In addition, software was installed on a laptop to capture the data received and for viewing analysis. The test equipment was calibration certified on February 19, 2003 (the certificate is provided as Exhibit 22). The receiver was programmed to record receiver signal strength at 156.105 MHz and 157.290 MHz. The threshold setting for distance and signal strength remained in the default settings. These settings allow the device to measure all ranges of signal strength and 1000 test points every 500 meters. The 1000 points are averaged and recorded.

## IV. EVALUATION THEORY

### A. Developing the Groupings for Analysis

Data was provided in four different formats, FEClientNet Survey database, the “additional survey information” file format, the FCC database format and the DOI file format. The data for the individual sites was separated by type of grouping and sorted. Data was separated into the following 8 groupings:

- Specific State Agencies (*i.e.*, WYDOT Maintenance, HP, SALECS, Wyoming State Forestry Division)
- State Mutual Aid
- Fire
- Law Enforcement
- Local Government
- Medical and Special Emergency
- Road and Bridge
- Bureau of Land Management and Department of Interior

The data groupings are detailed in Exhibit 1 (Wyoming Radio Coverage Assessment Groupings Analyzed).

When exact duplicate records within each grouping were identified, the duplicate records were removed leaving one entry for that record. In addition, duplicate sites containing everything identical except the frequency (in the same frequency band), as well as sites with duplicate latitude and longitude containing data lower than everything else in the first record were deleted. Finally, records that contained insufficient information to complete radio coverage analysis were removed. As a minimum, the information required to complete radio coverage analysis is:

- Latitude (degrees-minutes-seconds or decimal)
- Longitude (degrees-minutes-seconds or decimal)
- Tower height above ground (ft. or m.)
- Ground elevation at tower base (ft. or m. AMSL)
- Transmit and receive frequencies (MHz)
- Effective radiated power (watts or dBw)
- Antenna pattern
- Antenna azimuth (degrees)
- Antenna elevation (ft. or m.)

When data was missing or could easily be determined to be inaccurate, the data was verified and/or corrected with the end user. When verification and correction was unachievable or impractical, sound engineering assumptions were applied to the data sets, when reasonable assumptions could be made. Specific assumptions are described in Exhibit 2 (Wyoming Radio Coverage Analysis, Grouping

Assumptions for Data Analysis). The complete set of sites analyzed is described in Exhibit 23 (Evaluation Data).

Records in the FCC database were separated by service type as shown in the Federal Communications Rules and Regulations 47CFR, Part 90.20 which governs local and state government public safety frequency pools. The radio services found in the FCC data set provided are as follows:

<u>Radio Service Type:</u>	<u>Matched to:</u>
• PF--Fire Coordinator	Group 3: Fire
• PH--Highway Maintenance Coordinator	Group 7: Road and Bridge
• PM--Emergency Medical Coordinator	Group 6: Medical and Special Emergency
• PO--Forestry-Conservation Coordinator	Group 1: Specific State Agency
• PP--Police Coordinator	Group 4: Law Enforcement
• PS--Special Emergency Coordinator	Group 6: Medical and Special Emergency
• PW--Public Safety Coordinator	Matched to the other radio services based on frequency

Control stations were removed as it is generally assumed that control stations are not used to supplement coverage, but to provide connectivity between base stations and repeaters and a control point. Mobile station entries were then matched to FB (fixed bases), FB2 (repeaters), FBT (Temporary bases), and FB2T (Temporary repeaters) using call signs. If no mobile entry could be matched to a base or repeater, then the output power of the mobile was generally set to match the output power of the base/repeater. Specific exceptions to this generalization are described in Exhibit 2.

Once the data was combined and sorted, the information was converted to a consistent, usable format for use in the EDX program (*i.e.*, latitude and longitude into decimal format, ERP into dBw, and meters into feet). If a base, repeater, or mobile ERP was present in the data sets, the ERP was converted and used directly in the coverage calculations. When ERP was not shown, then it was calculated. Specific exceptions to the ERP analysis is shown in Exhibit 2. Finally, the data was copied to a new worksheet and data that was unnecessary to the coverage analysis was eliminated. The following resultant data was entered into EDX:

- Filename (Composed of grouping, call sign or system name, area of operation, unique system number - when needed)
- Frequency (MHz)
- Base/Repeater ERP (dBw)
- Base/Repeater Antenna Height above ground level (ft)
- Site Elevation AMSL(ft)
- Mobile ERP (dBw)

## B. Coverage Analysis

The Delivered Audio Quality values associated with specific calculated signal strength values were calculated with a Faded Performance Threshold using the algorithms found in the Telecommunications Industry Association's, "Wireless Communications Systems – Performance in Noise and Interference-Limited Situations – Recommended Methods for Technology-Independent Modeling, Simulation and Verification," (TIA/EIA Technical Service Bulletin TSB-88-A, January 1998, June 1999) on page 114. The results of these calculations are shown in Exhibit 3, "Channel Performance Criteria." The delivered audio quality scale utilized to determine actual DAQ levels is based on the receiver sensitivity provided by each user, and is assumed to reference 12 dB SINAD. The Delivered Audio Quality points displayed on the resultant maps were DAQ 3 (Orange), DAQ 3.4 (Blue) and DAQ 4 (Green). These are described below along with all the DAQ levels described in TSB-88-A.

### TIA/EIA Delivered Audio Quality definitions:

DAQ 1	Unusable. Speech present but not understandable.
DAQ 2	Understandable with considerable effort. Frequent repetition due to Noise/ Distortion.
DAQ 3	Speech understandable with slight effort. Occasional repetition due to Noise/ Distortion.
DAQ 3.4	Speech understandable with repetition only rarely required. Some Noise/ Distortion.
DAQ 4	Speech easily understood. Occasional Noise/ Distortion.
DAQ 4.5	Speech easily understood. Infrequent Noise/ Distortion.
DAQ 5	Speech easily understood.

The maps represent the resultant coverage of every site analyzed by EDX displayed so that the estimated RSS in each tile is the resultant value based on the contribution from all surrounding towers.

The Coverage Model will use the Land Use Land Clutter (LULC) database provided by EDX, which is based on the USGS LULC database. This data shows areas that are forested, densely urban or residential, among other categories. This data helps the engineer define signal attenuation versus frequency for each of the clutter types used in the database.

The LULC data used for the EDX database was contained in files derived from 1:250,000 and 1:100,000 scale maps dating from the 1970s. The following describes the categories found in the LULC data:

- Open land
- Agricultural
- Range Land

- Water
- Forest land
- Wetland
- Residential
- Mixed Urban/Buildings
- Commercial/Industrial
- Snow and Ice

The EDX provided LULC data grid was converted from the original LULC data to a 6 arc second (north-south) by 8 arc second (east-west) grid which results in an approximate dimension of 200 meter by 200 meter grid.

## V. TASK 4.1 RESULTS AND RECOMMENDATIONS

A mobile talk-in and talk-out map has been created for each grouping, which depicts the estimated 95% tile reliability within the State of Wyoming. The results are described generally by referencing the following county map. The points of concern described below represent areas for recommended improvement for individual groupings (white areas on exhibits).

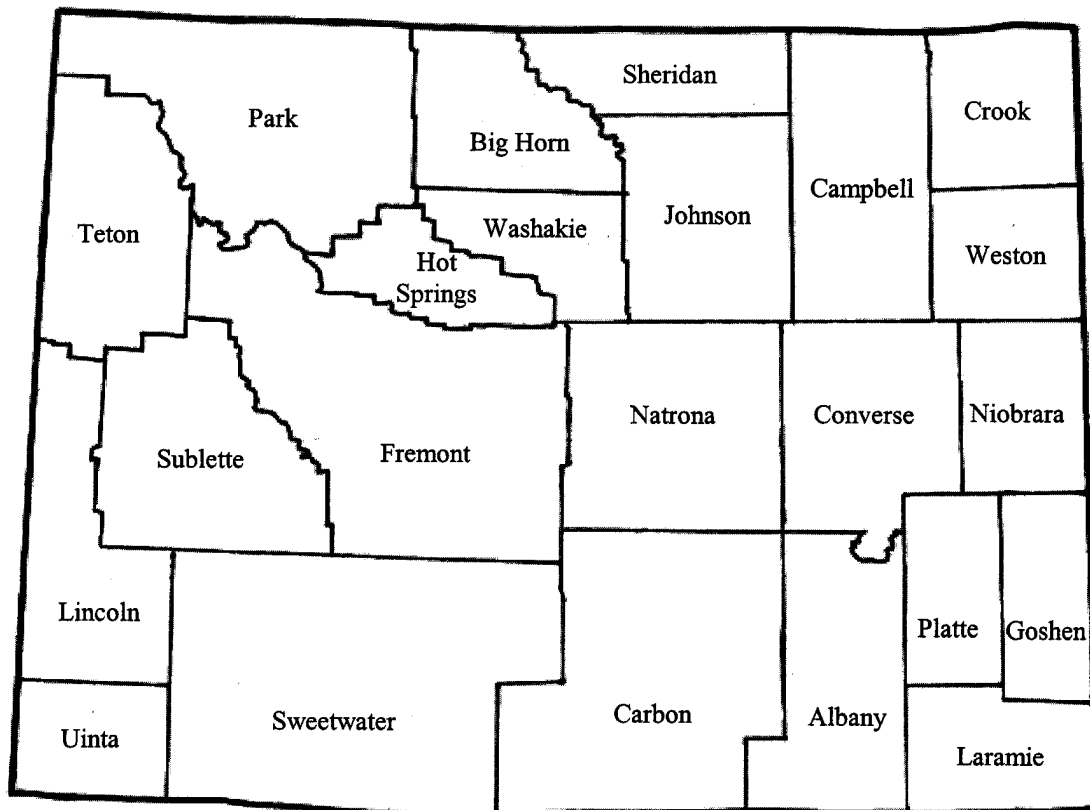


Exhibit 23 (Wyoming Radio Coverage Analysis Talk-in and Talk-Out Summary) provides a quick summary of the findings of each of the coverage maps indicating where the coverage gaps are generally located and whether they are significant, limited or minimal. If the term “Limited” or “Significant” is in a cell by itself, the coverage gap is dispersed throughout an entire county. If a “–” is displayed in a cell by itself, the coverage gap is minimal.

A. Specific State Agencies

1. Talk-In (Exhibit 4)

Coverage analysis indicates that most of Wyoming has excellent voice quality coverage for WYDOT maintenance, Highway Patrol, SALECS, and Wyoming State Forestry Division. However, there are specific significant areas of concern in:

- the western half of Park County,
- most of Teton County,
- the northern half of Lincoln County,
- most of Sheridan County,
- the northeastern three quarters of Johnson County,
- the northern portion of Campbell County,
- the northern portion of Converse County,
- the center portion of Washakie County along the interstate, and
- the southeastern portion of Carbon County.

2. Talk-Out (Exhibit 5)

Coverage analysis for talk-out is similar to talk-in for this grouping.

B. State Mutual Aid

1. Talk-In (Exhibit 6)

Coverage analysis indicates that much of Wyoming has excellent voice quality coverage for State Mutual Aid. However, there are specific significant areas of concern in:

- the western two thirds of Park County,
- most of Teton County,
- the northern half and the western portion of Lincoln County,
- small portions of Uinta County,
- a large majority of Sheridan County,
- the northern half of Johnson County
- the center portion of Washakie County along the interstate,
- the far eastern and far western portions of Hot Springs County,
- the southern portion of Fremont County,
- the northwestern portion of Converse County,
- the northern portion of Sublette County,
- various small areas of Sweetwater County,
- much of Platte County,
- areas along the border of Laramie County,
- much of Albany County,
- the southern and northeastern portion of Goshen County,



- the eastern half of Crook County,
- the northern half and the southern portion of Campbell County,
- the northern portion of Converse County, and
- the southeastern and northeastern portion of Carbon County.

2. Talk-Out (Exhibit 7)

Coverage analysis for talk-out is similar to talk-in for this grouping.

C. Fire

1. Talk-In (Exhibit 8)

Coverage analysis indicates that much of Wyoming does not have mobile talk-in coverage for fire agencies. The specific areas of concern are in:

- the western two thirds of Park County,
- most of Teton County,
- the western half of Lincoln County,
- most of Sublette County,
- a large majority of Sheridan County (coverage appears to exist along I-25),
- all areas except the northern half of Johnson County
- the center portion of Washakie County along the interstate,
- the southern and northwestern portions of Fremont County,
- the northern portion of Converse County,
- the eastern half of Sweetwater County,
- the center half of Natrona County (coverage appears to exist along I-25),
- most of Campbell County,
- the southern half of Weston County,
- small portions of the northern half of Platte and Goshen Counties,
- all of Niobrara County,
- small areas along the border of Albany County,
- areas along the border of Laramie County, especially the southeastern portion, and
- the southwestern half and the northwestern portion of Carbon County.

2. Talk-Out (Exhibit 9)

Coverage analysis for talk-out is similar to talk-in for this grouping. The Talk-out is slightly less in the western portion of Carbon County, eastern portion of Albany County, eastern portion of Sweetwater County, center portion of Natrona County, southern portion of Platte County, and the southern portion of Natrona County.

D. Law Enforcement

1. Talk-In (Exhibit 10)

Coverage analysis indicates that most of Wyoming has excellent voice quality coverage for local law enforcement agencies. However, there are specific significant areas of concern in:

- the western half of Park County,
- most of Teton County,
- small portions of the northern areas in Fremont and Sublette Counties,
- the western half of Lincoln County,

- small portions of the northwestern portion of Campbell County,
- most of Sheridan County,
- the northeastern portion of Johnson County,
- the areas from the northern portion of Converse County,
- the northern and southern portions of Platte and Goshen Counties,
- the northern portions of Laramie County,
- scattered portions of Albany County,
- scattered portions of Natrona County,
- scattered portion of Niobrara,
- the small portions of Sweetwater County, and
- the southern portion of Carbon County.

2. Talk-Out (Exhibit 11)

Coverage analysis for talk-out is similar to talk-in for this grouping. The Talk-out, however, is slightly better in all the counties.

E. Local Government (Exhibit 12)

1. Talk-In

Coverage analysis indicates that much of Wyoming has excellent voice quality coverage for local government agencies. However, there are specific significant areas of concern in:

- the western half of Park County,
- most of Teton County,
- the northern portion of Lincoln County,
- a small portion of the northwestern part of Fremont County,
- the northwestern portion of Sublette County,
- most of Sheridan County (east and west),
- the eastern two thirds of Johnson County,
- various areas within Natrona County,
- the northern portion of Converse and Niobrara Counties,
- the southwestern portion of Weston County,
- the western half of Campbell County,
- the northeastern two thirds of Crook County,
- the southern portions of Sweetwater County, and
- the northern and southern portions of Carbon County.

2. Talk-Out (Exhibit 13)

Coverage analysis for talk-out is similar to talk-in for this grouping. The Talk-out, however, is slightly better in most counties.

F. Medical and Special Emergency

1. Talk-In (Exhibit 14)

Coverage analysis indicates that some of Wyoming has excellent voice quality coverage for medical agencies and agencies that utilize special emergency frequencies. However, there are specific significant areas of concern in:

- the far western and large middle portions of Park County,

- the eastern and western portions of Teton County,
- the south and large portion of the northwestern areas in Fremont County,
- the northern portion of Sublette County,
- the center north and southern portions of Sweetwater County,
- various small areas within Hot Springs County,
- the western half of Lincoln County,
- most of Sheridan County (east and west),
- small portion of Northeastern Johnson County,
- small center portions of Big Horn County,
- the center portions along the interstate and small portion of western Washakie County,
- the small portions throughout Natrona County,
- the northeastern half of Converse County,
- the northern half of Albany County,
- the central portions of Niobrara County,
- most of Platte County,
- the northern half of Goshen County
- the northwestern portion of Laramie County,
- the northern portion of Campbell County, and
- the southern half and northeastern portions of Carbon County.

#### 2. Talk-Out (Exhibit 15)

Coverage analysis for talk-out is similar to talk-in for this grouping. The Talk-out, however, is slightly better in most counties.

### G. Road and Bridge

#### 1. Talk-In (Exhibit 16)

Coverage analysis indicates that most of Wyoming has excellent voice quality coverage for Road and Bridge agencies. However, there are specific significant areas of concern in:

- the western two thirds of Park County,
- the northern half and southeastern portions of Teton County,
- the southern areas and along the western border in Fremont County,
- small northern and southern portions of Sublette County,
- small northern, eastern, and southern portions of Sweetwater County,
- the western half of Lincoln County,
- various areas of Sheridan County,
- small portions in northwest and along I-25 in central Johnson County,
- the center portion of Washakie County along the interstate,
- small portions along the western and eastern borders of Hot Springs County,
- the northern portion of Converse County,
- small areas throughout of Albany County,
- the northern and eastern portions of Laramie County,
- small northern and southern portions of Campbell County, and
- the southern portions of Carbon County.

2. Talk-Out (Exhibit 17)

Coverage analysis for talk-out is similar to talk-in for this grouping. The Talk-out, however, is slightly better in all the counties, except Goshen, Platte, and Converse Counties, which was slightly worse.

H. BLM and DOI

1. Talk-In (Exhibit 18)

Coverage analysis indicates that most of Wyoming has excellent voice quality coverage for BLM and DOI. However, there are specific significant areas of concern in:

- small portions of western and the southern and center third of Park County,
- small portions of western and the eastern portion of Teton County,
- the western portion of Fremont County,
- small northern portions of Sublette County,
- the northern and western portion of Lincoln County,
- all of Sheridan County,
- the northern portion and small pockets of areas all I-25 in Johnson County,
- small pockets along the interstate in Washakie County,
- the southeastern portion and small pockets of northern Natrona County,
- the northeastern portion and a small portion of southwestern Converse County,
- the southern portion of Albany County,
- the southern half of Laramie County,
- the northern and eastern half of Campbell County,
- most of Crook County beyond approximately 10 miles of each tower,
- the western half of Weston County,
- most of the northern two thirds of Niobrara County,
- small portions of Goshen County, and
- small southern portions of Sweetwater and Carbon Counties.

2. Talk-Out (Exhibit 19)

Coverage analysis for talk-out is similar to talk-in for this grouping. The Talk-out, however, is slightly better in most the counties, particularly in Crook County.

**VI. TASK 4.1.1 RESULTS**

Coverage validation testing was performed February 25, 2003 (between approximately 9:00*a.m.* and approximately 7:30*p.m.*) to determine the comparability between the calculated signal strength using the EDX software with the technical data provided and the actual signal strength measured in the field. The weather conditions for testing were cold but clear. Participants included Larry Sheridan of WYDOT, Brian Merrell of SAIC, and Katherine Epstein-Leis of SAIC. Mr. Sheridan drove the vehicle, Mr. Merrell navigated, called out mile markers and reference locations and Ms. Epstein-Leis operated the Invex 3G and laptop equipment as well as manually recorded the findings as back up.

The Grayson Invex 3G software, as described in Section III. B. (on page 9), was loaded into a Compaq laptop computer for viewing and recording and was located in the back seat of the WYDOT

vehicle. The Invex 3G hardware was also located in the back seat and contained a GPS unit and a VHF analog receiver. The GPS unit was connected to a small magnetic mount antenna attached to the center roof of the WYDOT vehicle close to the window but in direct sight of available satellite receivers. The receiver was connected to a ½ wave dipole magnetic mount antenna located on the center roof of the vehicle.

Mr. Sheridan would begin a test sequence by depressing the PTT button and transmitting on the mobile talk-in frequency of 156.105 MHz . The signal would then be repeated back out and received by the Invex 3G on 157.290 MHz. The noise floor was verified as being significantly below the receive signal strength. The desense received at the time the PTT button was depressed was accounted for in the Invex 3G set up. A PTT was sufficient for determining what the signal strength would be when received by a mobile (and the Invex 3G), and would not interrupt communications on the actively utilized WYDOT maintenance channel.

The Invex 3G was set up to record the frequency of both channels, signal strength of the receive signal, latitude, longitude, type of record, the number of satellites captured, date, time and elevation. For each 500 meters, 1000 records were measured and an average value was recorded. The set up was completed in the parking lot of WYDOT maintenance, and pre-testing was performed on the way to the eastern state line along I-80. Seven files were created to verify that the Invex 3G was operating properly resulting in 25,413,000 test measurements and 25,413 average records.

The following describes the test route and the tower captured:

- Actual testing began on I-80 at the eastern state line proceeding west to SR-30. During this sequence transmissions from the Sherman Hill site were utilized.
- The testing proceeded north on SR-30 to SR-487. During this sequence transmissions from the Sherman Hill site were utilized.
- The testing proceeded north on SR-487 to SR-220. During this sequence testing continued with the Sherman Hill site. At mile 3, Casper, Sherman Hill and Shirley sites were evaluated to determine the strongest signal. From that point forward testing alternated between the Sherman Hill and Shirley sites. At mile marker 45, testing alternated between the Casper and Shirley sites.
- The testing proceeded north on SR-220 to I-25. During this sequence the transmissions from the Casper site were utilized.
- The testing proceeded east then south on I-25 to the southern state line. During this sequence testing alternated between the Casper and Morton sites until mile marker 121, where testing remained on the Morton site. At mile marker 102, testing alternated between the Morton and Virgin Hill sites. At mile marker 85, testing alternated between the Virgin Hill and Hill 77 sites. At mile marker 70, testing remained on the Virgin Hill site. At mile marker 45, testing alternated between the Virgin Hill and Sherman Hill sites. At mile marker 13, testing remained on the Sherman Hill site to the state line.

During the testing, eight records were created resulting in 110,780,000 test measurements and 110,780 averaged records. During testing we manually listened to the conversations that occurred

in the same test area and the conversations matched the expected DAQ readings given the signal strength levels recorded.

The assumptions used to determine the losses used in the calculations to compare the EDX predicted signal strength and the actual measured signal strength are found in Exhibit 2 (Wyoming Radio Coverage Analysis, Grouping Assumptions for Data Analysis).

Manual analysis was required to compare the results of coverage testing versus coverage calculations. Because the EDX software does not generate a spreadsheet containing the latitude, longitude and predicted signal strength that can be utilized outside of the software, SAIC had to compare the results of the Invex 3G values to EDX values by manually finding the latitude and longitude on the computer screen and reading the signal strength. The dozen randomly selected test points for comparison all came within 2 dB of calculated values from EDX predications. These points were determined to be the intersections of the state road and county roads when a new file was created and randomly in-between these intersections where manual recordings were made during testing. The identified manual recordings were located in the Invex 3G datasets and then again on the EDX software map. Since values of signal strength appeared to match the DAQ levels experienced while listening to conversations, and the randomly evaluated test points all came within 2dB of EDX predicted values, SAIC feels testing provided a high confidence level that the EDX predictions accurately reflected the actual coverage.

## **VII. TASK 4.2 RESULTS AND RECOMMENDATIONS**

Section V (Task 4.1 Results) can provide the recommended improvement areas as viewed on an individual grouping basis. However, if all groupings were treated as a single grouping the results are slightly different regarding the areas of concern and the areas that are recommended for improvement. Exhibit 20 and 21 were created to provide a single view of the coverage provided by all the towers and systems analyzed for mobile talk-in and talk-out. The results are shown below:

### 1. Talk-In (Exhibit 20)

Coverage analysis indicates that most of Wyoming has excellent voice quality coverage. However, there are specific significant areas of concern in:

- a small portion of western Park County,
- the southern central half of Park County (may require two or three towers),
- the southeastern and east portion of Teton County (may require two towers),
- the northern portion of Lincoln County (may require two towers)
- the northern portion of Sublette County (however, a strategically place tower in the southeastern area of Teton County might cover both areas),
- the small southeastern corner of Sublette County,
- the northwestern portion of Fremont County,
- the east and west corners of Sheridan County (may required two towers),
- the northern portion of Converse County (may require two towers),



- the northwestern portion of Campbell County,
- the northwestern and eastern portion of Niobrara County (may require two towers, however a strategically placed tower near the northeastern portion of Converse County may cover the northwestern area)
- the northern and west central portions of Natrona County (may require two towers),
- the southern portion of Carbon County (may require two towers),
- the southwest portion of Weston County (a strategically placed tower in the northeastern portion of Converse County or northwest portion of Niobrara County may cover the southwestern portion of Weston County).
- the center portion of Sweetwater County (may require two or three towers), and
- the southern portions of Albany County (a strategically placed tower in the southeastern portion of Carbon County may cover the southwestern portion of Albany County).

## 2. Talk-Out (Exhibit 21)

Coverage analysis for talk-out is similar to talk-in for this grouping. The Talk-out, however, is slightly better in all the counties. The specific significant areas of concern are:

- a small portion of western Park County,
- the southern central portion of Park County,
- the southeastern portion of Teton County,
- the northern portion of Lincoln County (potentially two towers based on geography)
- the northern portion of Sublette County (however, a strategically placed tower in the southeastern area of Teton County might cover both areas),
- the western and eastern portion of Sheridan County,
- the north central portion of Converse County,
- the southern portion of Albany County, and
- the southern portions of Carbon County.

## VIII. INDEX OF EXHIBITS

- Exhibit 1 - Wyoming Radio Communications Analysis, Groupings Analyzed
- Exhibit 2 - Wyoming Radio Coverage Analysis, Grouping Assumptions for Data Analysis
- Exhibit 3 - Channel Performance Criteria for Wyoming Radio Communications Systems
- Exhibit 4 - Mobile Talk-In - Specific State Agencies, WYDOT Maintenance, SALECS, HP, Wyoming State Forestry Division
- Exhibit 5 - Mobile Talk-Out - Specific State Agencies, WYDOT Maintenance, SALECS, HP, Wyoming State Forestry Division
- Exhibit 6 - Mobile Talk-In - State Mutual Aid
- Exhibit 7 - Mobile Talk-Out - State Mutual Aid
- Exhibit 8 - Mobile Talk-In - Fire
- Exhibit 9 - Mobile Talk-Out - Fire
- Exhibit 10 - Mobile Talk-In - Law Enforcement
- Exhibit 11 - Mobile Talk-Out - Law Enforcement
- Exhibit 12 - Mobile Talk-In - Local Government
- Exhibit 13 - Mobile Talk-Out - Local Government
- Exhibit 14 - Mobile Talk-In - Medical and Special Emergency
- Exhibit 15 - Mobile Talk-Out - Medical and Special Emergency
- Exhibit 16 - Mobile Talk-In - Road and Bridge
- Exhibit 17 - Mobile Talk-Out - Road and Bridge
- Exhibit 18 - Mobile Talk-In - BLM and DOI
- Exhibit 19 - Mobile Talk-Out - BLM and DOI
- Exhibit 20 - Mobile Talk-In - Composite
- Exhibit 21 - Mobile Talk-Out - Composite
- Exhibit 22 - Grayson Wireless Invex 3G Certificate of Calibration
- Exhibit 23 - Wyoming Radio Coverage Analysis Talk-in and Talk-Out Summary