KLAMATH INTEROPERABILITY RADIO GROUP

MissionCriticalPartners
Because the Mission Matters

Radio System Assessment

Final Report

PREPARED APRIL 2021 FOR
KLAMATH INTEROPERABILITY RADIO GROUP, OREGON

MissionCriticalPartners.com
State College Office | 690 Gray's Woods Blvd. | Port Matilda, PA 16870 | 888.8.MCP.911 or 888.862.7911

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Executive Summary

Mission Critical Partners, LLC (MCP) respectfully submits this radio system assessment report to Klamath Interoperability Radio Group (KIRG). KIRG hired MCP to assess its existing radio communications system, with the goal to determine the best approach for enhancing and improving public safety radio communications for first responders in Klamath County.

To analyze KIRG's radio system, MCP used a proprietary methodology called the Model for Advancing Public Safety^{SM} (MAPS^{SM}). MAPS combines the collective body of knowledge gained from MCP's 100+ specialized public safety experts with a variety of mature, broadly accepted public safety and information technology (IT) standards, formalized accreditation programs, and industry best practices. The analysis output allows KIRG to easily discern and understand where the organization stands in relationship to several critical factors. Data was collected in three distinct ways:

- Review of documentation provided by KIRG and/or publicly available
- Structured interview with representatives of KIRG
- Onsite visit by an MCP engineer, with some follow-up phone conversations with KIRG members

As part of MCP's methodology, a MAPS blueprint was developed for KIRG to compare the current state of the system with industry standards and best practices. Detailed recommendations will be provided separately.

MAPS is intended to help KIRG:

- Understand its strengths and weaknesses to drive future investment and highlight risk
- Establish a metric for measuring progress
- Plan a course for the future, which will help KIRG attain its long-term goals and vision

A key element of MAPS is a color-coded visual blueprint that depicts the status of each factor assessed. Factors in the green area are considered public-safety-grade and thus not in need of immediate attention, factors in the yellowish area are at risk, and factors in the red area are at high risk.

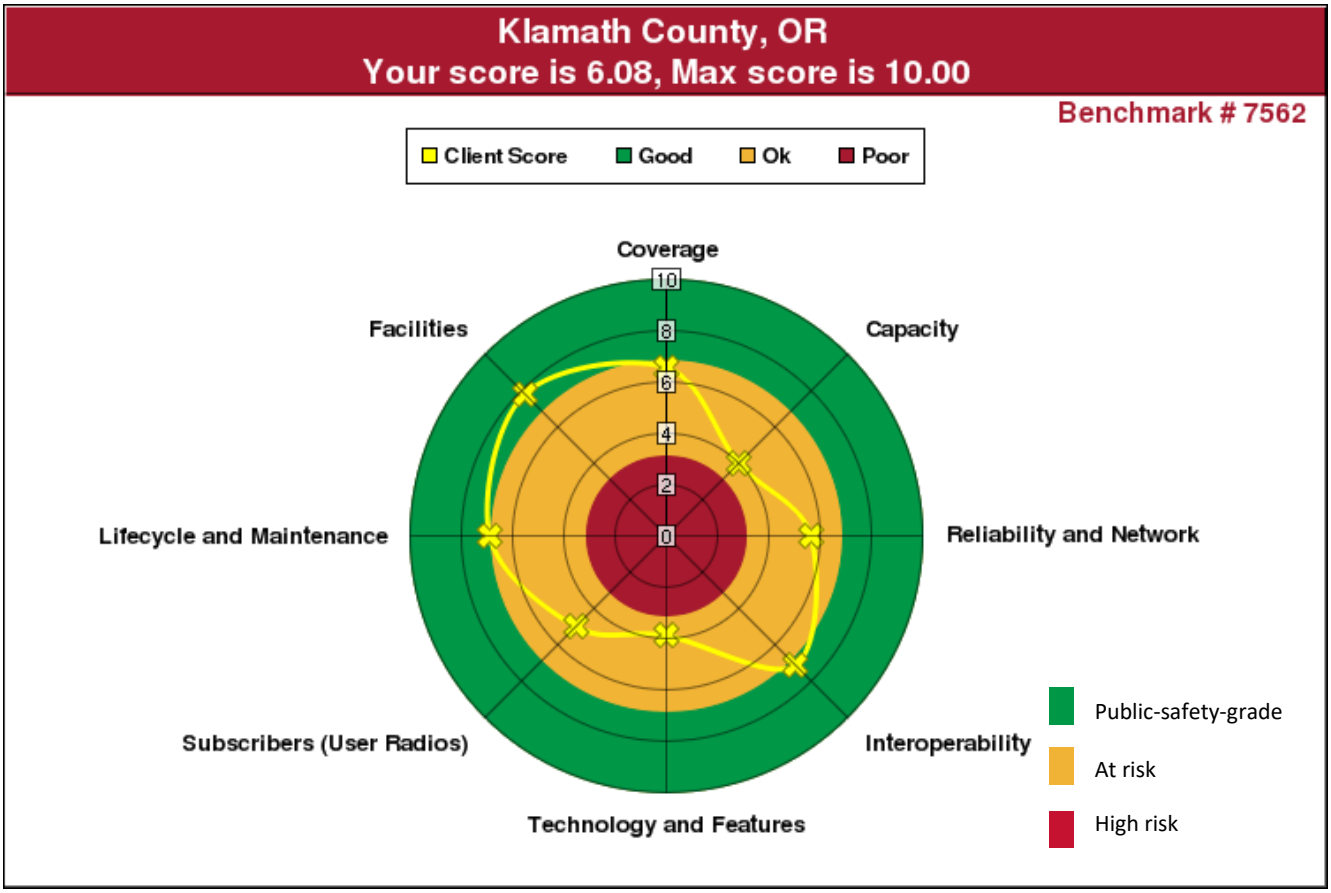

Figure 1: KIRG Radio System MAPS

A summary of the findings and key improvement areas follow.

Coverage. Klamath County is a challenging environment because of its terrain configuration, large size, and limited population density. For these reasons, typical coverage requirements used by the public safety community are not feasible—achieving 95% reliability for 95% of the county area for portable radios in typical buildings would be prohibitively expensive. The practical desired coverage is thus limited to populated areas and main roads. Even in this limited desired coverage area, there seems to be several opportunities for improvement, especially for portable radios.

Capacity. Despite the relatively small number of users, they experience excessive congestion daily, especially when any major incidents occur and the two simulcasted channels are reserved for handling them. *This is the most significant weakness of the system.*

Reliability and Network. The system experiences failures infrequently. The lack of alternative links on the backhaul network makes these incidents more critical than they otherwise would be.

Interoperability. Due to the size and location of Klamath County among other rural areas, the need for interoperability with other public safety organizations outside the county is limited. The agencies within the county can communicate with each other sufficiently.

The relatively high rating in this area reflects the County's high level of self-sufficiency, rather than access to any advanced interoperability means. The largest other agency within the county—Oregon State Police (OSP)—has very-high frequency (VHF) capabilities and can communicate with users on the KIRG system.

Technology and Features. The KIRG system uses analog frequency modulation (FM) technology. The system lacks all modern features provided by digital technologies, yet it seems to serve users well. There is limited interest in digital features, such as encryption, among law enforcement.

Subscribers. A wide range of equipment is in use, with varying ages and levels of functionality.

Lifecycle and Maintenance. The system is, in general, not regularly maintained. The sites indicate need for better care and maintenance. As KIRG uses a mix of old and new equipment, different devices are at different lifecycle stages and some, such as Motorola Quantar repeaters, deserve prompt replacement. Some crucial items, such as the microwave equipment, have reached end of life and are no longer supported by manufacturers.

Facilities. The facilities are generally in good condition, although they would benefit from more systematic maintenance and upkeep.

In MCP's opinion, the areas in most urgent need of improvement are capacity, maintenance, and coverage.

To address the majority of KIRG's radio system challenges, MCP recommends a number of specific steps, including significant system upgrades/replacements, which will result in increased capacity, enhanced coverage, and significant improvements in features available to system users, administrators, and technical personnel.

MCP believes that the expected upcoming Federal aid funds present a unique opportunity for KIRG to implement these significant upgrades to its system and encourages KIRG to take advantage of that opportunity.

According to the estimates obtained by MCP from three separate vendors, the recommended system changes should require under $4 million. MCP believes that KIRG should seek $5 million in funding to also implement some improvements related to, but directly a part of the radio system, including some subscriber units and procurement/implementation assistance services.

1 Background

KIRG, created in 2016 by ordinance under Oregon Revised Statute 190.010(5), is an intergovernmental entity whose purpose is "to own, maintain, finance, and operate a county-wide interoperable radio communications system throughout Klamath County." Participating agencies are primarily fire and law enforcement entities.

Table 1: KIRG Participating Entities

Participating Entities		
Basin Ambulance Service	Keno Fire Department	Klamath County Sheriff
BLM	Kingsley Field Fire Department	Klamath Falls Police Department
Bly Rural Fire Protection District	Klamath 9-1-1 Emergency Communications District	Malin Rural Fire Protection District
Bonanza Ambulance Service	Klamath Air	Malin Police Department
Bonanza Rural Fire Protection District	Klamath County Fire District #3	Merrill Rural Fire Protection District
BV	Klamath County Fire District #4	Merrill Police Department
Central Cascade Fire	Klamath County Fire District #5	Oregon Institute of Technology
Chemult Rural Fire Protection District	Klamath County Fire District #1	Oregon Outback Rural Fire Protection District
Chiloquin Fire & Rescue	Klamath County Parole and Probation	Rocky Point Fire
Crescent Fire District	Klamath County Public Works	United States National Forestry

Klamath County, with an area of 6,136 square miles, has an estimated population of 68,238 (2019). Much of the terrain is mountainous and not easily accessible, resulting in most of the population residing in and around Klamath Falls, the county seat, as shown on the map below.

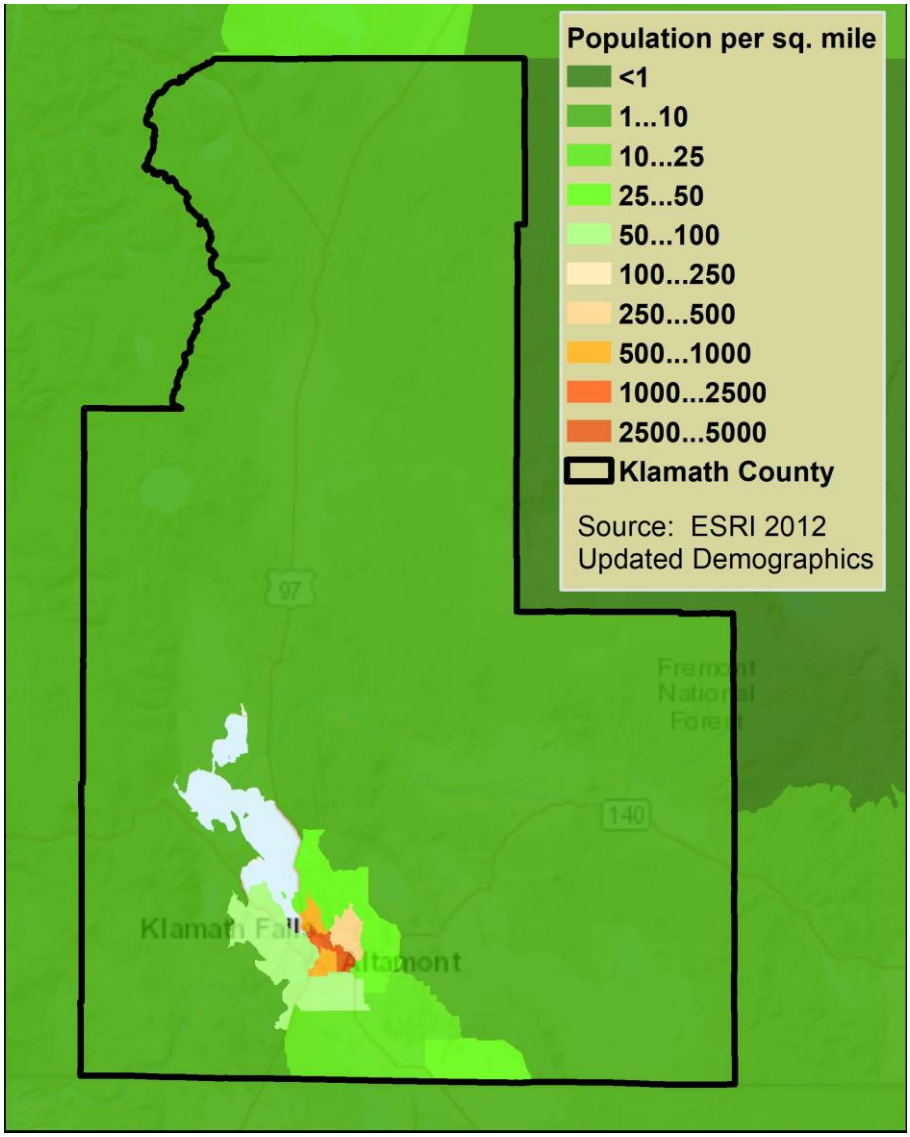

Figure 2: Klamath County Population Density

The total number of users on the radio system is unknown as each agency is responsible for its own radios. Using typical ratios of first responders to general population, the total number of radios in Klamath County should be in the range of 300 units. At the time of completion of this report, exact numbers of subscriber units utilizing the KIRG system is yet to be determined; only partial results are known.

The typical number of active users on the current system at any time, estimated based on input from Klamath 9-1-1, is:

Fire: 30 – 45	Law: 20 – 35	Other: 10 – 15

2 Methodology

The MAPS assessment is customized based on KIRG's specific needs and circumstances.

Project Kickoff/Stakeholder Discussion

MCP subject-matter experts (SMEs) and KIRG stakeholders discussed the key factors most relevant to KIRG. Typical radio assessment factors were used with a focus on coverage, capacity, and maintenance.

Industry Standards and Best Practices

The project team identified industry standards and best practices that align with the factors being assessed. For KIRG, these were primarily best practices related to equipment lifecycles, system and user equipment maintenance, and support.

Question Set Development

A comprehensive question set was developed—based on those standards and best practices—which was both quantitative and qualitative, with the latter characterization driven by the fact that the questions are weighted based on KIRG's perceived importance.

Data Collection Method

Data was collected using several methods:

1. Analysis of data provided by KIRG prior to engagement
2. Web research
3. Interview with KIRG committee members and invitees via videoconference on January 18, 2021
4. Individual follow-up calls
5. Site survey the week of February 1, 2021
6. Reviews of technical documentation
7. Coverage simulation study

Interviewees

Keith Endacott	*Mike Cook*
Randall Swan	*Chris Kaber*
Jack Daniel	*James Wilson*
Matt Hitchcock	*Ron Woita*
Brian Bicknell	*Brandon Fowler*
Dylan Webb	*Larry Woodruff*
John Ketchum	*Jessica Gibson*

Rob Dentinger

Data Analysis

MCP interpreted the standards and best practices and then determined how they should be applied, resulting in a quantifiable assessment that manifests in the MAPS scores and blueprint diagram.

3 Current Radio System

3.1 System Overview

The current KIRG simulcast system in its current form was implemented in November 2017, by Day Wireless. It is configured as a four-site VHF simulcast, with a total of two channels in operation (one on fire and one on law). Each site also has standalone and much older tactical repeaters. The sites are backhauled to Klamath 9-1-1, the public safety answering and dispatch point for Klamath County (dispatch center), via KIRG-owned microwave and are served by a voter/comparator located in the dispatch center's backroom.

In addition, there are three sites with standalone repeaters that are not connected to the simulcast system. Communications from these sites are not recorded or connected to KIRG's backhaul. The dispatch center only has access to the nearby tactical repeaters via an over-the-air consolette dispatch console interface.

Table 2: Radio and Microwave Sites

Site Name	Function	Latitude	Longitude
Hamaker	Simulcast	42° 4' 10" N	121° 58' 22" W
Hogback	Simulcast	42° 14' 34" N	121° 42' 25" W
Applegate	Simulcast	42° 42' 26" N	121° 43' 7" W
Odell Butte	Simulcast	43° 28' 15" N	121° 51' 48" W
Pelican Butte	Standalone	42° 30' 49" N	121° 8' 44" W
Swan Lake Point	Standalone	42° 24' 29" N	121° 40' 7" W
Bly	Standalone	42° 24' 25" N	121° 2 56" W
Walker Mountain	Microwave only	43° 18' 21" N	121° 42' 58.3" W

Note: The Hamaker site consists of two facilities—one housing the main repeater site and the other housing control stations controlled by dispatch via microwave to control radios at other repeater sites. See the existing system diagram, Figure 4, below.

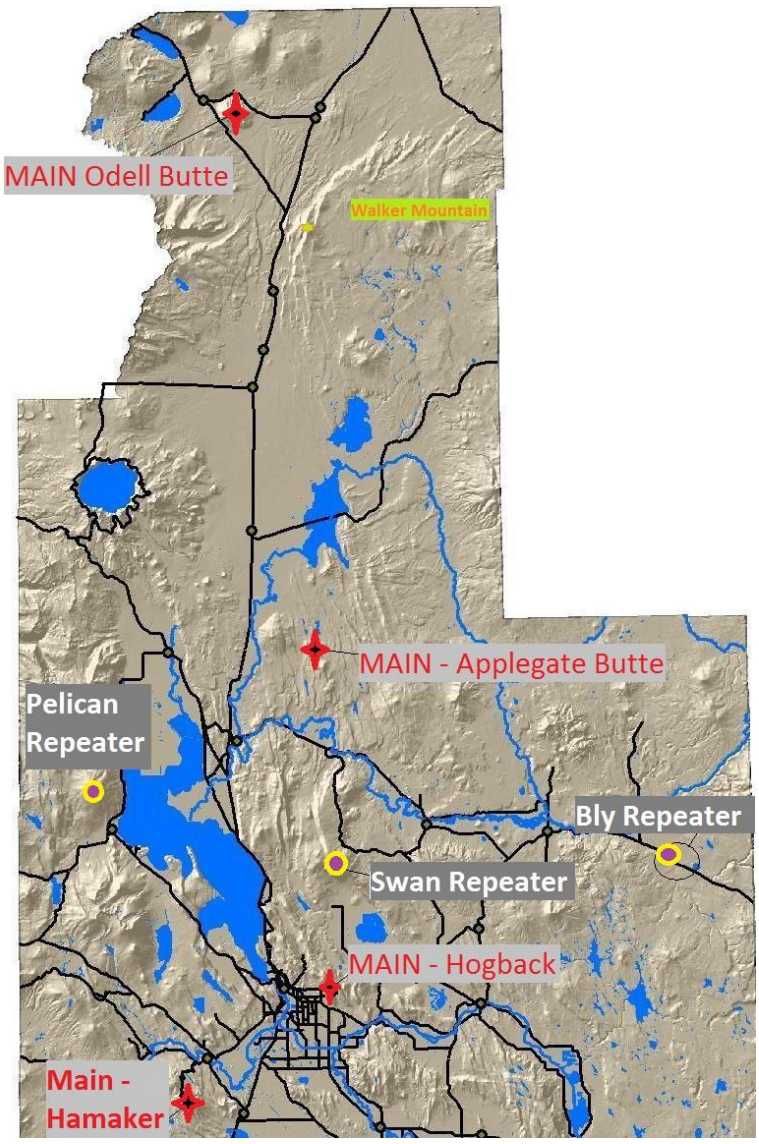

Figure 3: KIRG Radio Sites

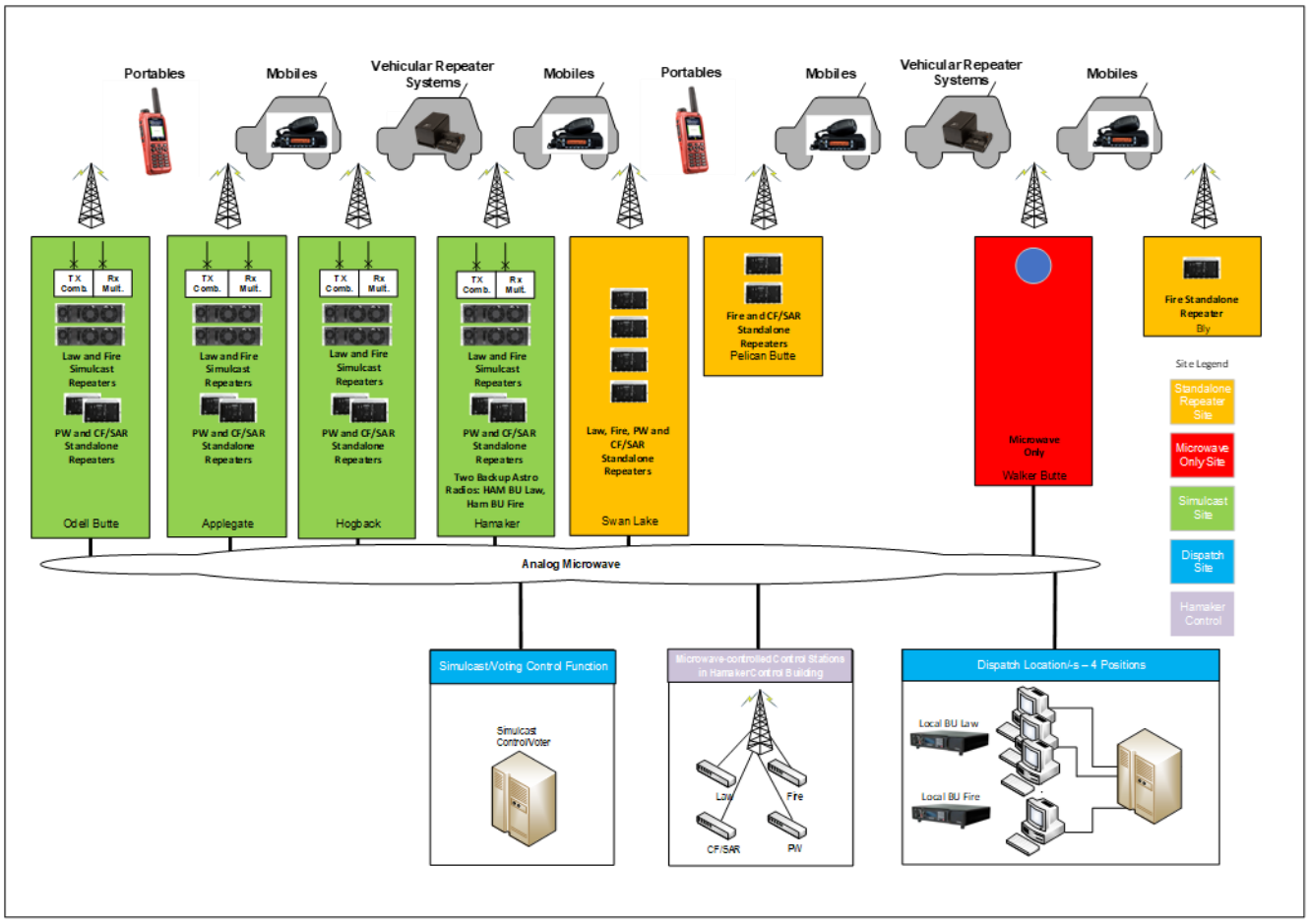

Figure 4: KIRG Radio System (Conceptual Diagram)

The backhaul network is built with an Alcatel MDR-8000 series, hot standby, digital microwave system. The microwave system is at end of life and has not been sold by the manufacturer since June 30, 2016.

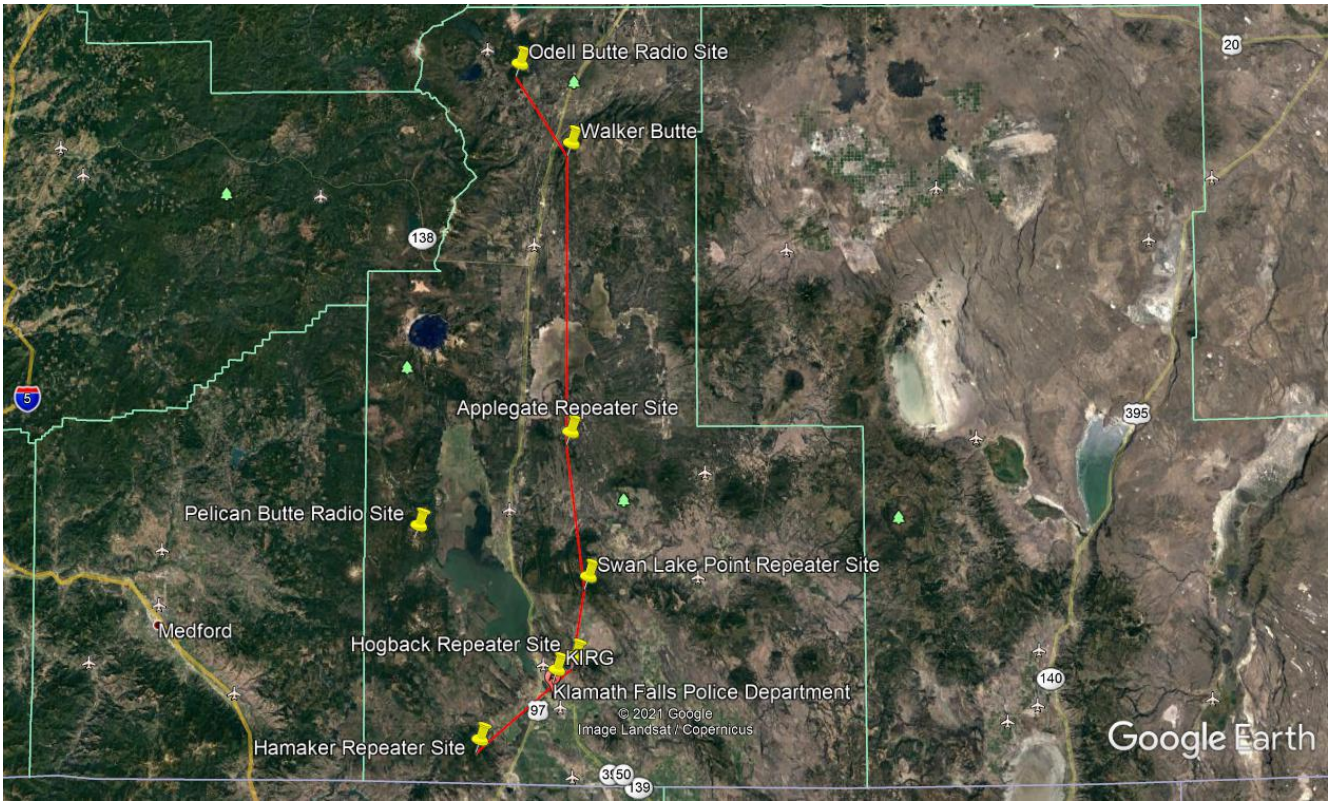

Figure 5: KIRG Backhaul System

The microwave links and corresponding frequency licenses are shown in the table below.

Table 3: Microwave Links and Frequency Licenses

Links		Call Sign 1	Call Sign 2
Odell Butte	Walker Mountain	WQRD234	WQRD227
Walker Mountain	Applegate	WQRD234	WQRD225
Applegate	Swan Lake Point	WQRD232	WQRD225
Swan Lake Point	Hogback	WQJM338	WQJM339
Hogback	Klamath 9-1-1	WQJM338	WQJM342
Hogback	Hamaker	WQSM338	WQJM341

3.2 FCC Licenses

Federal Communications Commission (FCC) license information for the microwave and land mobile radio (LMR) systems are shown in the table below. PW and MW in the radio service column stand for public safety pool, conventional, and microwave public safety pool, respectively. For each license, the FCC registration number[1] (FRN) is the same (0026368456) and is associated with the licensee for each, KIRG.

Table 4: License Information

Call Sign	Radio Service	Description	Expiration
KNIQ200	PW	LMR – Fire Simulcast	10/21/2023
KSQ544	PW	LMR – Law Simulcast	12/12/2024
WQGQ400	PW	LMR – CF/SAR[2] Standalone Sites	03/22/2027
WQUN767	PW	LMR – CF/SAR Standalone Sites	08/27/2024
WQVH842	PW	LMR – Hamaker Only	02/18/2025
WQJM338	MW	Microwave	10/31/2028
WQJM339	MW	Microwave	10/31/2028
WQJM341	MW	Microwave	10/31/2028
WQJM342	MW	Microwave	10/31/2028
WQRD225	MW	Microwave	04/18/2023
WQRD227	MW	Microwave	04/18/2023
WQRD232	MW	Microwave	04/18/2023
WQRD234	MW	Microwave	04/18/2023

While specific frequency search and coordination are not part of this project, MCP did review FCC licenses in the region and concluded that, if needed, additional VHF channels are likely to be available.

[1] The FRN is a 10-digit number assigned to an entity conducting business with the FCC. In this case, KIRG's FRN is 0026368456.
[2] County Fire/Search and Rescue

3.3 Infrastructure/Facilities

MCP conducted a site inspection at the Hamaker repeater site, which is on BLM property. The access road is paved and in good condition.

The exterior of the shelter, the compound fence, the gate, and the tower appear to be in good condition. There is a small gap in the shelter air conditioning that might be an incursion point for rodent activity. The interior of the shelter appears to be in good condition, although there are signs of rodent activity.

The generator shelter's exterior and interior are in good condition. The generator itself appears to be in good working order; according to a Day Wireless representative, an exercise schedule has been established. There are signs of rodent activity inside the generator shelter as well.

The main site equipment is in good working order, clean, and appears to be well maintained. All equipment is properly bolted, racked, and grounded per Motorola *Standards and Guidelines for Communications Sites* (R56). All cables appear to be in good condition. All coax connections appear to be properly bonded and grounded.

The site is monitored via a video system with a feed to the dispatch center and is accessible remotely by authorized personal.

KIRG officials consider the nearby associated Hamaker control site housing four control stations expensive and inferior, due to the high rent to the current landlord and the facility housing the control stations in major need of repair. The main shelter housing the current simulcast system is in good repair and well maintained; this building is not under contract with the same landlord as the control station building.

Site photographs for the Hamaker repeater site are shown on the following page.

Figure 6: Hamaker Shelter Interior

Figure 7: Hamaker Tower

Figure 8: Hamaker Generator

As the simulcast system setup at the other sites is the same as Hamaker, and due to limited road access at the time of MCP's site visit, a joint decision was made by KIRG and MCP to visit only the Hamaker site and the dispatch center.

3.4 Dispatch Center

The dispatch center has four positions. The radio consoles are Motorola MCC 5500, which Motorola announced will be end of life in late 2021. There are also two Motorola APX consolettes.

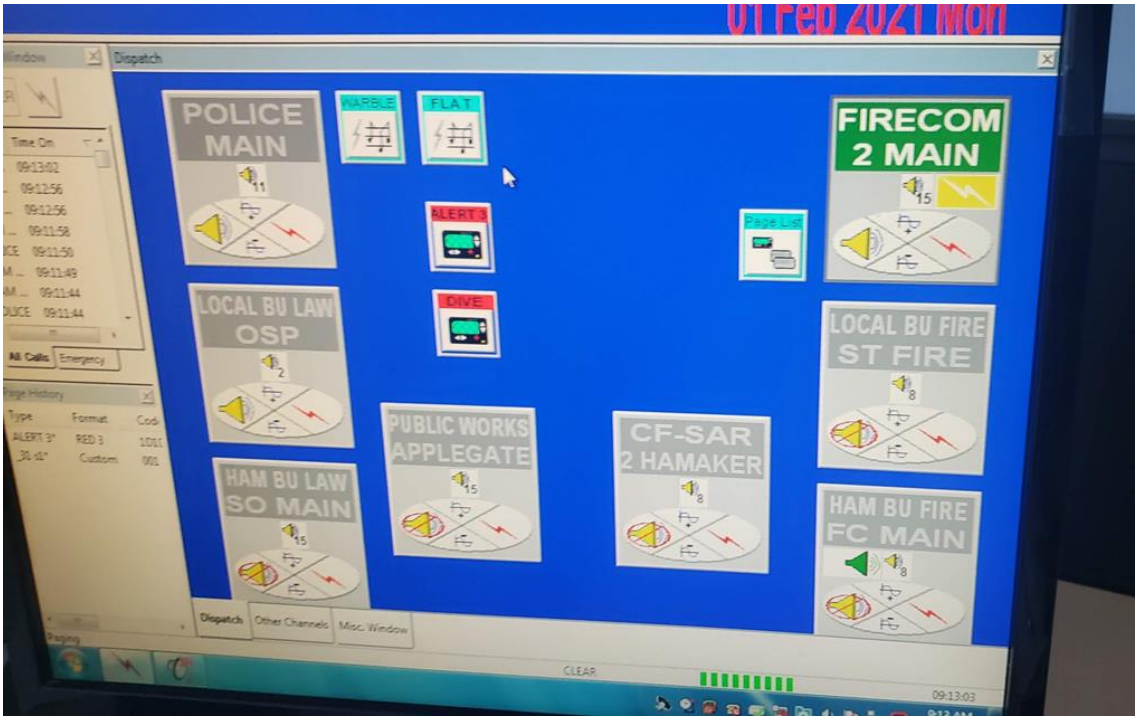

Figure 9: Dispatch Console

3.5 Interoperability

There are no network connections, gateways, patches, or any other specialized technical means to achieve interoperability with any other system. OSP can be reached via a base station installed at the dispatch center and interfaced with the consoles. OSP radios are programmed with KIRG frequencies and provide the capability for users to communicate directly with the dispatch center and local first responders.

4 Findings and Analysis

A key element of MAPS is a color-coded visual blueprint that depicts the status of each factor assessed, which allows KIRG to compare the current state of its system—based on the data collected—to industry standards and best practices. MAPS is intended to help KIRG:

- Understand its strengths and weaknesses to drive future investment and highlight risk
- Establish a metric for measuring progress
- Plan a course for the future

Factors in the green area are considered public-safety-grade and thus not in need of immediate attention, factors in the yellow area are at risk, and factors in the red area are at high risk.

The ratings below are based primarily on best-in-class public-safety communications, modeled to KIRG's specific circumstances and needs.

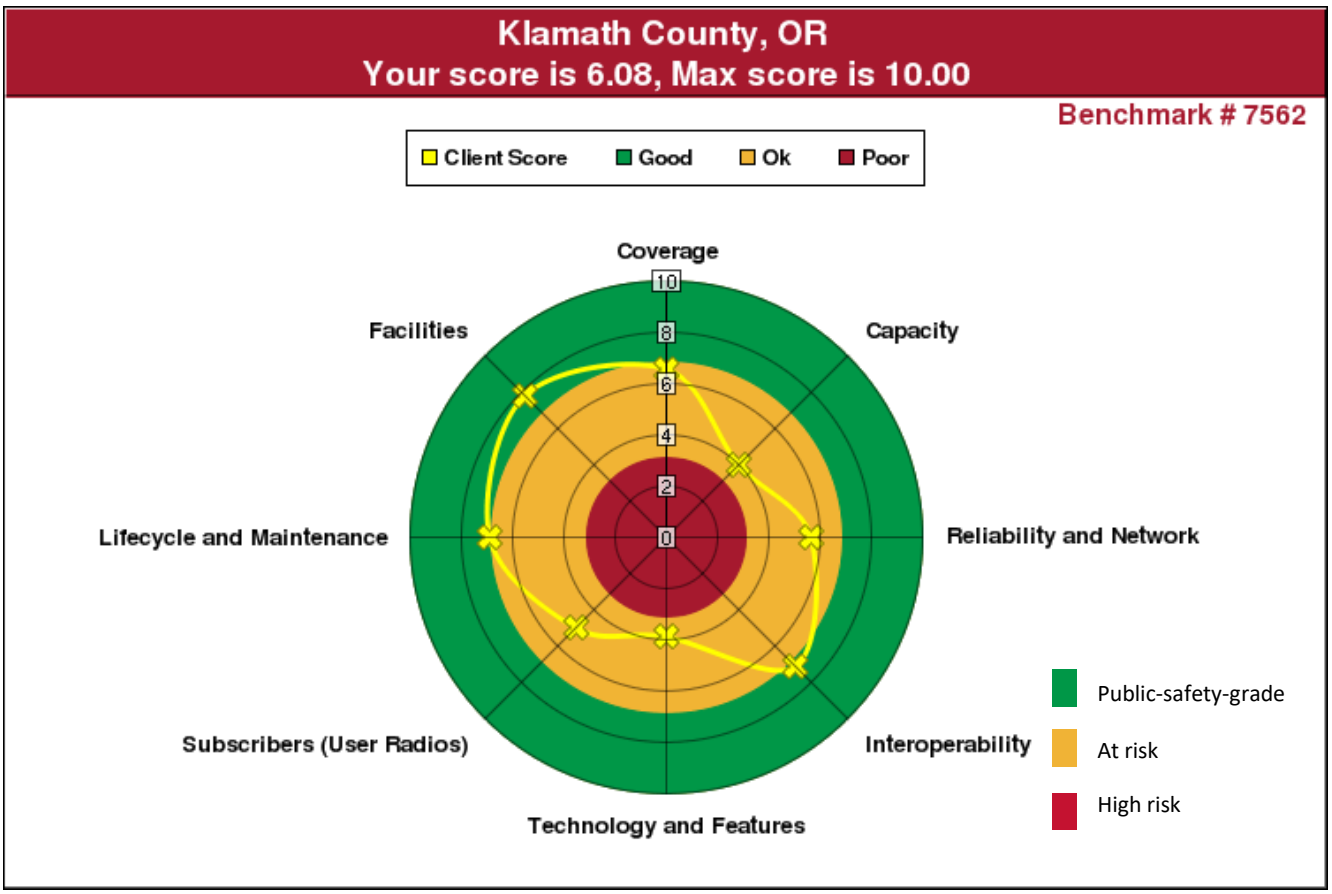

Figure 10: MAPS Analysis – KIRG Radio System

4.1 Coverage

Findings

Although the perception varies among agencies, overall, the current VHF system provides coverage adequate for most agencies relying on mobile users. The system was designed and built for mobile coverage. Portable coverage is considered poor outdoors and very poor indoors. In-building coverage is a problem, especially in schools and colleges, large stores, the hospital, concrete buildings, basements downtown, every building in Merrill, and the lumber mills.

Coverage in northern Klamath County is much poorer than in the south, which causes serious challenges when trying to use the radio system outside of an apparatus. The other major problems involve the tactical repeaters in the county—the repeaters have no audio link back to the dispatch center and are not recorded.

Paging coverage is deemed satisfactory in southern Klamath County, but not in the north.

Vehicular repeaters have been tested in a few forestry trucks and in other cases but there is no widespread use.

Analysis

Klamath County is a challenging environment because of its terrain configuration, large size, and limited population density. For these reasons, typical coverage requirements used by the public safety community are not feasible—achieving 95% reliability for 95% of the county area for portable radios in typical buildings would be prohibitively expensive. The practical desired coverage is thus limited to populated areas and main roads. Even in this limited desired coverage area, there seems to be several opportunities for improvement, especially in northern Klamath County and for portable radios around Klamath Falls.

4.2 Capacity

Findings

Channel congestion has been reported as a daily occurrence but is more serious during major incidents. When this happens, non-priority users are sent to talk-around operation and with it the disadvantages—limited range, no monitoring by the dispatch center, and no call recording.

The system has one primary law and one primary fire channel. When a major incident occurs or when there is increased call activity, users must wait in queue to communicate with the dispatch center or among each other. During a major incident when the channel is reserved, users must go to a simplex talk-around frequency. This poses a major challenge for anyone assisting remote units as they cannot communicate until they are in talk-around range of a given incident.

At this time, the dispatch center is typically staffed with two cross-trained, multi-functional telecommunicators on a given shift. Dispatch capacity is an issue because the telecommunicators also are 9-1-1 call-takers and handle multiple other tasks such as computer-aided dispatch (CAD) inputs, fire station alerting, and several other key dispatch requirements. KIRG board members advise that Klamath 9-1-1 dispatchers are the busiest in the state; the root cause of this problem is personnel, not equipment, limitation. Staffing is the main challenge.

Analysis

Despite the relatively small number of users, they experience excessive congestion daily, especially when any major incidents occur and the two simulcasted channels are reserved for handling them. *This is the most significant weakness of the system.*

4.3 Reliability and Network

Findings

Random intermittent issues are reported three or four times per year, but there are no persistent or recurring problems. There are very limited, insufficient, redundancies in the radio system, dispatch center, and backhaul.

The County does not publish any type of communications plan for users showing frequency or channel assignments or other coordinated document explaining available system resources and neighboring agency communication resources. There is no zone channel assignment plan that is followed and enforced; however, several agencies have developed their own channel plans for subscriber units, which causes confusion when working with other agencies. There is no fallback plan for dispatch center evacuation. 9-1-1 calls can be routed, but it is not clear where they would be forwarded in the event of dispatch failure or evacuation.

Simulcast central equipment is in the dispatch center. Losing connectivity to the dispatch center disables simulcast.

Another area of concern is the potential loss of the microwave link between the dispatch center and the Hamaker site. If this link is lost, there is no redundant microwave path to other sites within the simulcast cell. This leaves the dispatch center on radio frequency (RF) control stations for primary dispatch and may not allow talkpath audio to be recorded.

Another concern is support resources. KIRG is serviced by Day Wireless, a local provider, and maintains a great relationship with the vendor. While Day Wireless is technically competent to service the system, there is no local backup personnel available. If the primary technician in the area is unavailable, similar resources are several hours away, which delays resolution of critical issues.

Analysis

The system experiences failures infrequently. The lack of alternative links on the backhaul network makes these incidents more critical than they otherwise would be.

4.4 Interoperability

Findings

There is a very limited need for communications with agencies outside of the county. As all users within the county use VHF, with the exception of OSP, interoperability among local agencies is considered satisfactory. The fire entities have standard operating procedures (SOPs) in place for communicating with adjacent counties.

The dispatch center and field users have the ability to communicate with OSP's VHF system directly from the console and a dedicated channel programmed in the subscriber units. Klamath County users do not have access to the 700 megahertz (MHz) trunked P25 OSP system currently in routine use. Consequently, there is no capability to monitor or use OSP encrypted channels.

Interagency training typically occurs once a year.

County-to-county interoperability is a concern as the surrounding counties are in the process of switching to P25-based systems.

Analysis

Due to the size and location of Klamath County among other rural areas, the need for interoperability with other public safety organizations outside the county is limited. The agencies within the county can communicate with each other sufficiently.

The relatively high rating in this area reflects the County's high level of self-sufficiency, rather than access to any advanced interoperability means. The largest other agency within the county—OSP—has VHF capabilities and can communicate with users on the KIRG system.

4.5 Technology and Features

Findings

The system and subscribers operate in analog conventional mode. Thus, the functionality available to radio users is very limited by the current standards for digital trunking. While the value of digital features, such as encryption or location services, has been acknowledged by KIRG members, especially law enforcement, these features are not in high demand. This may be due to a lack of familiarity with the available enhancements and their value to first responders.

Some broadband data devices are in use, but there is no consistency on devices or carriers.

The technical and functional capabilities of the logging recorder are considered satisfactory. Due to interface issues, the current recorder may be replaced; a decision is expected by the end of 2021.

Analysis

The KIRG system uses analog FM technology. The system lacks all modern features provided by digital technologies, yet it seems to serve users well. There is limited interest in digital features, such as encryption, among law enforcement.

4.6 Subscribers (User Radios)

Findings

Entities are responsible for their own subscriber equipment. Consequently, there is great variety in the equipment.[3] Most radios are Motorola ATX5000, but there are other makes/models (e.g., some BK radios were purchased recently). There is even variety within departments. Some radios observed while onsite are not public-safety-grade.

Radios are not regularly maintained and are only repaired when they break.

There are no other common complaints about the subscriber units, including with battery life. A concern, however, is a relatively low level of awareness regarding advanced subscriber equipment functionalities with which KIRG members are not familiar.

There is a common radio programming plan; although not mandatory, it is followed by most agencies.

Analysis

A wide range of equipment is in use, with varying ages and levels of functionality.

4.7 Lifecycle and Maintenance

Findings

KIRG has no dedicated maintenance schedule for its mountain-top equipment. No entities on the KIRG system have maintenance schedules for their subscriber equipment. Any mountain-top maintenance or system testing that may be performed is conducted by Day Wireless on an ad hoc basis, when and if a problem is identified. KIRG is solely reliant on Day Wireless, which has a radio shop within Klamath Falls staffed by one technician. If the technician is unavailable, the nearest technician is dispatched from Bend, or Medford, which are a few hours' drive away.

KIRG does not have a support plan with any company or equipment provider, other than dispatch consoles and generators. Calls for service on radio equipment are provided on a time and materials basis by Day Wireless.

The dispatch consoles were updated approximately three years ago and are under a maintenance contract through Day Wireless. Motorola issued the end-of-life notice (late 2021) for the consoles.

The backhaul microwave system had an end-of-life notice effective in 2016.

[3] An inventory is pending from KIRG.

KIRG uses Motorola GTR3000 repeaters on the main simulcast system, which are still within Motorola's supported equipment pipeline. These units are backed up by Quantar spare base stations; these base stations are operational but no longer supported by the manufacturer. This includes Quantar base stations still in use at tactical repeater sites. Parts for both the GTR3000 equipment and the Quantar equipment are available, with the GTR3000s supported directly from Motorola and Quantar base stations supported via third-party parts providers.

Maintenance funding and operational funding are secured via user agency fees based on agency size. Total user fees are $100,000 annually.

Parts are reported to be available as needed. There were no reports of any major service outages due to a lack of spare parts. Spare equipment is maintained by service providers; again, there have been no major disruptions due to a lack of spare equipment.

There are no routine software updates.

Day Wireless provides regular monitoring of equipment. Personnel also may notice when equipment is not working and report it to KIRG.

Analysis

The system is, in general, not regularly maintained. The sites indicate need for better care and maintenance. As KIRG uses a mix of old and new equipment, different devices are at different lifecycle stages and some, such as Motorola Quantar repeaters, deserve prompt replacement. Some crucial items, such as the microwave equipment, have reached end of life and are no longer supported by manufacturers.

4.8 Facilities

Findings

Facilities are a mix of owned and leased. The towers and shelters are between 15 and 50 years old. The towers owned by KIRG have spare capacity over 30%. All towers but Pelican, which is solar, have the capability for additional commercial power if necessary.

Most shelters are concrete and well equipped, with some (varying) room for expansion. All sites are Motorola R56-compliant.

Generators are six to seven years old, as are the direct current (DC) power plants. There is some extra capacity, but it is unknown.

Analysis

The facilities are generally in good condition, although they would benefit from more systematic maintenance and upkeep.

5 Recommendations

5.1 Coverage

Klamath County is a challenging environment because of its terrain configuration, large size, and limited population density. For these reasons, typical coverage requirements used by the public safety community are not feasible—achieving 95% reliability for 95% of the county area for portable radios in typical buildings would be prohibitively expensive. The practical desired coverage is thus limited to populated areas and main roads. Even in this limited desired coverage area, there seems to be some opportunities for improvement, especially for portable radios.

MCP recommends focusing coverage improvement activities and investments in two geographic areas and on one technical solution:

1. As the coverage is generally unsatisfactory, even for mobile units, in the north part of the county, additional site(s) should be developed and integrated into the existing network, to be upgraded and expanded at the same time.
2. Portable coverage in Klamath Falls and the developed vicinity also should be improved.
3. The use of vehicular repeaters should be increased for the areas where providing portable coverage is not feasible.

A vehicular repeater solution can provide additional coverage and extend system performance in most areas of Klamath County. This approach would allow users in the field to activate, when required, a portable to mobile link to the radio system, providing enhanced coverage for first responders stepping away from vehicles. This solution also could be used in a static/in-building location to provide enhanced coverage.

This capability could be provided via an in-band (VHF-to-VHF) unit, with at least 5-MHz separation. Manufacturers that provide these services include:

- Pyramid Communications
- Futurecom® – A Motorola Solutions company
- Tracer Technology Systems

The average cost for these systems includes:

- Purchase of equipment (average cost between $4,000 to $7,000 per unit, depending on the vendor and needs; these costs would be considerably higher for digital trunked systems, which MCP does not recommend for Klamath County)
- Equipment installation costs (approximately four hours of labor per unit)
- Licensing costs, if required (may be able to reuse existing licenses if available)

Training would be required for proper operation and deployment; these costs would need to be factored into the final numbers for the overall cost analysis.

5.2 Capacity

Despite the relatively small number of users, they experience excessive congestion daily, especially when any major incidents occur and the two simulcast channels are reserved for handling those incidents. *This is the most significant system weakness.*

MCP recommends an upgrade and expansion of the existing simulcast system, improving its footprint and doubling its capacity from two to four channels. The proposed channel expansion would consist of an additional Police channel and an additional Fire channel. This will prevent current challenging situations when non-prioritized radio traffic is delegated to local repeater or even talk-around mode operation, severely limiting its coverage, the ability to contact dispatch, or to be recorded. The existing licenses will have to be reviewed and modified to allow this change, but the initial review (see Section 5.11.3) indicates the required modification should be relatively straightforward.

MCP recommends working directly with an organization whose sole focus is navigating the FCC licensing process. Two recommendations are Comsearch and Washington Radio Reports.

The Association of Public-Safety Communications Officials (APCO) International also provides frequency search and licensing assistance, as does KIRG's current service provider, Day Wireless.

The current dispatch capacity is another aspect of system capacity that needs to be addressed. Investing in more capacity for the radio system will only pay off if radio users can communicate with dispatch. There are several problems to be remedied.

- The current consoles are end of life later this year (2021); they should be replaced soon.
- Given how busy the current positions are reported to be, it is imperative to have at least one backup position, for any major emergency and, maybe more importantly, for potential failures of any main position.
- Most importantly, the staffing issues need to be resolved. Working with public safety organizations across the nation, MCP understands that this issue is a national crisis. While some relief finally may be coming from the Federal government, the shape, form, size, and timing are still to be determined so local action is recommended. MCP has additional expert resources that can help with understanding and resolving the problem.

5.3 Reliability and Network

The system experiences failures infrequently. The lack of alternative links on the backhaul network makes these incidents more critical than they otherwise would be.

The geography of Klamath County works against the traditional approach to network reliability—a loop/ring configuration—under which losing any single link does not affect operations and losing any single site impacts only that site. Since KIRG's backhaul is essentially a straight line of approximately 100 miles, geographical expansion of the microwave network into an actual ring architecture is not feasible. However, it may be feasible to create a hybrid network using a wireline broadband connection between the sites closest to Klamath Falls and Crescent, redirecting traffic via such a connection should any microwave link fail, thus creating a virtual ring.

The existing microwave has not been supported by the manufacturer since 2016. It needs to be replaced promptly with an Internet Protocol (IP)-based network. Each Project 25 (P25) radio site will require connectivity to function; the type of connectivity will vary based on the type of site. Physical connectivity should be redundant and reliable for each site.

Although the recommended system solution can function with lower data capacity, a minimum of 155 megabits per second (Mbps) of capacity is recommended for microwave paths and a minimum of 10 Mbps for fiber connections is recommended to accommodate additional functionality. Although the microwave capacity is greater than that required, it is recommended to provide for possible future needs at radio sites, such as remote monitoring or potential private mobile data additions. For fiber, the vendor should be required to provide peak traffic calculations for each fiber path to determine if a given path requires more than the 10 Mbps minimum. A network topology providing multiple rings throughout the county provides alternate paths. When viewed from the switching and routing perspective, the physical network rings and paths provide redundant communications backhaul.

Management and monitoring of an IP network typically involves implementing the Simple Network Management Protocol (SNMP). The recommended version is v3, but not all equipment vendors support it. Version 3 implements a number of security features not in earlier versions, such as encryption of alarm traffic. To effectively manage the network, the monitoring system must have full visibility of all fiber and microwave segments, network devices, and network-attached systems. This creates a unified view of the network and improves the trouble isolation and resolution process.

Another aspect of network reliability, as clearly shown by the struggles of many dispatch centers during the COVID-19 pandemic, is the ability to move operations to a backup facility or to multiple facilities. There are many possible solutions, including a fully functional mobile command center, but all require a multi-discipline approach covering emergency procedures, personnel preparation, personnel policies, radio operations, CAD operations, cybersecurity, 911 operations, and others. Specific recommendations are out of scope for this project but can be provided by MCP separately. The recommended system solution, however, is based on an IP-based backbone and will, therefore, support portability or geographical dispersion of dispatch positions.

5.4 Interoperability

Due to the size and location of Klamath County among other rural areas, the need for interoperability with other public safety organizations outside the county is limited. Agencies within the county can communicate with each other sufficiently.

The relatively high rating in this area reflects the County's high level of autonomy, rather than access to any advanced interoperability means. The largest other agency within the county—OSP—operates on its main 700 MHz trunked P25 system, but also has VHF capabilities and can communicate with users on the KIRG system.

While interoperability is not high on the list of day-to-day operational needs, KIRG users should have access to reliable and user-friendly methods to talk to all adjacent agencies. Since all agencies within the county use the same system and operate in the same frequency range, in-county interoperability is automatically available. It could be further improved with subscriber management policies addressing the types of radios allowed on the system and with implementation of uniform programming templates.

For interoperability with outside agencies, including OSP, additional means should be considered to enable communications between different frequency bands and technologies. There are several means available for this purpose and, depending on the needs of specific users, a range of technical means may be applied.

1. For the field users that may have to roam into adjacent areas out of KIRG coverage, it might be best to invest in multi-band, multi-protocol radios for them. These units are in the high price range, but they are universal enough to enable the user with a properly programmed radio to roam onto almost any system. Please note, operating on anyone else's trunked system will require access to that system programming data/key and an interagency formal agreement.
2. KIRG dispatch should be able to talk to any adjacent agency. This will require integration of properly equipped, programmed, and appropriately placed base or control stations with the dispatch equipment. This will allow patching those other agencies with KIRG users. This also will allow communicating with dispatchers in digital and encrypted modes. A review of publicly available records indicate that Klamath County neighbors use the following frequencies/technologies:
   - Jackson County: All analog conventional VHF
   - Douglas County: All analog conventional VHF
   - Lane County: Fire – All analog conventional VHF, Sheriff – UHF conventional P25 and SW 7 County Interoperable Public Safety Radio Partnership UHF/700 P25 trunking
   - Deschutes County: All on Oregon State Radio Project
   - Lake County: All analog conventional VHF
   - Siskiyou County, California: All analog conventional VHF

   The list above indicates that the addition of approximately eight strategically placed control stations connected to the dispatch system would enable full interoperability across county lines and with OSP on demand. Again, switching to an IP-based backhaul will enable easy integration of these radios with

the dispatch system. Appropriate governance agreements with the County's neighbors and partners should be developed and executed.

3. For any operations that may involve larger numbers of users roaming out of their primary coverage area, whether KIRG users getting outside of Klamath County or other agencies coming to the aid of KIRG responders in the county, some form of portable repeaters and gateways may also be considered. In some cases (where all users have properly programmed VHF radios), the previously recommended vehicular repeaters will be sufficient. These can be part of a mobile command center or installed in some portable cases and set up at the location of an incident or planned event.
4. Advanced interoperability measures, such as Inter RF Sub-System Interface (ISSI), are not recommended unless KIRG decides to build a P25 trunked system (not recommended by MCP). Depending on the selected replacement dispatch consoles and radio technology, some other means connecting dispatch with adjacent counties' system cores, such as Console Sub-System Interface (CSSI), may be available and feasible, though likely not essential, in the future.

5.5 Technology and Features

The KIRG system uses analog FM technology. The system lacks all modern features provided by digital technologies, yet it seems to serve many users sufficiently well. There is some interest in digital features, such as encryption, mainly among law enforcement.

Staying with FM conventional technology is a viable option for KIRG. As outlined in this section, substantial performance improvements in multiple areas are possible without switching to a digital platform. There are, however, some strong pro-digital modulation arguments to consider:

1. Digital signaling makes encryption easy and relatively affordable. While not essential in everyday public safety operations in the county, encryption should be available at least to some law enforcement whenever sensitive operational or personal (e.g., as required by the Health Insurance Portability and Accountability Act [HIPAA]) information is being transmitted.
2. Digital signaling brings additional functionality not available or not easy to implement in analog mode. Location services, unit identification, short messaging, and other features come as standard in digital systems. (See Section 5.2)
3. Digital modulation may deliver modest coverage improvements in some areas.

Eligibility for Federal grants requires that all equipment being purchased is P25-compliant. This is the main reason some other digital technologies (digital mobile radio [DMR], NEXEDGE), while theoretically suitable, are not considered here.

Trunking

P25 systems often are automatically associated with trunking, a method of operation in which channels are automatically allocated to radio users. Such systems are more technically complex and expensive. Trunking typically becomes feasible for systems that handle hundreds of active users at any given time. This is not the case for KIRG.

Frequency Band

Another frequent association is for P25 and 700/800 MHz systems; this, indeed, is a common combination, but P25 is not limited to that band. Different frequency bands have different characteristics. Each one comes with trade-offs, advantages, and disadvantages. The frequency range used most commonly for P25 systems is not universally the best one for every application. For Klamath County, unlike 700/800 and UHF systems that provide primarily line-of-sight communications, VHF performs better over longer distances, in open spaces, and is capable of more non-line-of-sight communications, thus becoming a clear choice for KIRG despite its own set of challenges (high RF noise floor, scarcity of available channels).

MCP recommends upgrading and expanding the existing simulcast system so that it is capable of both analog and digital (P25) operations. This will allow all current analog subscriber units to stay on the system indefinitely while enabling digital communications on an as-needed basis.

5.6 Subscribers

A wide range of equipment is in use, with varying ages and levels of functionality.

MCP recommends a methodical, system-wide policy for procuring, managing, and maintaining the subscriber units on the system. There is no need to force everyone to buy and use the same radios, but limiting the options to a few selected, verified, and regularly maintained models[4] would have several benefits.

1. Some radios observed onsite are not public-safety-grade. Such underperforming units are not reliable and may interfere with system operation or other users.
2. Some radios observed onsite are excessively old and none are regularly maintained. All should be regularly checked, and maximum allowable lifespans should be established. (See Section 5.7)
3. All radios should be programmed using the same basic frequency plan/template/channel naming convention.
4. All radio users should attend annual refresher training on how to use their radios and the system.

Using un-tested, un-verified, and not regularly maintained subscriber units brings unnecessary risk to users and makes troubleshooting and diagnostics of the system itself difficult. KIRG needs to control that part of the operations at a reasonable level.

5.7 Lifecycle and Maintenance

The system is, in general, not regularly maintained. The sites indicate need for better care and maintenance. As KIRG uses a mix of old and new equipment, different devices are at different lifecycle

[4] An example of this type of governance can be found at https://alaskalandmobileradio.org/governing-documents/cooperative-and-mutual-aid-agreement-appendices/

stages and some, such as Motorola Quantar repeaters, deserve prompt replacement. Some crucial items, such as the microwave equipment, have reached end of life and are no longer supported by manufacturers.

Lifecycle

The MTR base stations used in the main simulcast system are in current production. Many other elements of KIRG's system need to be replaced. The Quantar repeaters used as standalone repeaters are no longer maintained by the manufacturer. The consoles face end of life later this year; support for the microwave backhaul stopped in 2016. Some subscriber units also are past their recommended lifespan. It is time for a significant update of the system and replacement of many, if not most, of its components.

The current logging recorder, as a software-based product, is satisfactory both for current use and for the recommended system upgrades. The vendor, Equature, when contacted by MCP, stated that the recorder can handle the proposed technologies and changes in the system without any hardware upgrades. Depending on selected technologies, a software upgrade may be required.

Recommendations for maintenance include the following:

- All user equipment should be checked and tuned annually. The recommended lifespan is 5–7 years for portables and 7–10 years for mobiles and control stations.

- Dispatch equipment, base stations, microwave equipment, and associated antenna systems should be checked and, if needed, adjusted annually. The recommended lifespan is 12–15 years.

- Backup power systems should be checked monthly, and generators should be exercised remotely bi-weekly. The recommended lifespan is 12–15 years.

- All sites should be monitored remotely with automatic alarms set up for several parameters. Common parameters often monitored at remote radio sites include:
  - Radio and microwave equipment performance (power out, interference, bit error rate [BER])
  - Fire/Smoke detector
  - Shelter Door Open Alarm (each door)
  - Site gate open alarm (each gate)
  - Site intrusion alarm (multiple motion detectors as required)
  - Shelter high temperature
  - Shelter low temperature
  - Auxiliary exhaust fan run
  - Commercial alternating current (AC) power
  - High and low humidity sensors
  - Floor water sensors
  - Surge arrestors

  - Transfer switch (normal or bypass state)
  - Battery voltage
  - Heating, ventilation, and air conditioning (HVAC)
  - Uninterruptible power supply (UPS)/direct current (DC) power
  - Generator status

    Please note, moving to an IP-based platform allows for inclusion of almost an unlimited number of parameters to be monitored real-time. A growing number of vendors provide very extensive monitoring capabilities for items like base stations, UPS, microwave, generators, and others. KIRG is encouraged to take full advantage of these capabilities.

- The current situation, where the ability to restore system operation depends entirely on a single local technician, poses high risk, especially considering the lack of regular maintenance. Potential remedies may include using different suppliers, negotiating an agreement under which the current supplier provides a second local technician or delegates temporary support whenever the primary resource is unavailable/absent, training KIRG's own resources so that they can be used as the first line of defense, or a combination of thereof.

- The new recommended system should be covered by a comprehensive plan that includes the following main components:
  - Definition of all covered subsystems (radio, backhaul, dispatch, power, monitoring, facilities)
  - Regularly scheduled preventive maintenance plan
  - Guaranteed response and restoration times
  - Software updates
  - Hardware refreshment
  - Performance guarantees
  - Cybersecurity
  - Contacts/escalation procedures
  - Spare parts plan
  - Support plan with severity definitions and corresponding responses
  - Delineation of responsibilities between KIRG and the vendor(s)
  - Exclusions

5.8 Facilities

The facilities are generally in good condition, although they would benefit from more systematic maintenance and upkeep.

MCP recommends monitoring (covered above), quarterly clean-up, annual detailed inspections, and rodent-proofing.

5.9 Prioritized Recommendations

As requested by KIRG, MCP offers the following prioritized recommendations. The priorities represent our subjective balance of the respective issues' importance, urgency level, and ease of implementation.

1. Lifecycle: At a minimum, replace end-of-life items (dispatch consoles, Quantar repeaters, microwave).
2. Capacity: Add capacity to the simulcast system – four channels.
3. Coverage: Increase use of vehicular repeaters.
4. Reliability and Network: Provide network redundancy.
5. Technology and features: Implement an automatic mixed-mode P25/analog system.
6. Subscribers: Implement policy covering approved radios, maintenance requirements, and common programming.
7. Maintenance: After implementing the new system, enter into a long-term support agreement including upgrades and preventive maintenance.
8. Coverage: Consider improving mobile coverage, mid-county, and portable coverage in Klamath Falls area.
9. Reliability and Network: Implement site monitoring.
10. Interoperability: Add connections to all adjacent systems via simple dispatch solution.
11. Facilities: Include systematic maintenance and upkeep in support agreement.

5.10 Conceptual Design – Rationale for Recommended Approach

Before developing the recommended conceptual design, MCP considered several options, presented below in progressive order:

1. Do nothing. Not a viable option for several reasons:
   a. Several critical parts of the system (some base stations, microwave network, dispatch consoles) already are or are soon becoming obsolete. While still functional, they are no longer supported by the manufacturers, thus posing risks of unacceptably long service interruptions when the right parts or people with appropriate skills can no longer be found to restore the system after failures.
   b. The current system is not meeting users' needs, especially when it comes to capacity and coverage.
   c. The current system is missing a multitude of features useful or even essential to first responders.
   d. The current system may be a legal risk with significant parts of communications inaccessible to dispatch and call recording.

2. Minimum update program: Maintain current architecture but replace obsolete equipment with current-equivalent equipment: microwave, consoles, standalone repeaters. This is a potentially viable, but not recommended, option because it only addresses one challenge—equipment obsolescence. The updated system would be more reliable, but without any improvements in performance in terms of coverage, capacity, or features.

3. Minimum update plus: In this scenario, the updates in the minimum update program (listed in #2) is enhanced by adding two analog channels to the simulcast system and by the addition of simulcast

sites enhancing coverage. This is a viable option as it would address all observed main challenges, although without providing any modern digital functionality.

4. Step into the digital world with IP-based P25: In MCP's opinion, the minimum update plus option stops just short of the optimum solution, even though, once channels and sites are added, microwave and consoles are replaced, the additional cost of crossing into the digital world is relatively minor. In this option, the minimum update plus scenario is enhanced by using digital IP-based backhaul microwave and enabling digital conventional P25 operations. Every channel would be capable of transmitting both conventional analog and conventional P25 transmissions (including encryption) and of switching automatically between these modes of operation.

5. Implement a P25 trunked system: As mentioned in the first part of the report, switching from conventional P25 is a significant expense, but it also comes with additional challenges. While it is possible to seamlessly combine conventional analog and conventional P25 operations, thus allowing very flexible transition time or even using mixed mode indefinitely, switching to trunking requires all users to purchase new subscriber units—very likely an unacceptable expense to many KIRG member agencies. The OSP system is far from providing satisfactory coverage in Klamath County, so joining it is not a viable option for KIRG, even if the cost of buying all new subscriber equipment were not an issue. The advantages of switching from conventional to trunked P25 are much less significant than commonly believed, as shown in the table below:

Table 5: P25 – Comparison of Conventional and Trunked Features

Feature	P25 Conventional	P25 Trunked
IP backbone	Available	Available
Analog and digital operation (repeaters/subscribers)	Yes/yes	No/yes
Simplex/half-duplex/duplex (repeaters)	Simplex/half-duplex/duplex	Half-duplex/duplex
Access control/subscriber registration	Yes	Yes
Supports analog and digital consoles	Yes	Yes
End-to-end encryption	Yes	Yes
Distributed, centralized, or switched voting	Yes	Yes
Simulcast	Yes	Yes
Multisite (automatic roaming)	Yes	Yes
Self-calibration (simulcast)	Yes	Yes

Feature	P25 Conventional	P25 Trunked
Receive voting	Yes	Yes
Multisite switching	Distributed/centralized	Centralized/distributed
Advanced remote monitoring and diagnostics	Yes	Yes
Analog line interface	Yes	Yes
MDC 1200 interface support	Yes	Yes
Multiple linking options, including RF	Yes	Yes (stricter requirements)
OTAR[5]	Yes	Yes
Packet data support	Yes	Yes
Voice call types	Group, individual, announcement, broadcast, emergency	
Non-voice call types	All standardized P25 supplementary services – status, radio check, monitor, call alert, inhibit/uninhibit, short message	
Talkgroup identification (ID)	Yes	Yes
Individual ID	Yes	Yes
Emergency ID	Yes	Yes
Emergency alarm	Yes	Yes
Talkgroup scanning	Yes	Yes
Interfaces	ISSI, PSTN[6], DFSI[7]	ISSI, PSTN, CSSI
Late entry	Yes (limited)	Yes
Call queuing	No	Yes

Marginal options: Some additional popular options were dismissed by MCP without extensive considerations.

[5] Over-the-air-rekeying
[6] Public switched telephone network
[7] Digital fixed station interface

1. Non-P25 technologies may be attractive but are not eligible for Federal grants and are not compatible with P25 systems used or being implemented by KIRG's neighbors and partners.
2. Different frequency bands, such as UHF or 700/800 MHz, were dismissed due to coverage performance characteristics. No frequency range is without drawbacks but the currently used VHF range is optimal for large, mountainous, scarcely populated areas.
3. As of early 2021, wireless broadband cannot be recommended to public safety organizations as the primary system. MCP believes public carriers someday may be able to offer the level of services required for first responders, including reliable group voice and off-network communications. MCP highly recommends and encourages KIRG to keep a close watch on the developments in this area and to continuously experiment with new technologies as they become available.

5.11 Conceptual Design – System Architecture

The diagram below depicts the conceptual design of the proposed changes to the KIRG system.

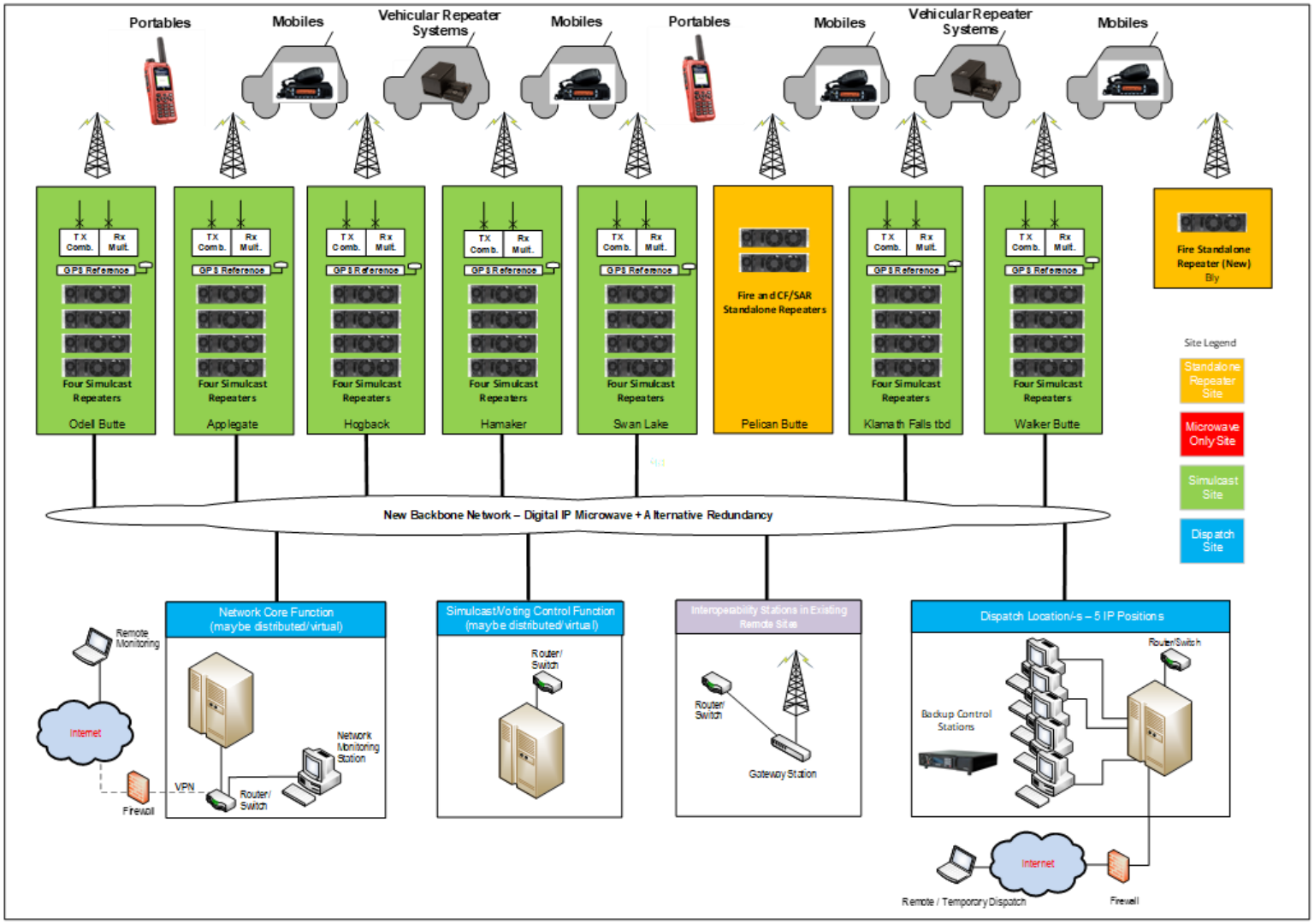

Figure 11: Proposed New KIRG Radio System

5.11.1 Site Number and Location

Under the proposed scenario, two new radio sites would be added: Walker Mountain, currently used as a microwave repeater only, and a to-be-determined site in Klamath Falls to provide additional in-building coverage for portable radios in town and in close vicinity. Please note: an additional analysis of costs and benefits needs to be performed by KIRG to determine the feasibility of adding these two sites. MCP will provide the necessary coverage prediction maps, and, if desired, financial estimates.

Swan Lake would be converted from a standalone site to become a part of the simulcast network. The existing simulcast sites would all carry four simulcast channels.

The extent of changes for Bly and Pelican Butte sites would be limited to replacing the obsolete repeaters with new radios.

5.11.2 Core Technology

The key enabling change for the functional enhancements is replacing the obsolete microwave with a digital IP backbone and the addition of a reliability-enhancing ring around Klamath Falls.

The proposed core technology is P25 Phase 1 Conventional VHF with the ability to automatically switch between P25 and analog modes of operation.

5.11.3 Spectrum Analysis

MCP conducted an evaluation of the VHF band to determine if enough frequencies could potentially be licensed to support a radio system that meets the coverage and capacity needs of Klamath County. Specifically, MCP evaluated if sufficient licensable frequencies are present to license a 4-channel conventional simulcast system with radio sites covering all of Klamath County.

To achieve this number of channels, eight individual frequencies must be licensed: four base station transmit frequencies with an FCC station class of FB2 (mobile relay) and four mobile frequencies. Because all final site locations are not yet known, the analysis considers frequencies adequately spaced from co-channel and adjacent-channel incumbents so that sites anywhere within Klamath County could potentially be licensed.

To perform the analysis, MCP conducted a VHF search based on the center point of Klamath County. Frequencies were identified with significant co-channel and adjacent-channel separation from incumbent operations.

The analysis is intended to capture the overall availability of VHF spectrum within the band to determine suitability for construction of a new radio system. Once site locations are finalized, individual frequencies can be selected for the frequency band that meet the following criteria:

1. Provide sufficient separation based on an interference contour analysis utilizing 19/37 decibel unloaded (dBu) coverage and interference contours
2. Provide sufficient protection from tower-to-tower interference
3. Provide sufficient separation between the transmit and receive frequencies (approximately 1 MHz)
4. Provide adequate separation between transmit frequencies to minimize combiner insertion losses and allow use of a single transmit antenna on each site
5. Pass an intermodulation analysis that results in no third order products on the selected receive frequencies

The table below summarizes candidate frequencies that should be licensable by Klamath County, along with the associated co-channel and adjacent-channel separation to the closest incumbent licensees:

Table 6: Frequency Research Information

Frequency	Co-channel Distance (km)	Adjacent-channel distance (km)
151.085	194	None within 250 km
151.0925	None within 250 km	144
151.22	131	None within 250 km
153.905	188	103
154.0025	None within 250 km	96
154.1525	None within 250 km	93
154.1675	None within 250 km	104
154.2275	165	110
154.265	180	None within 250 km
154.3025	None within 250 km	99
154.7475	None within 250 km	109
154.755	220	None within 250 km
154.7925	None within 250 km	113
154.8075	None within 250 km	130

Frequency	Co-channel Distance (km)	Adjacent-channel distance (km)
154.8225	None within 250 km	130
154.8975	None within 250 km	109
154.9575	None within 250 km	103
154.9875	149	99
155.0475	216	98
155.085	152	103
155.2575	197	112
155.265	166	197
155.2725	206	103
155.2875	None within 250 km	103
155.325	200	192
155.3625	None within 250 km	100
155.3775	None within 250 km	100
155.415	135	174
155.4675	None within 250 km	93
155.5125	None within 250 km	116
155.595	178	None within 250 km
155.6475	None within 250 km	141
155.6625	None within 250 km	90
155.7825	247	123
155.79	189	247

Frequency	Co-channel Distance (km)	Adjacent-channel distance (km)
155.8425	201	109
155.8875	None within 250 km	103
155.9025	None within 250 km	103
156.03	153	None within 250 km
156.075	None within 250 km	107
156.0975	None within 250 km	108
158.7825	206	87
158.85	157	146
158.9175	None within 250 km	93
158.9625	189	89
158.9775	247	102
159.015	153	197
159.15	219	104
159.1725	None within 250 km	130

Based on the analysis, it is MCP's opinion that there are sufficient VHF frequencies throughout the band for Klamath County to license a 4-channel conventional simulcast system.

5.11.4 Backbone Requirements

The backhaul to support the proposed radio system will need to support IP traffic and provide capacity to support mission-critical voice traffic. Network requirements for P25 voice traffic include the following:

- One-way latency ≤ 20 milliseconds (ms)
- One-way jitter ≤ 10 ms
- Packet loss ≤ 0.01%

The network must be designed and provisioned to minimize the introduction of latency, jitter, and packet loss into the applications. Therefore, the network must support Quality of Service (QoS) tagging to ensure critical traffic is delivered during periods of network congestion and to minimize latency, jitter, and packet loss. Implementing QoS in the network allows for priority marking of network traffic to ensure that critical traffic, such as voice packets, is not dropped or delayed across the network.

Network availability must be 99.999% uptime. Note that with multiple paths, a ring topology, appropriately selected network devices, and proper protocol selection and configuration, every segment in the network does not have to meet the 99.999% uptime for the whole network to meet it.

For physical connectivity, microwave is the preferred solution. When possible, redundant microwave paths are recommended for each site. If KIRG desires to connect the Bly site to the rest of the network, it will require fiber connectivity as the only means of backhaul due to the non-viability of microwave paths.

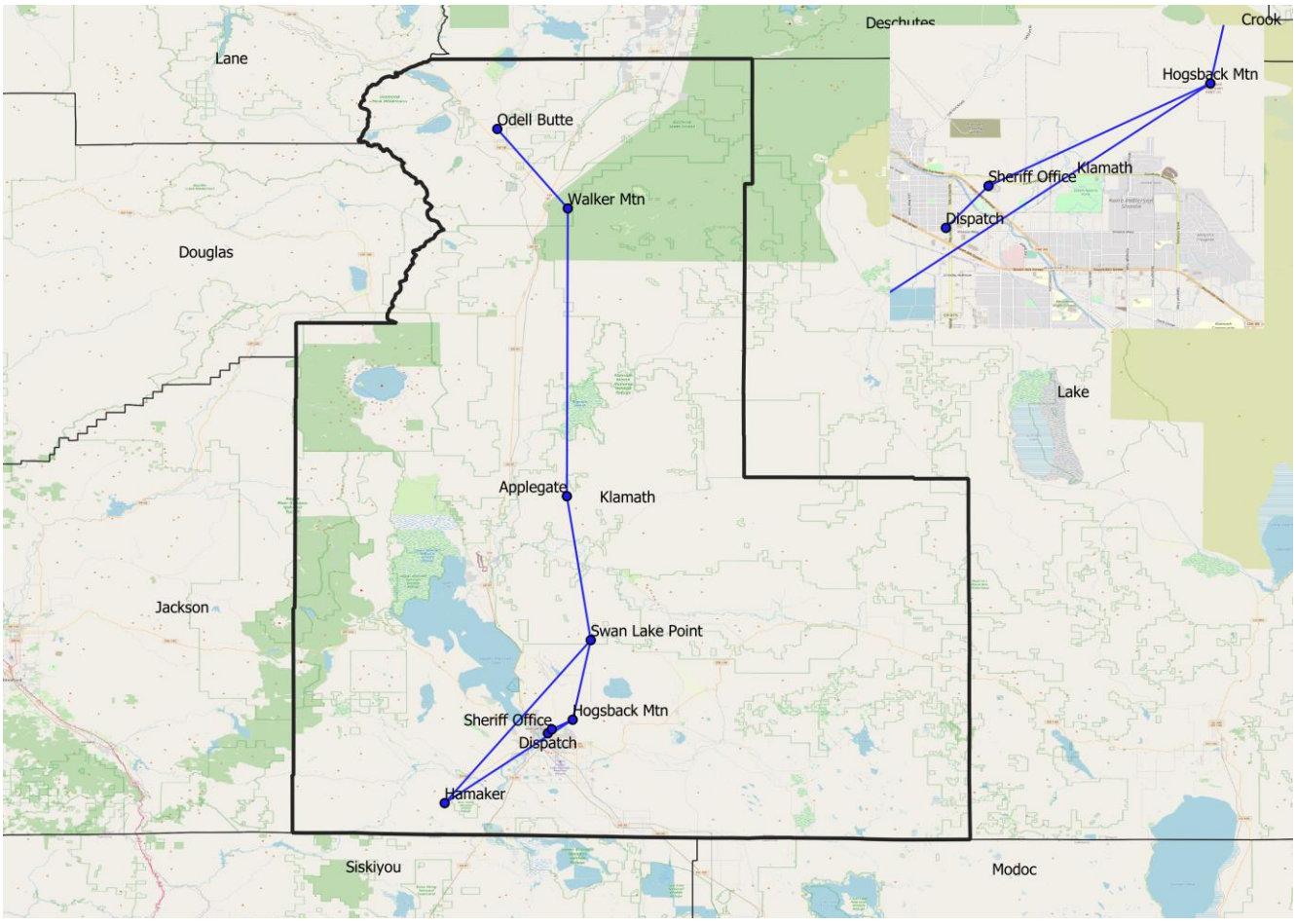

Figure 12: Conceptual Microwave System

5.11.5 Dispatch Console Requirements

The replacement dispatch consoles will require detailed specifications for procurement. In addition to the functional requirements, it is important that the consoles support the following:

- IP connectivity
- P25 Phase 1 operation
- CSSI
- Portability

5.11.6 Standards and Recommendations

The standards and recommendations below, listed alphabetically by author, should be considered in the development of the system upgrade/replacement RFP.

Table 6: Standards and Guidelines References

Author	Specification Reference	Document Title
American Association of Agency and Highway Transportation Officials (AASHTO)	AASHTO HB-17	Standard Specifications for Highway Bridges, 17th edition
American Concrete Institute (ACI)	ACI 301-05	Specifications for Structural Concrete
	ACI 302.1R-04	Guide for Concrete Floor and Slab Construction
	ACI 318-08	Building Code Requirements for Structural Concrete and Commentary
American National Standards Institute (ANSI)	ANSI T1.313-2003	Electrical Protection of Communications Towers and Associated Structures (Superseded ATIS 0600313, 12/2013)
	ANSI T1.334-2002	Electrical Protection for Telecommunications Central Offices
	ANSI	American Society for Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) ASHRAE Handbook—Fundamentals, 2009 Edition

Author	Specification Reference	Document Title
	ANSI J-STD-607-A-2002	Commercial Building Grounding (Earthing) and Bonding Requirements for Telecommunications
	ANSI/ASSE Z359	Fall Protection Code
ANSI/Telecommunications Industry Association (TIA)	ANSI/TIA-1019A	Standard for Installation, Alteration and Maintenance of Antenna Supporting Structures and Antennas
	ANSI/TIA-222-H	Structural Standard for Antenna Supporting Structures and Antennas and Small Wind Turbine Support Structures
American Society for Testing and Materials (ASTM)	ASTM A615-08a	Standard Specifications for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
	ASTM C31-08a	Practice for Making and Curing Concrete Test Specimens in the Field
	ASTM C33-01a	Standard Specifications for Concrete Aggregates
	ASTM C39-05e1	Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
	ASTM C150-00	Standard Specification for Portland Cement
	ASTM D1557-07	Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000-ft-lbf/ft3 (2,700 kN-m/m3))
	ASTM D2487-06e1	Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
	ASTMD 420-98	Standard Guide to Site Characterization for Engineering Design and Construction Purposes

Author	Specification Reference	Document Title
	ASTM D6938-08a	Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
	ASTM D1556-07	Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method
	ASTM G57-06	Standard Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method
American Society of Civil Engineers	ASCE-7	Minimum Design Loads for Buildings and Other Structures
Chain Link Fence Manufacturers Association	CLF-SFR0111	Chain Link Fence Manufacturers Institute Security Fencing Recommendations
Code of Federal Regulations	47 CFR	Code of Telecommunications
Electronics Industry Alliance (EIA)	EIA/ECA-310-E	Cabinets, Racks, Panels and Associated Equipment
Federal Aviation Administration (FAA)	150/5245-43F	Specification for Obstruction Lighting Equipment
	70/7460-1K	Obstruction Marking and Lighting
Federal Communications Commission	OET- Bulletin 65	Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields, Office of Engineering and Technology Bulletin 65
	Bulletin 65	Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields
Institute of Electrical and Electronics Engineers	IEEE C62.45	Surge Protection Device Testing
	IEEE STD 1100	Recommended Practice for Powering and Grounding [Revised 2005]

Author	Specification Reference	Document Title
	IEEE STD 1159	Recommended Practice for Monitoring Electric Power Quality [Revised 2009]
	ANSI/IEEE Std. 81.2-1991	Guide to Measurement of Impedance and Safety Characteristics of Large, Extended or Interconnected Grounding Systems
	IEEE Std. 81-1983	Guide for Measuring Earth Resistivity, Ground Impedance and Earth Surface Potentials of a Ground System
International Electrotechnical Commission	IEC 61643-1	Low Voltage Surge Protective Devices, Testing
	IEC 61024-1-2	Protection of structures against lightning – Part 1-2: General principles – Guide B – Design, installation, maintenance and inspection of lightning protection systems
Motorola Solutions, Inc.	Motorola R56	Standards and Guidelines for Communication Sites
National Electrical Contractors Association (NECA)	NECA 1-2006	Standard Practices for Good Workmanship in Electrical Contracting
National Electrical Manufacturers Association	NEMA 250	Enclosures for Electrical Equipment, 1000V Maximum
National Fire Protection Association	NFPA 1061	Standard for Public Safety Telecommunications Personnel Professional Qualifications
	NFPA 1144	Standard for Reducing Structure Ignition Hazards from Wild land Fire
	NFPA 1221	Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems
	NFPA 70	National Electric Code (NEC)
	NFPA 72	National Fire Alarm and Signaling Code

Author	Specification Reference	Document Title
	NFPA 780	Standard for the Installation of Lightning Protection Systems [Revised for 2014]
	NFPA 101	Life Safety Code
	NFPA 110	Standard for Emergency and Standby Power Systems
	NFPA 111	Standard on Stored Electrical Energy Emergency and Standby Power Systems
	NFPA 2001	Standard on Clean Agent Fire Extinguishing Systems
Underwriters Laboratories (UL)	UL 1449	Standard for Surge-Protective Devices
	UL 1778	Uninterruptible Power Systems
	UL 467	Grounding and Bonding Equipment
	UL 752	Standard for Bullet-Resisting Equipment
	UL 72	Tests for Fire Resistance of Record Protection Equipment
	UL 96A	Lightning Protection Components

5.12 ROM Cost of the New System

MCP contacted three different vendors and asked for rough order of magnitude (ROM) estimates for the selected technology. The costing scenarios below are based on the combination of data obtained from the vendors and MCP's databases and is for the version depicted in the diagram above (seven simulcast sites).

Please note that two of these estimates are based on distributed network technologies (no centralized switching or core) and one takes into consideration re-use of the new base stations.

Table 7: ROM Estimates for the Proposed System

Category	Vendor A	Vendor B	Vendor C
Radio system	$860,688	$1,223,000	$1,391,672
Antenna Systems	$175,000	$1,050,000	$700,000
Dispatch Systems	$250,000	$120,000	$250,000
Microwave System	$2,070,000	$1,350,000	$1,800,000
TOTAL	$3,355,688	$3,743,000	$4,141,672

Notes:

1. The lists above do not include any subscriber units or software upgrades for subscribers; these cannot be determined without a full inventory of these units and their currently installed options.
2. The lists above do not include the costs of a third party assisting KIRG in the procurement.
3. The lists above do not include any civil work to be undertaken by KIRG to prepare the sites for installation (e.g., power and backup power, grounding, security, shelters, towers).
4. In a competitive bid, MCP expects the above totals to decrease by approximately 20% due to vendor system discounts and/or incentives.

5.13 Conceptual Design – How Users Will Experience The Proposed Changes

Upon implementation of the above system, users will notice the following changes:

1. Mobile coverage will improve countywide, although it will not become universal.
2. Portable coverage will improve in Klamath Falls and the vicinity.
3. Congestion will become an uncommon occurrence.
4. Users will be able to keep the same radios they have (unless required otherwise by the separately recommended subscriber management policy).
5. Users with properly equipped and programmed radios will be able to communicate in P25 (digital) mode using encryption if needed.
6. Dispatchers will be able to patch KIRG users with outside agencies.
7. Dispatchers will be able to dispatch from alternative/backup locations.
8. The system will become more reliable.
9. Dispatchers and radio users will have access to additional functionalities courtesy of digital P25 signaling.

5.14 Next Steps

MCP understands that significant Federal funding is likely to become available imminently for upgrading public safety communications systems. KIRG needs to track related developments and ensure that it takes full advantage of the available financial assistance.

KIRG needs to estimate the available funding and apply for it. Based on the available budget, the recommendations may have to be scaled up or down for the best outcome for the County's first responders.

In the next step, detailed functional and technical requirements (request for proposal) for the new system need to be developed. For a project of the expected size and scope, MCP recommends an open competitive procurement process, as there are several vendors capable of developing detailed designs and providing a solution that meets KIRG's needs.

6 Conclusion

This report identifies areas where improvements could be beneficial, both immediately and for the long-term continued success of KIRG that will move the system toward the "ideal" state, which MAPS defines as public-safety-grade, or best-in-class public safety organization.

Appendix A – Coverage Maps – Existing System

Coverage maps can be found on the pages that follow.

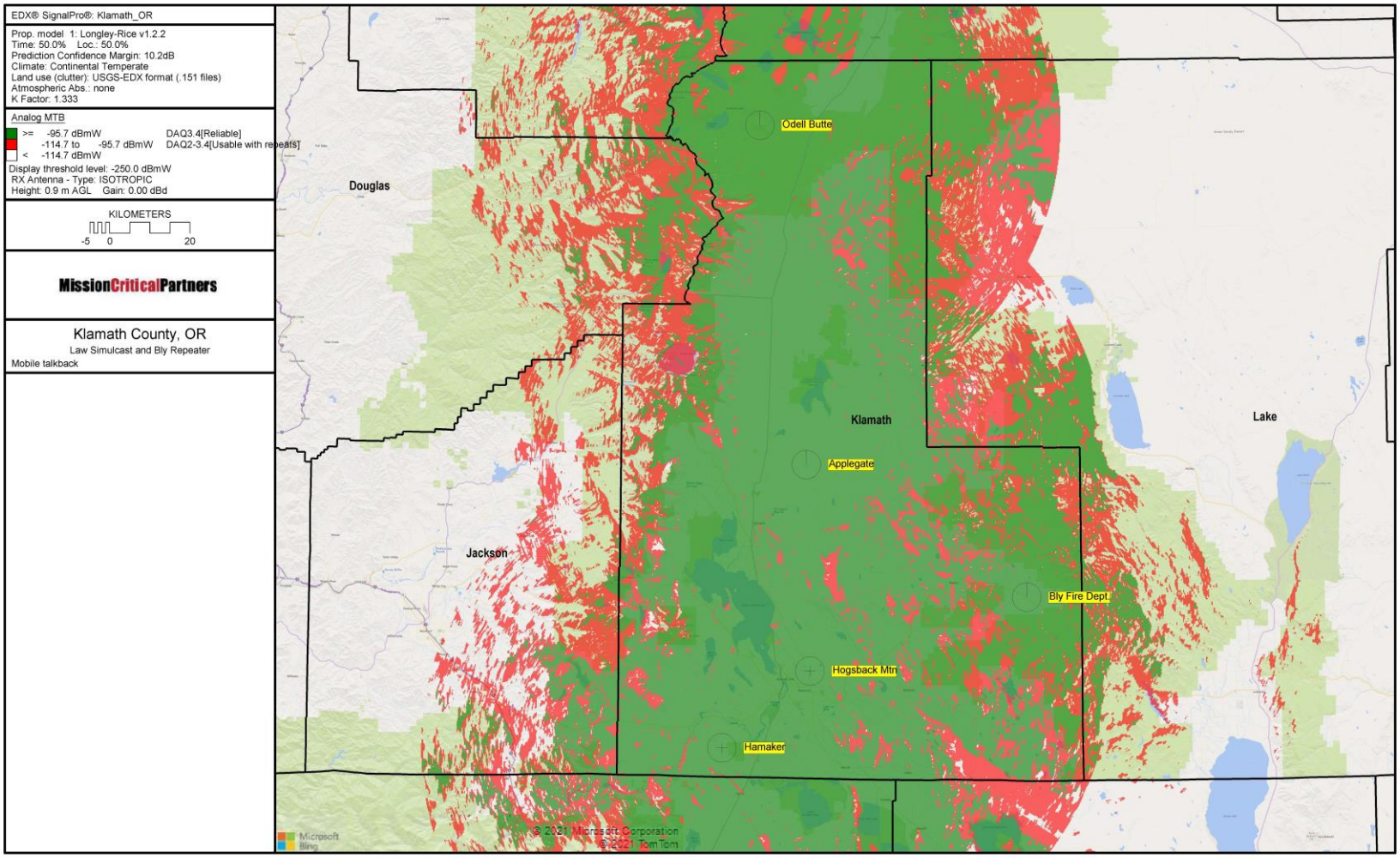

Figure 13: Mobile to Base Coverage

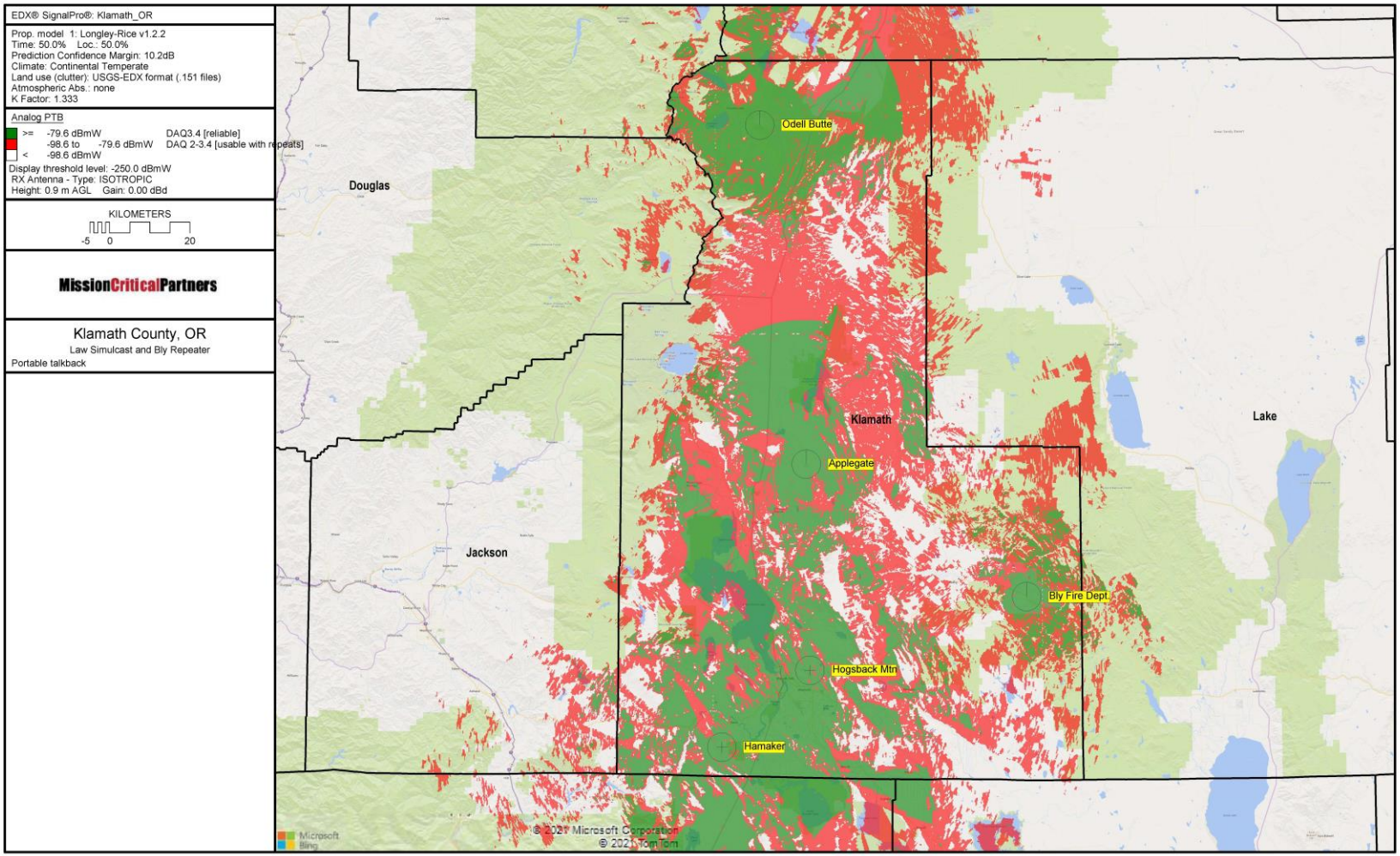

Figure 14: Portable to Base Outdoors

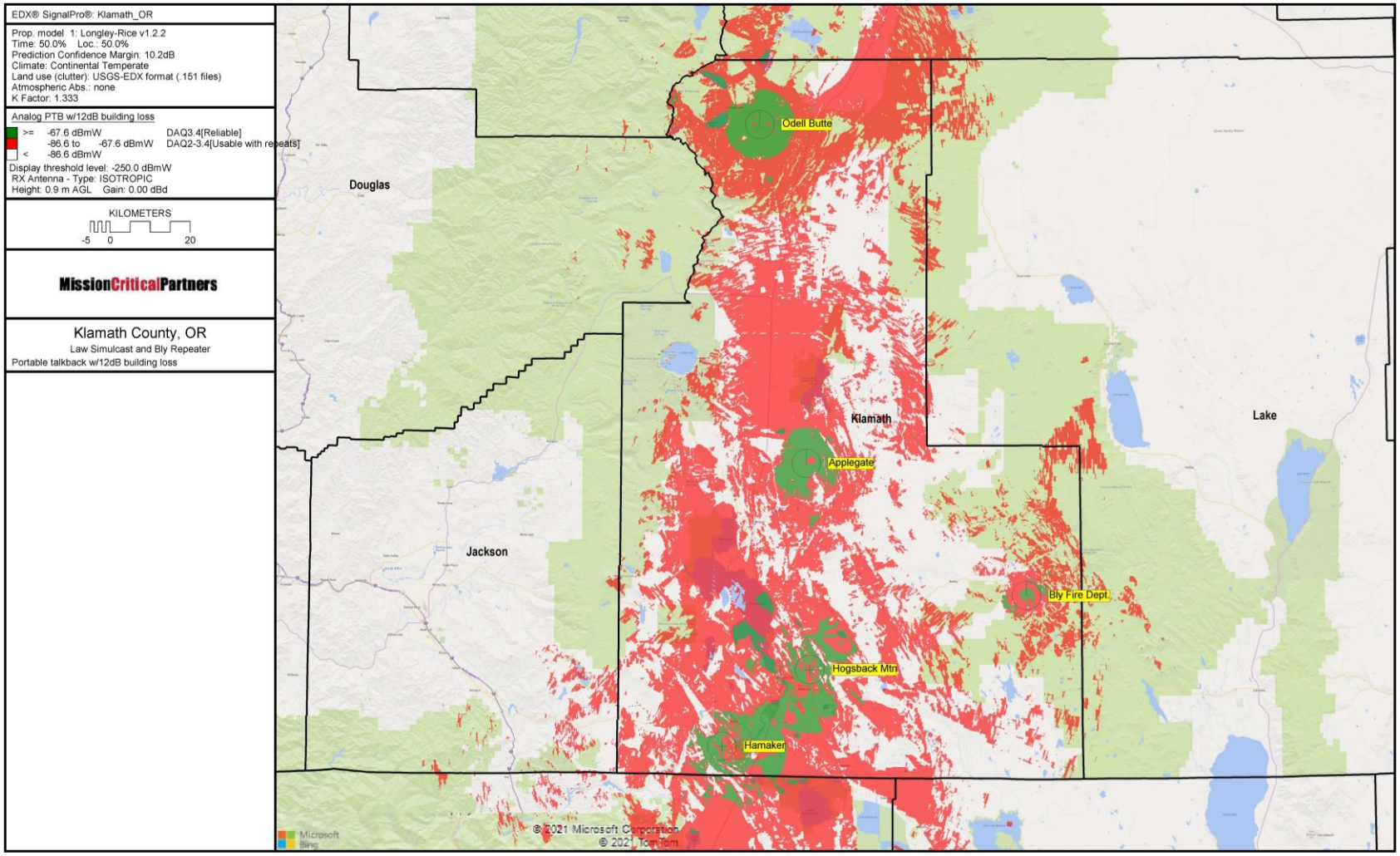

Figure 15: Portable to Base from Typical Residential Structures (12 dB)

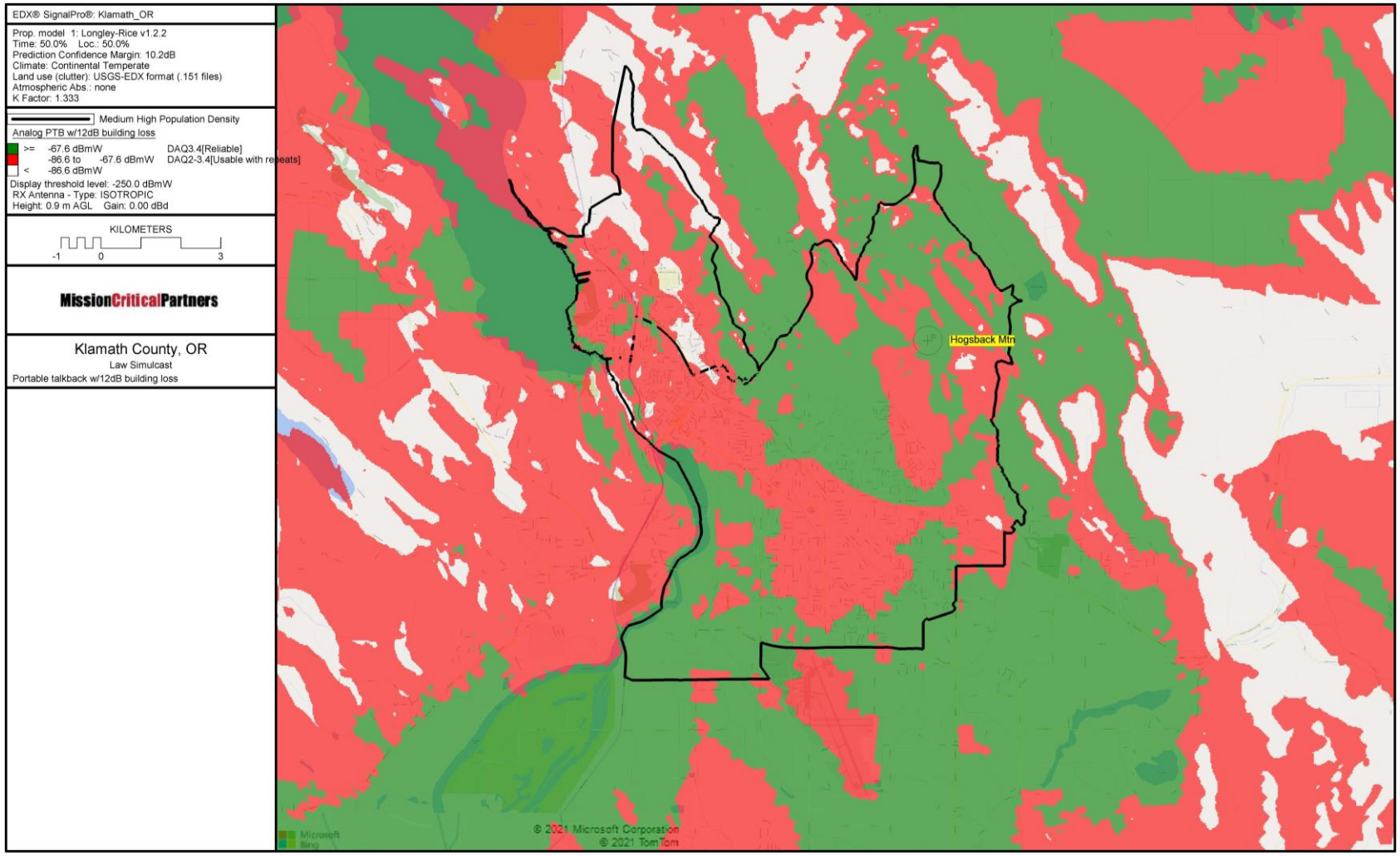

Figure 16: Klamath Falls - Portable to Base from Typical Residential Structures (12 dB)

Appendix B – Coverage Maps – Proposed System

Coverage maps for the proposed system can be found on the pages that follow.

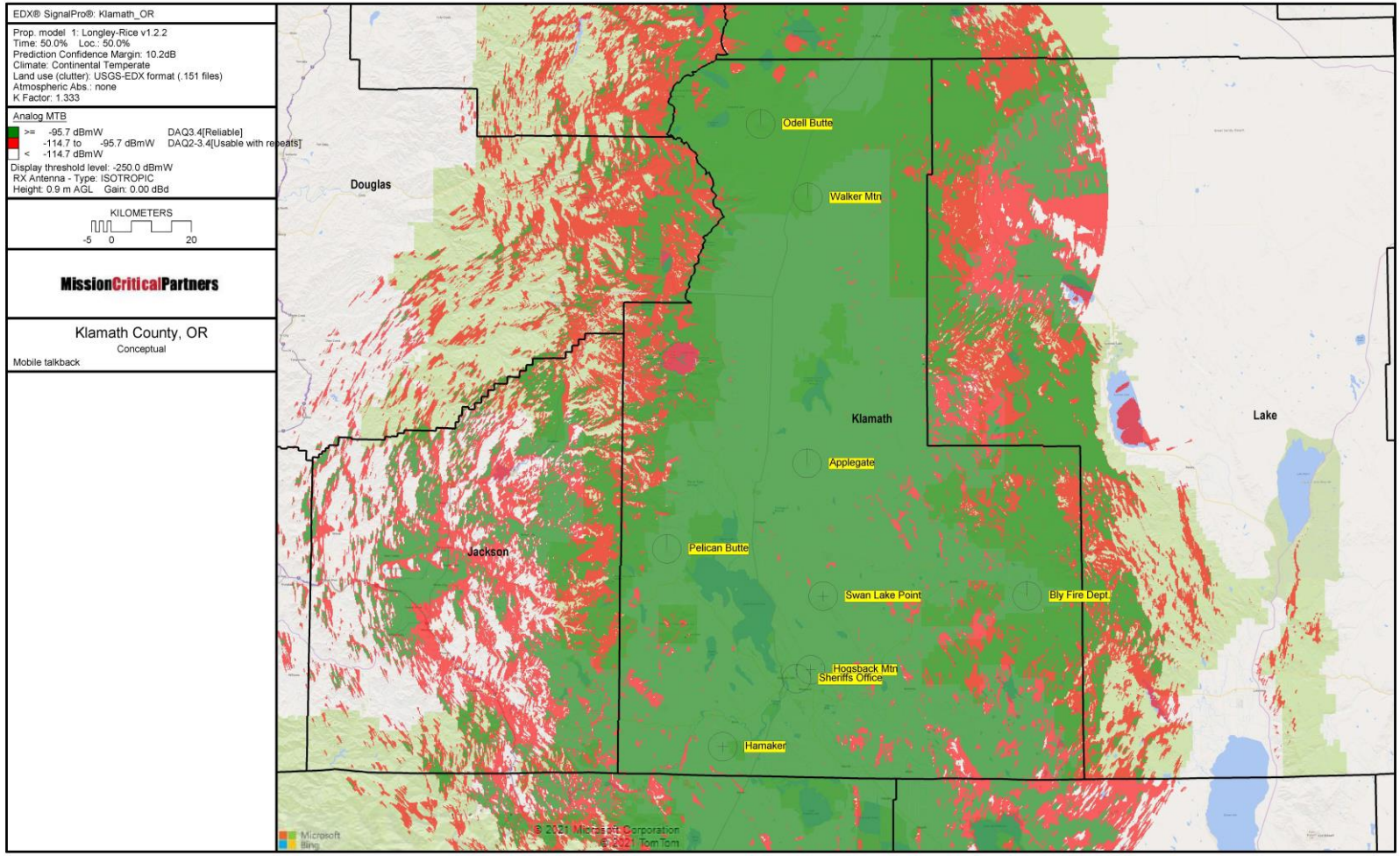

Figure 17: Mobile to Base Coverage

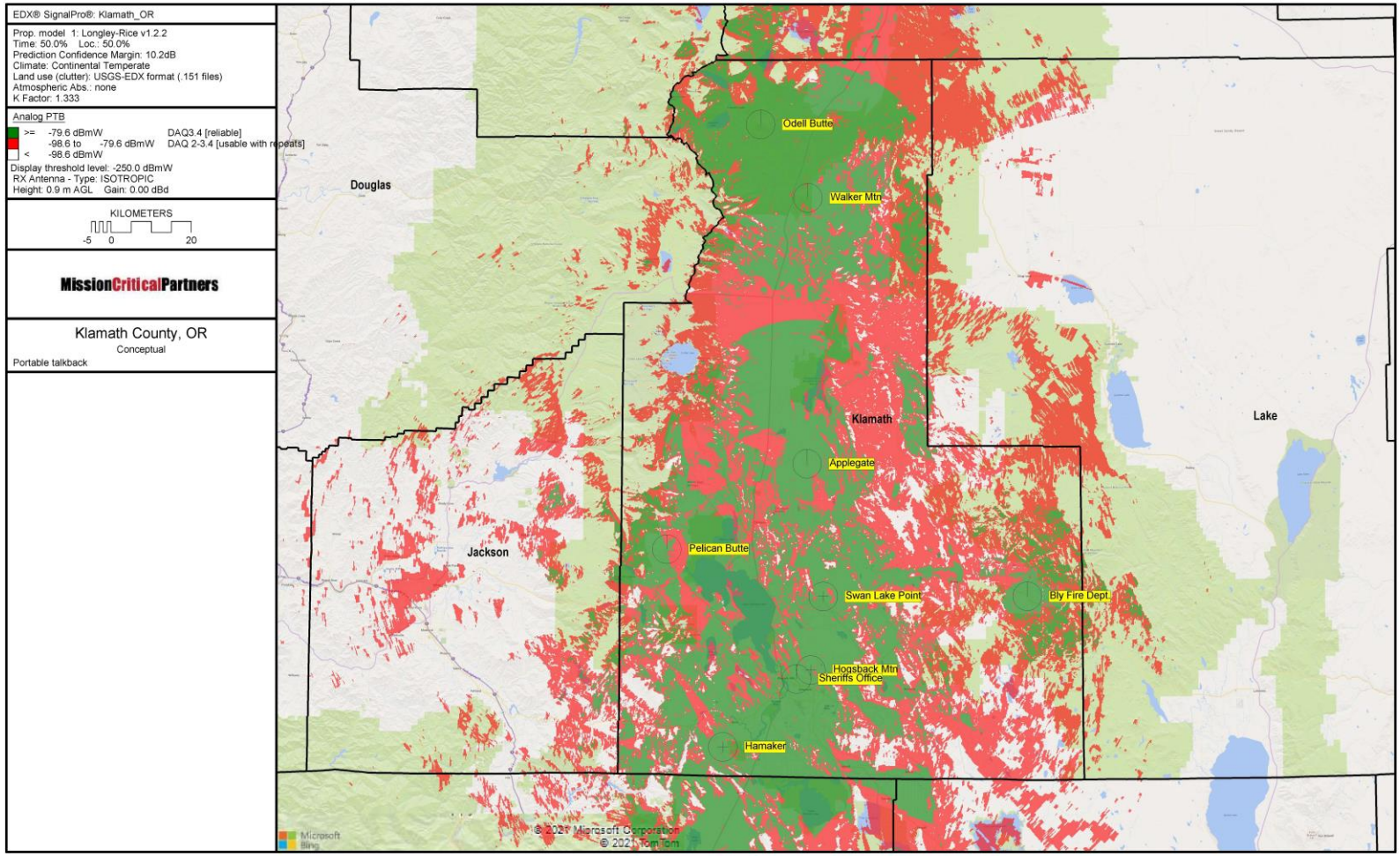

Figure 18: Portable to Base Outdoors

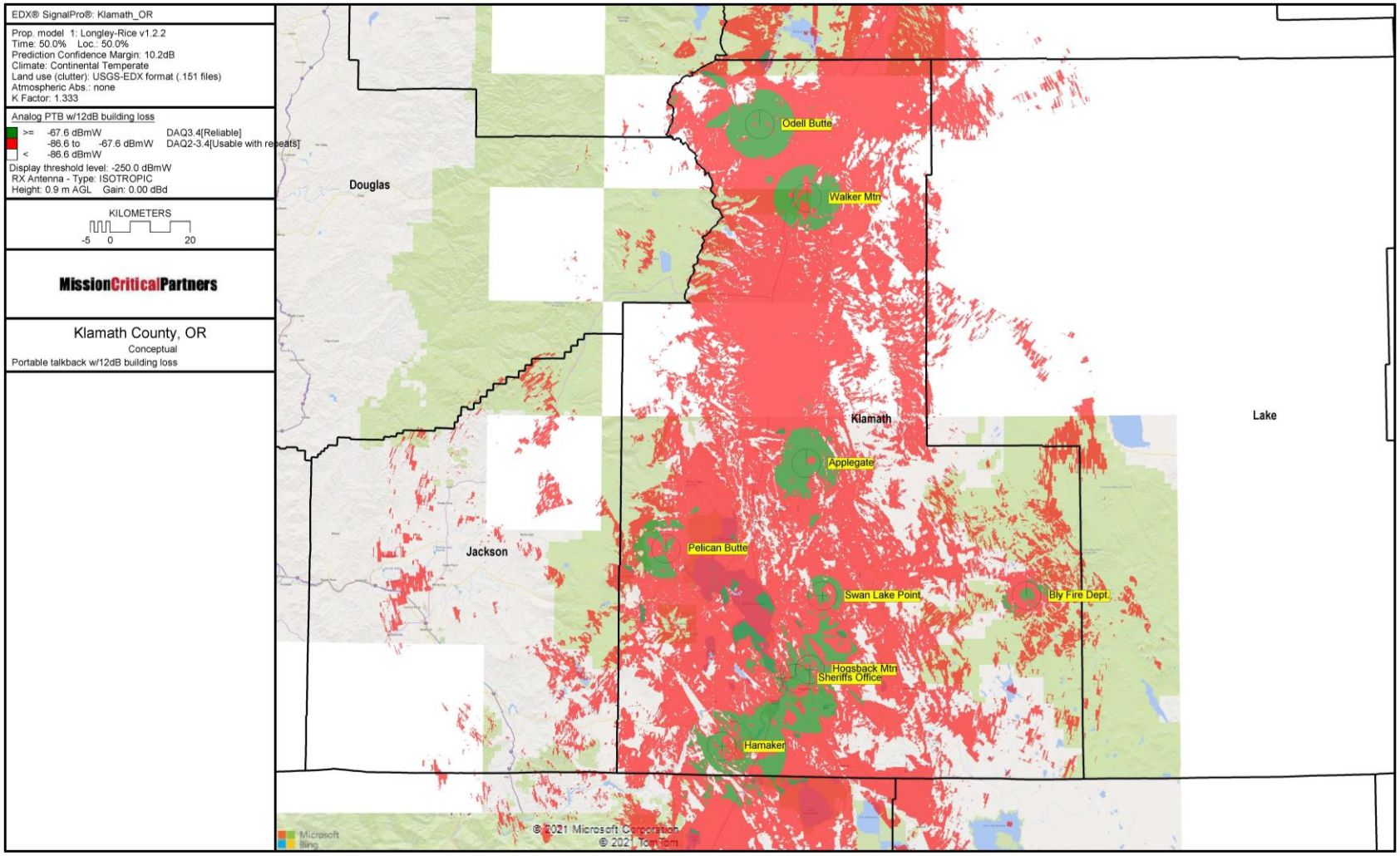

Figure 19: Portable to Base from Typical Residential Structures (12 dB)

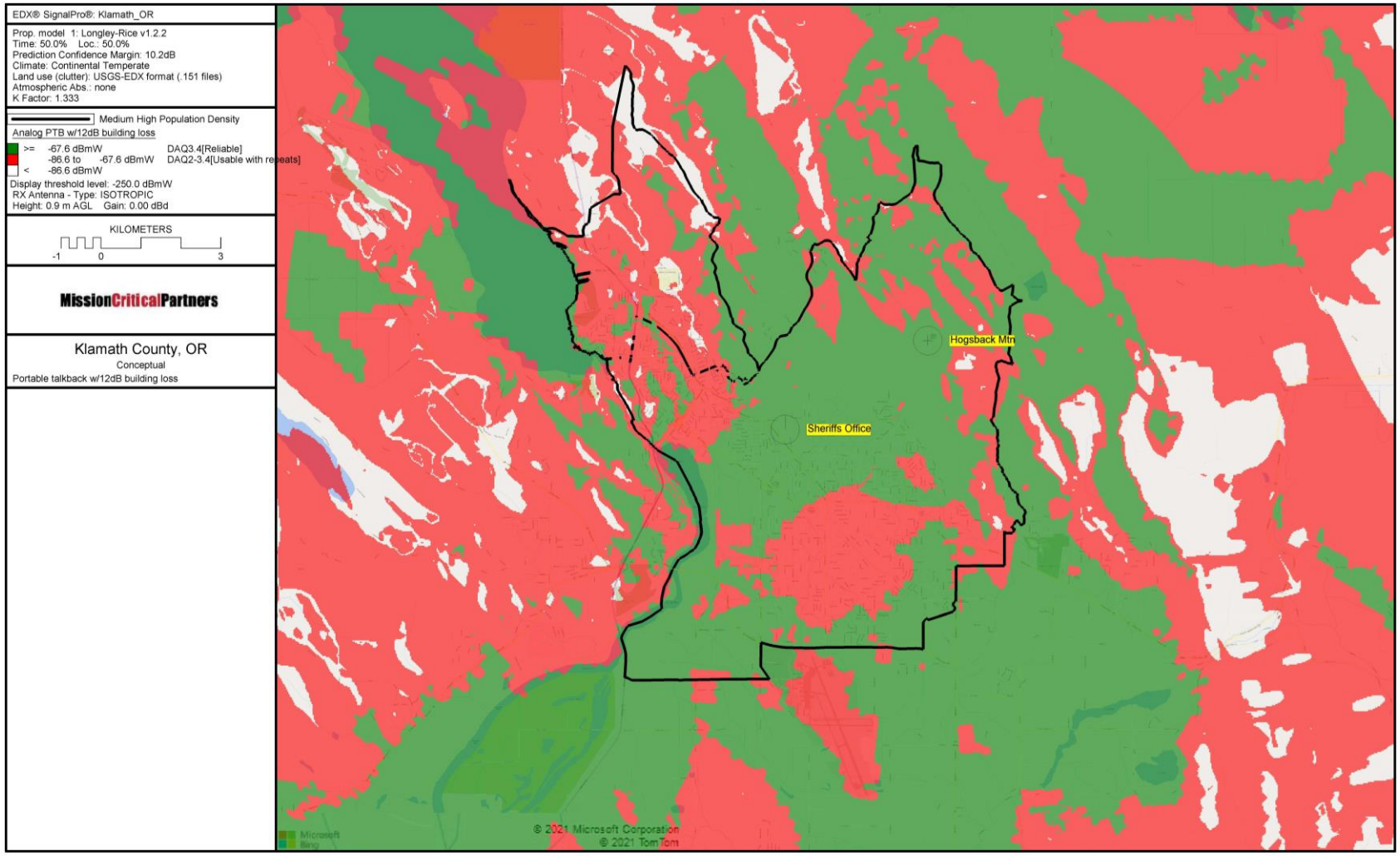

Figure 20: Klamath Falls Portable to Base from Typical Residential Structures (12 dB) – OPTION 1

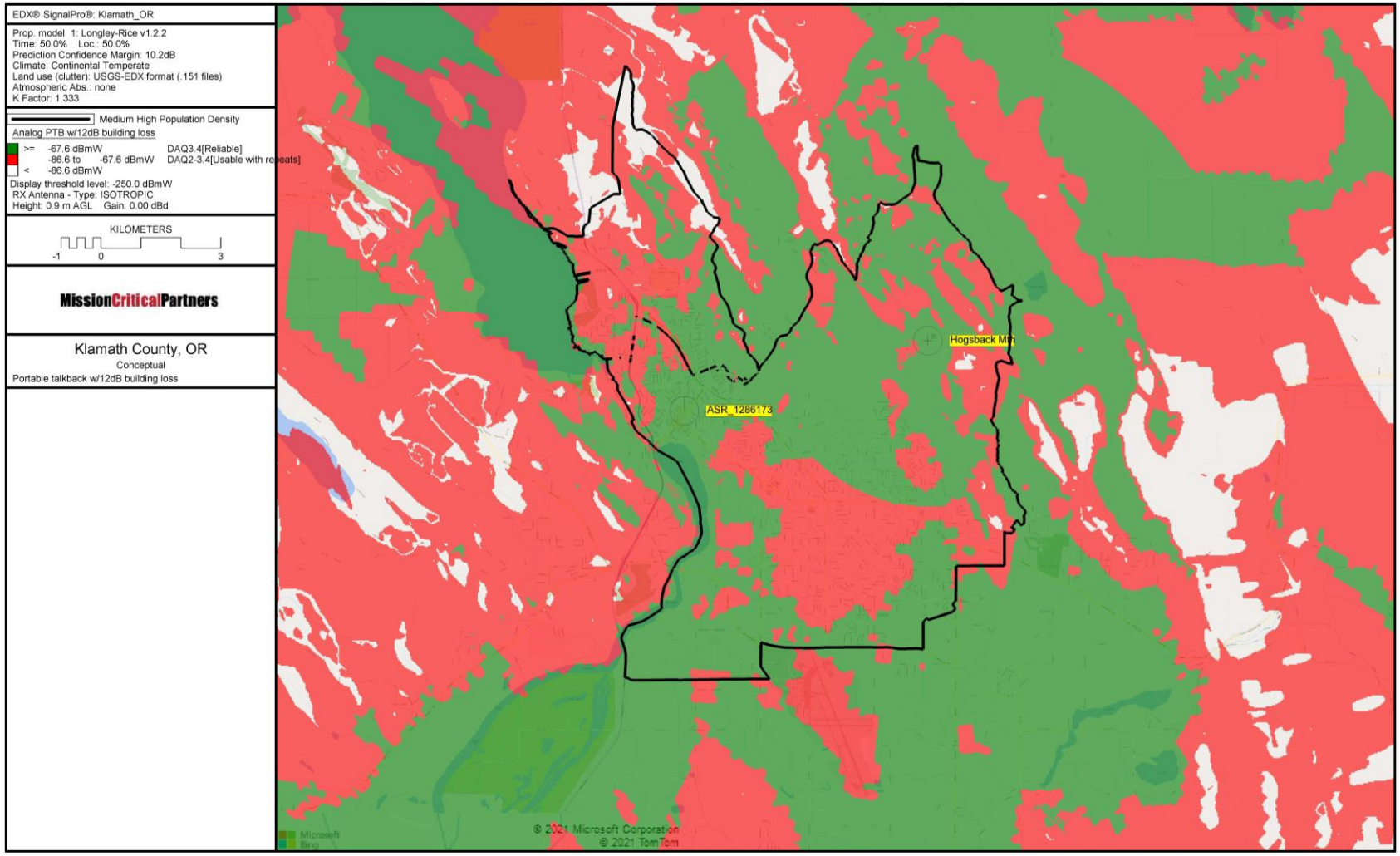

Figure 21: Klamath Falls Portable to Base from Typical Residential Structures (12 dB) – OPTION 2

Addendum Report

An addendum to the Klamath County Radio System Assessment Report is provided on the following pages.

KLAMATH
INTEROPERABILITY
RADIO
GROUP

MissionCriticalPartners
Because the Mission Matters

Addendum to the Radio System Assessment Report

Final Report

PREPARED MAY 2021
FOR KLAMATH INTEROPERABILITY RADIO GROUP, OREGON

MissionCriticalPartners.com
State College Office | 690 Gray's Woods Blvd. | Port Matilda, PA 16870 | 888.8.MCP.911 or 888.862.7911

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1 Introduction

In April 2021, Mission Critical Partners, LLC (MCP) submitted a radio system assessment report to Klamath Interoperability Radio Group (KIRG). KIRG hired MCP to assess its existing radio communications system, with the goal to determine the best approach for enhancing and improving public safety radio communications for first responders in the county.

In a subsequent conference call with Brandon Fowler, Keith Endacott, and John Ketchum—members of KIRG—a request was made for MCP to propose recommendations for limited budget alternatives, assuming that the available funds may be limited to $500,000. At the same meeting, some ideas were discussed, mainly the desire to stop using the Hamaker control site and Odell Butte site.

MCP recommends two alternative approaches for the limited budget:

1. Purchase vehicular repeaters for the maximum number of mobile radio users.
2. Replace the existing microwave system with current Internet Protocol (IP)-based equipment and implement a Radio-over-IP (RoIP) system to control standalone repeaters at remote sites.

Additionally, MCP recommends KIRG consider moving all land mobile radio (LMR) equipment from the Odell Butte site to the Walker Mountain site and shutting down the Odell Butte site without replacing it. The final decision should be made based on review of the coverage prediction maps provided by MCP from the point of view of local operational needs.

In a meeting with KIRG on May 10, 2021, a request was made to propose a plan for receiving multiple $500,000 budgets. One possible approach is included in Section 4 of this addendum.

2 Option 1: Vehicular Repeaters

Based on field observations and computer simulations, mobile coverage in Klamath County is generally satisfactory, especially taking into consideration challenging circumstances—large, mountainous areas. Portable coverage, however, is inferior. Widespread use of vehicular repeaters would allow field responders to benefit from the good mobile coverage using their portable radios. In addition, some of these vehicular repeaters may be placed in semi-permanent stationary locations, providing temporary coverage improvement on an as-needed basis.

Based on current market pricing and current KIRG system configuration (vehicular repeaters for digital trunked systems, not recommended by MCP, are typically 50%-150% more expensive), the $500,000 budget would allow the purchase of 50–80 such devices, their installation, and the necessary associated frequency planning and licensing.

This option solves only one of KIRG users' challenges, inferior portable coverage. However, since coverage is the most essential performance characteristic of any radio system, this approach is worthy of serious consideration.

3 Option 2: System Upgrade

In the main report, MCP identified replacement of obsolete equipment as a top priority for KIRG, with the microwave system being the top concern in this category. System congestion was named the most important issue to be addressed overall. KIRG's desire to cut the annual lease costs for the Hamaker control and Odell Butte sites also has been considered.

All these concerns can be addressed for under $500,000 by taking the following steps:

1. Replace the obsolete microwave radios with current-production digital, IP models, reusing the existing power and antenna systems at the existing sites (except Odell Butte and Hamaker control, to be removed from operations)
2. Add RoIP control system/devices to replace the Hamaker control equipment

MCP's conservative budgetary calculations indicate that using high-end microwave and networking radios, the current microwave can be replaced for approximately $410,000 (excluding installation costs). A subsequent quote obtained by MCP from a reputable alternative vendor (Ceragon) indicates that the costs can be significantly (>25%) reduced. This is based on reusing current power supply and antenna systems, both of which will have to be verified for suitability and checked for performance by a qualified service provider.

A side benefit of replacing the current microwave system with an IP-based system is the ease of interfacing a multitude of inexpensive devices allowing detailed remote monitoring of the remote sites for security and performance. Examples of the parameters recommended for monitoring are included in Section 5.7, Lifecycle and Maintenance, Lifecycle, of the main report.

Implementation of RoIP will be enabled by upgrading the microwave system to the IP-enabled platform. RoIP systems and devices can be used to emulate standard remote-control methods, such as E&M or tone control using IP backbone. This will enable KIRG to control base stations and other radios as desired from the dispatch positions at any site where the new microwave can be interfaced. This means the exclusion of Bly and Pelican Butte sites; Bly would remain an independent repeater and Pelican Butte would be controlled by the existing control radios placed at another suitable site, for example Swan Lake Point.

Please note: The Bly repeater also could be controlled remotely using the same RoIP technology; it would only require an alternative IP connection. Even if a public-safety-grade connection cannot be obtained from commercial wireless or wireline carriers, any connection would be an improvement over the current status.

The ability to control all remote base stations would have two significant benefits. First, it would enable recording of all traffic in the system. Second, by giving the dispatcher control over each individual non-simulcast repeater, it would relieve current system capacity concerns because the dispatchers would have the flexibility to patch any repeater or simulcast channel together to enable wide-area operations, as needed, depending on the nature and location of the incidents and participating agencies.

This option would not affect the existing simulcast system other than:

- Requirement for proper configuration of the new backhaul's interfaces
- Addition of the ability to patch the simulcast system with any other repeater in the network
- Potential relocation of LMR equipment from the Odell Butte site either to the Walker Mountain site or an alternative new site (see Section 5 below)

Initial budgetary research indicates that RoIP can be implemented using all existing KIRG radios, even the old Quantar units, for approximately $3,000 per link. Compatibility of all remote radios and repeaters with remote control schemes should be verified with the current technical support services provider or during a potential bidding process.

Accounting for all existing standalone repeaters (except Bly but including control radios for Pelican Butte) and HAM backup radios yields 16 radios requiring remote control, for a budgetary total of $48,000.

Assuming a total budget of $500,000 the above two suggestions would still leave approximately $40,000 to $140,000 (depending on the selected microwave supplier) for any associated implementation, planning, and/or licensing services.

The following diagram represents a conceptual design of the updated network. The grey box on the left side represents the potential new site replacing Odell Butte. Please note: Relocating the simulcast site from Odell Butte to Walker Mountain would require re-engineering simulcast parameters. This likely can be accomplished by adjusting settings in the system, but some additional steps, such as provisioning directional antennas, may be required. (Additional related details are discussed in the next section.)

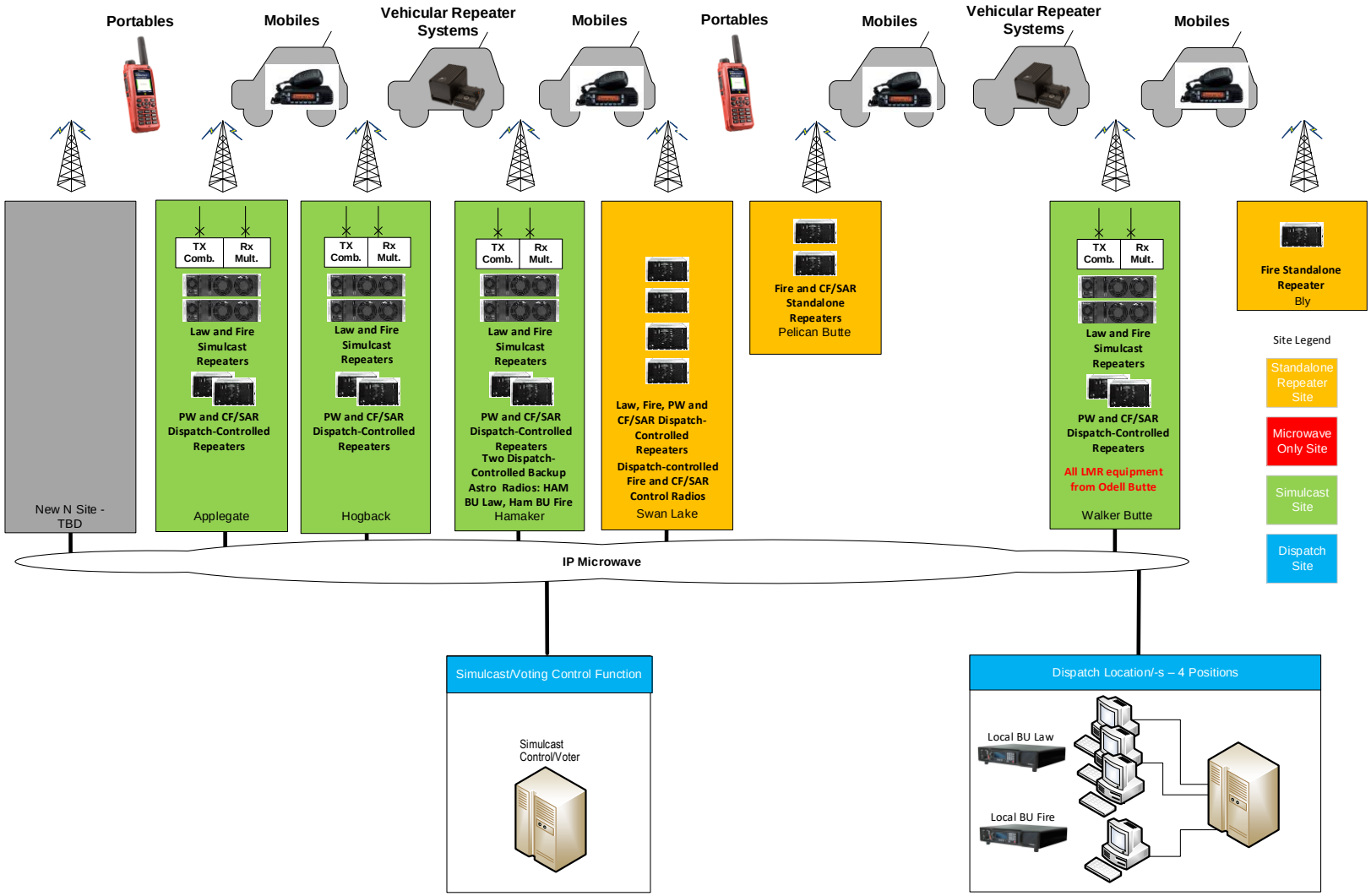

Figure 1: Updated Network (Conceptual Design)

4 Plan for Additional Funding

As requested in the May 10th meeting, MCP reviewed the recommendations included in the main report and determined that the proposed system could be implemented in the following steps, based on the budget being available in $500,000 tranches.

Table 1: Proposed System Implementation Steps (By Budget Availability)

Tranche #	Expenditures
1	Project plan; move equipment from the Odell Butte site to the Walker Mountain site; upgrade microwave; implement RoIP; add system monitoring capabilities
2	Replace some standalone repeaters (two per site) with a new county-wide simulcast system (while retaining the current simulcast system)
3	Upgrade the current simulcast system to match the newly implemented system (control system and repeaters)
4	Upgrade all remaining base stations and repeaters to currently supported models; replace the dispatch system with current production IP-based model
5	Replace all mobile radios with vehicular repeaters
6	Upgrade all portable radios

The order of investments presented above could be changed to suit KIRG's priorities. The exception is the implementation of IP-based microwave backbone (step 1), which is the necessary condition for most of the proposed improvements.

5 New Site Discussion

KIRG is considering shutting down the Odell Butte site and provided MCP with data on a potential replacement site. MCP performed computer simulations and then compared predicted coverage from Odell Butte, Walker Mountain, and the proposed (potential) new location.

The three following figures describe mobile-to-base predicted coverage for the proposed new site, Odell Butte and Walker Mountain. The "new north site" provides a relatively small coverage area, although it fills out the northwest corner of the county well. Odell Butte and Walker Mountain provide similar coverage in the entire northern area, but Walker Mountain would fill in the central area of the county better than Odell Butte.

The maps used in this document are just a sample of the set of maps provided separately to KIRG.

The ultimate decision needs to be made with participation of the KIRG members familiar with the operational needs of first responders in the northern part of the county.

Please note: MCP recommends against using Walker Mountain and the new proposed location together as simulcast sites; the overlap in coverage between these two locations would make simulcast design extremely difficult if not impossible. If both sites are needed for operational needs, MCP recommends operating only one site as a part of simulcast system and the other one as a non-simulcasted repeater.

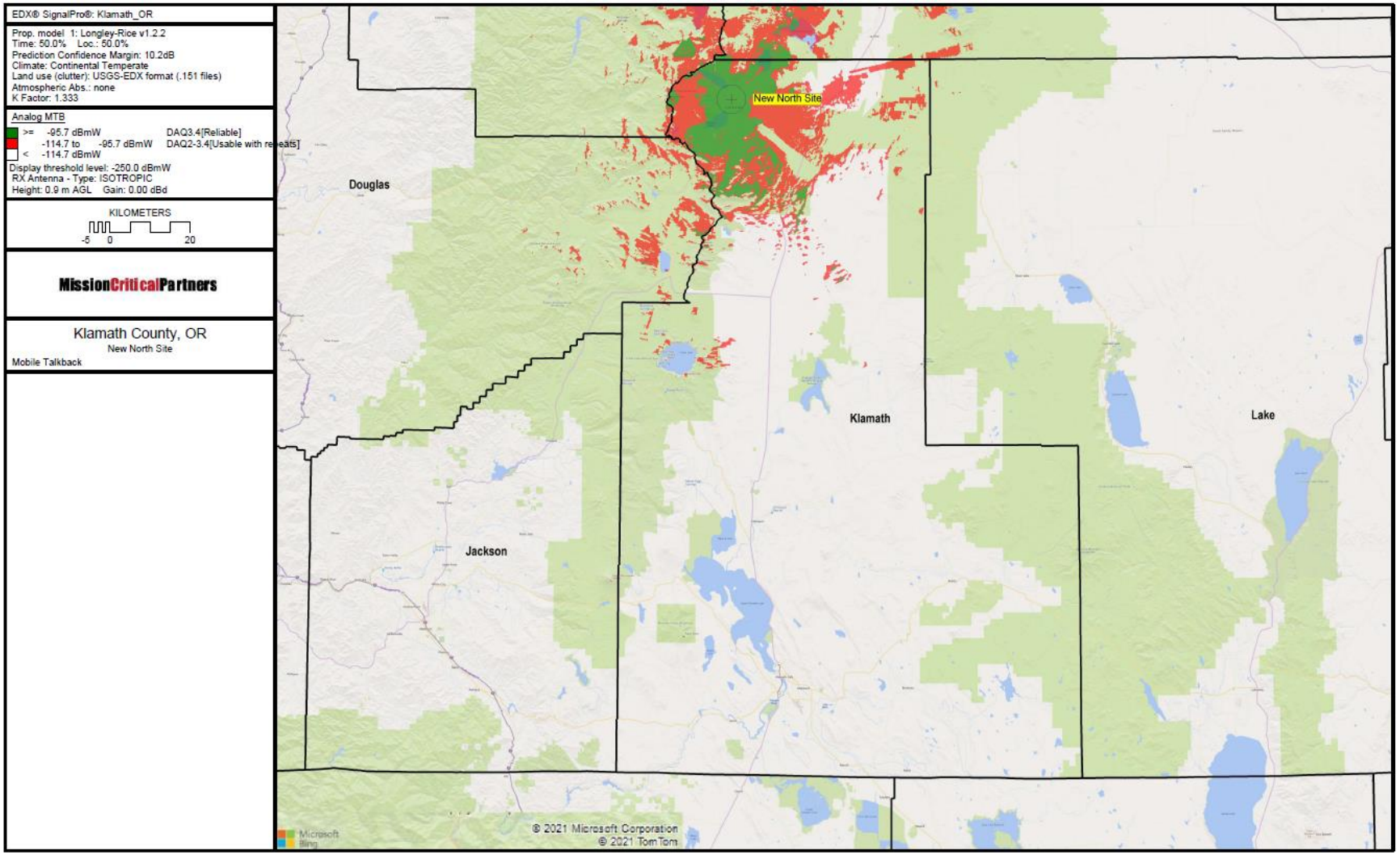

Figure 2: Proposed New North Site

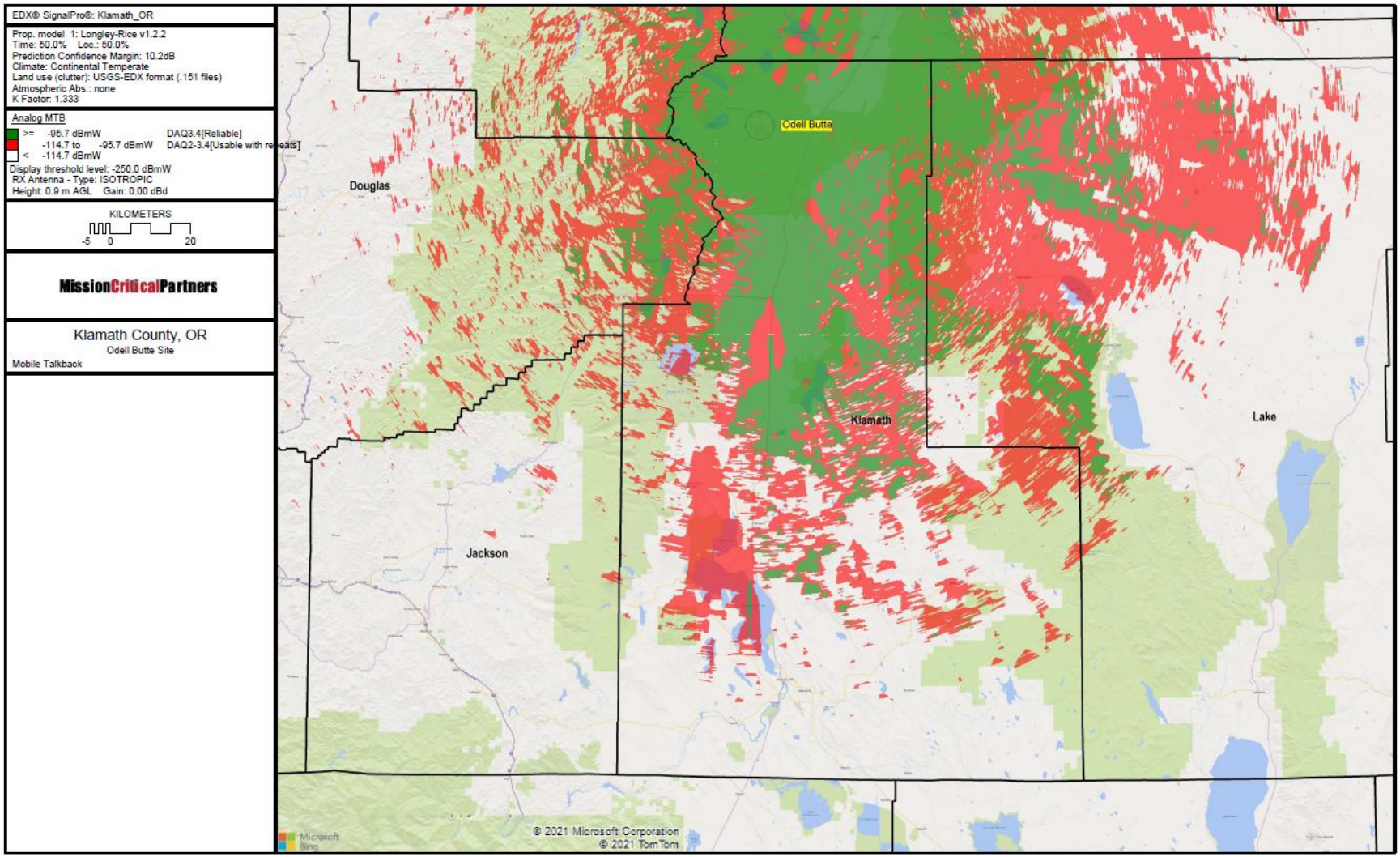

Figure 3: Odell Butte Site

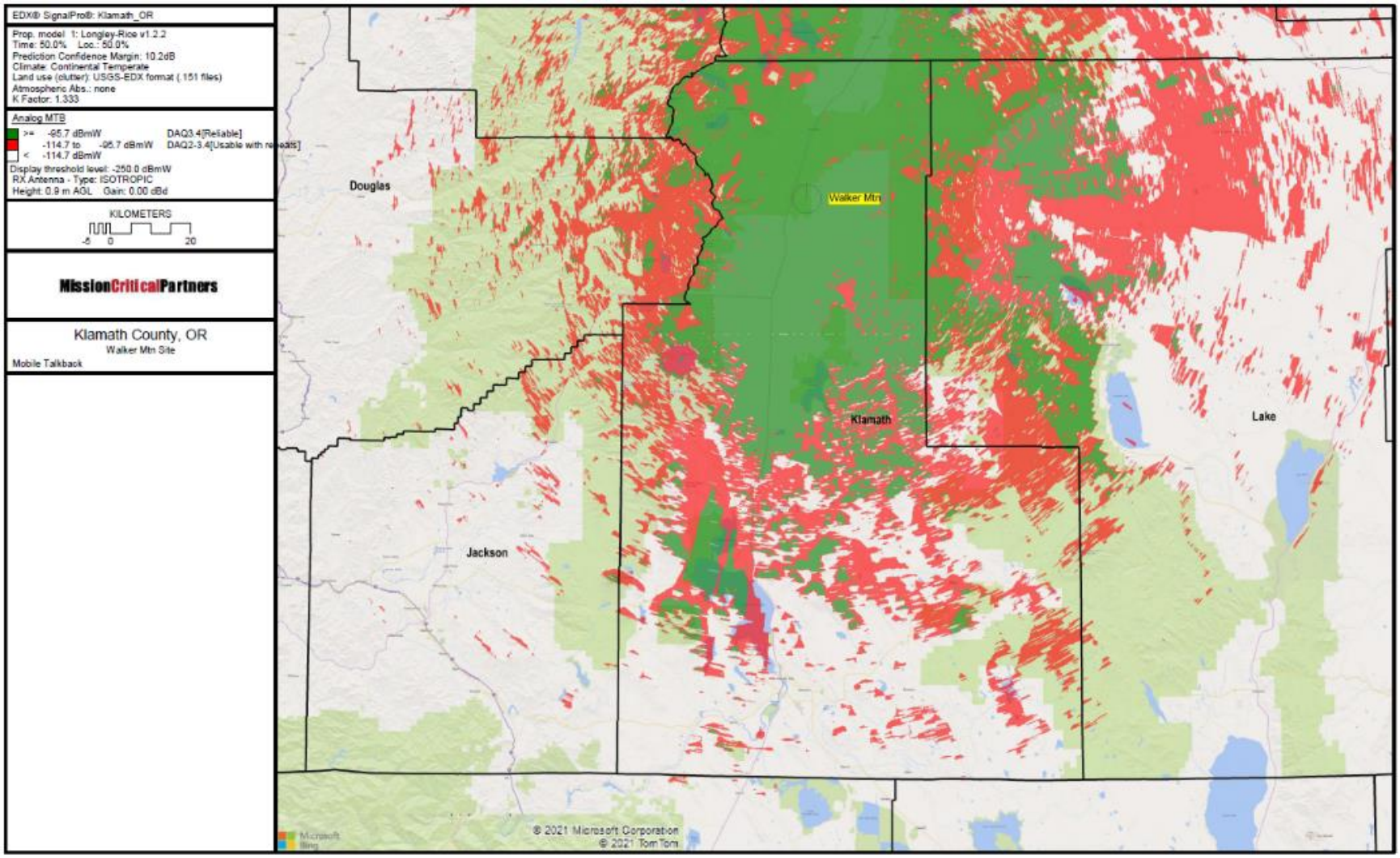

Figure 4: Walker Mountain Site

6 Conclusion

The first suggestion—widespread use of vehicular repeaters—would improve the experience of KIRG's users in terms of coverage; specifically, allowing use of portable radios wherever mobile coverage is sufficient if the connection between the participating portable(s) and mobile is possible. It would not address any other concerns identified in MCP's report.

The second suggestion—updating the microwave system and implementation of RoIP—would not improve coverage performance, but would allow KIRG to drop the Hamaker control site and address several other concerns identified in MCP's report:

- Equipment obsolescence (microwave only)
- System congestion
- Radio traffic recording
- Site monitoring

The plan presented in the main report by MCP is suitable for incremental implementation using the hypothetical $500,000 tranches of financing. Each action presented in Section 4 above would bring incremental significant change to system users and managers.

Finally, from a perspective of quantitative analysis of predicted coverage areas, the Walker Mountain site is superior to the Odell Butte site and the new proposed site is of limited utility. Still, MCP recommends that site selection in this case be based on the actual operational needs rather than arithmetic analysis.

Securing the financing and issuing a request for proposal for the entire system or for selected subsystems should be KIRG's next step. MCP is ready and would be honored to assist KIRG in any such future steps including new system specifications, procurement, and implementation.