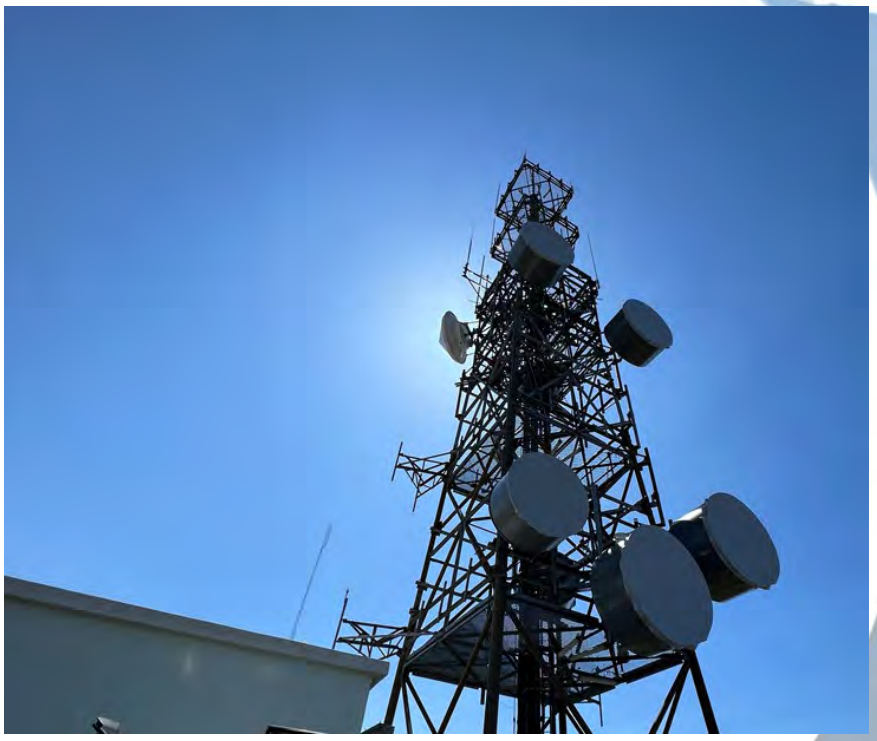


Keith Koeppen, P.E.

Caltrans, District 2

2023

Broadband Communication Design Strategies and Considerations for ITS Applications

Red Bluff Wireless Expansion

Acronyms

CalOES – California Office of Emergency Services, also OES

CCTV – Close Circuit Television

CMS – Changeable Message Sign

CT - Caltrans

DPAC – Department of Procurement and Contracts (Caltrans)

DSA – Division of the State Architect

ITS – Intelligent Transportation Systems

NASPO – National Association of State Procurement Officials

OES – Office of Emergency Services, also CalOES

ORC – Office of Radio Communications (Caltrans)

SR – State Route, i.e. SR-44

TMC – Transportation Management Center

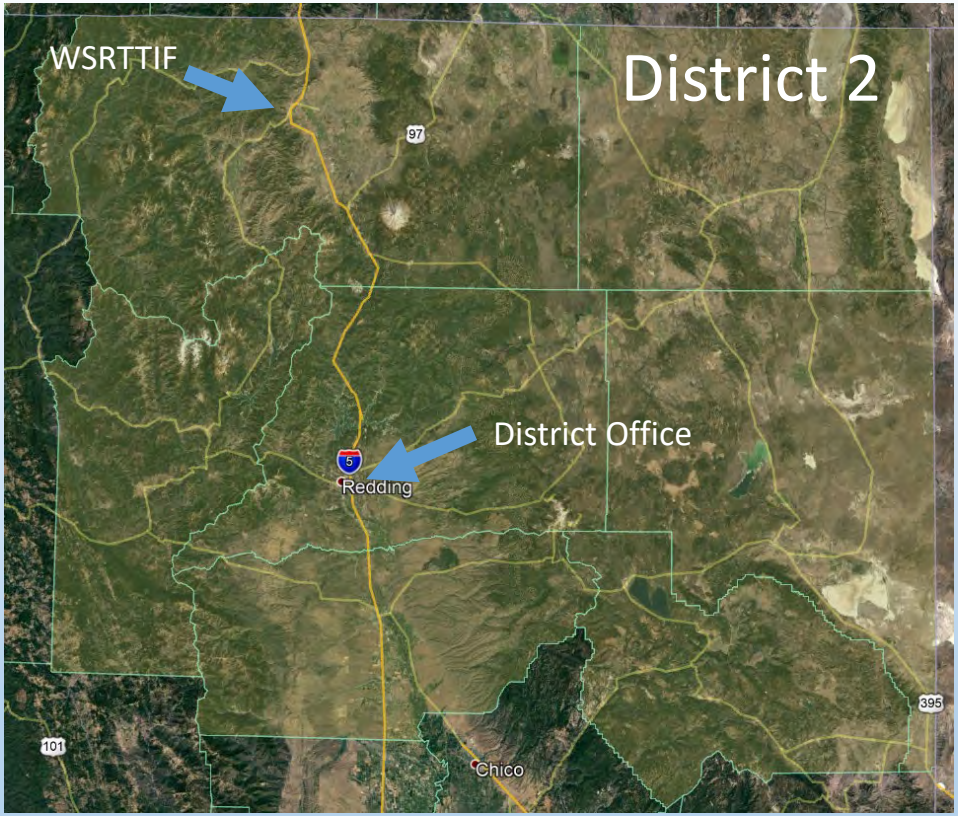
UPRR – Union Pacific Railroad

US Route – United States Route, i.e. US-395

WSRTTIF – Western States Rural Transportation Technology Implementers Forum

Background

District 2



Background

District 2

- Very Rural District
- Interstate 5
  - Major North/South freight corridor
- State Route 299
- State Route 44
- US Route 395

Background

Existing Private Point-to-point Microwave System

- Existing Microwave System
  - Redding Area
  - Bass Mtn Area
  - Sugarloaf Area

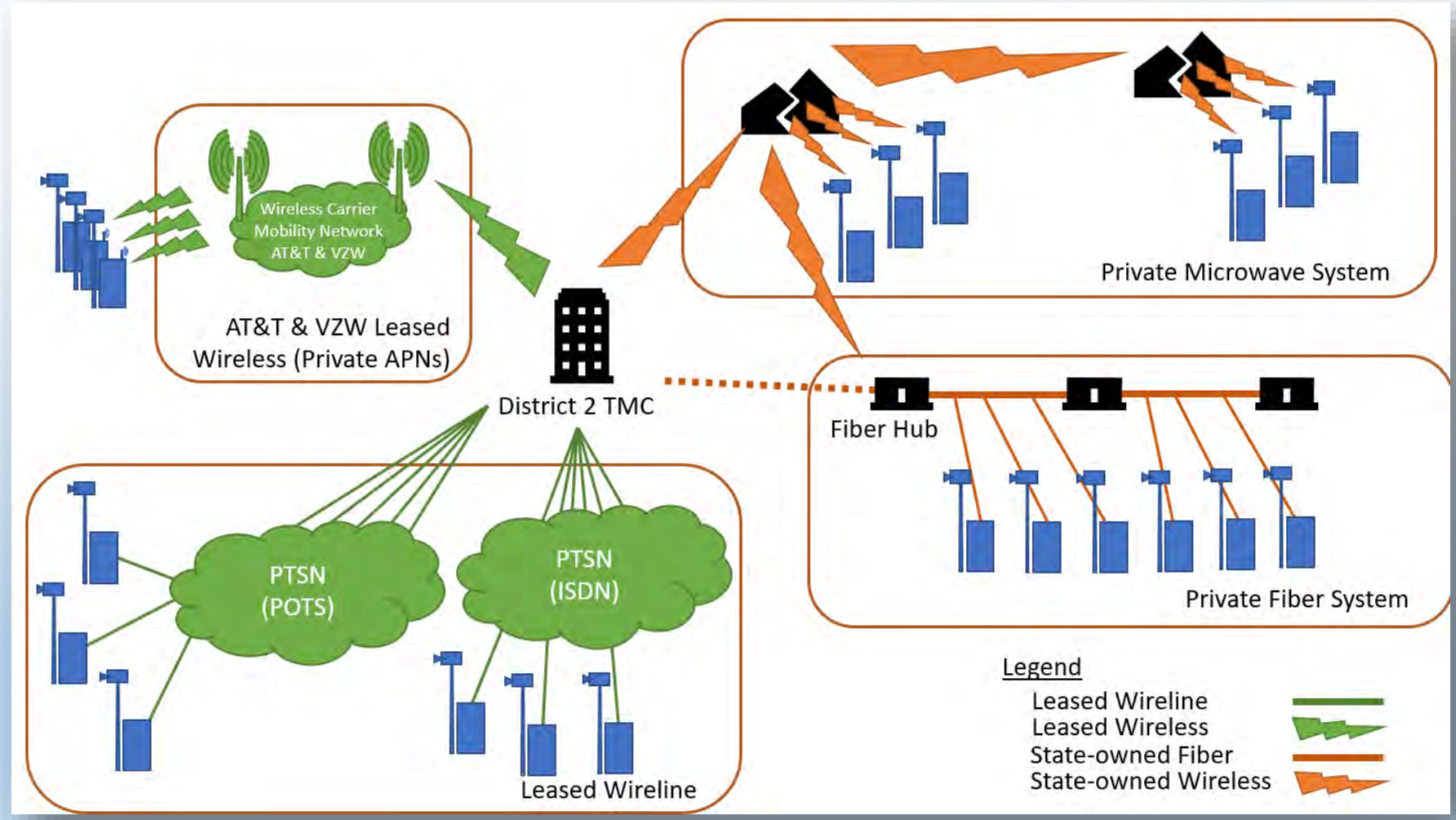
Background

Existing Private Point-to-point Microwave System

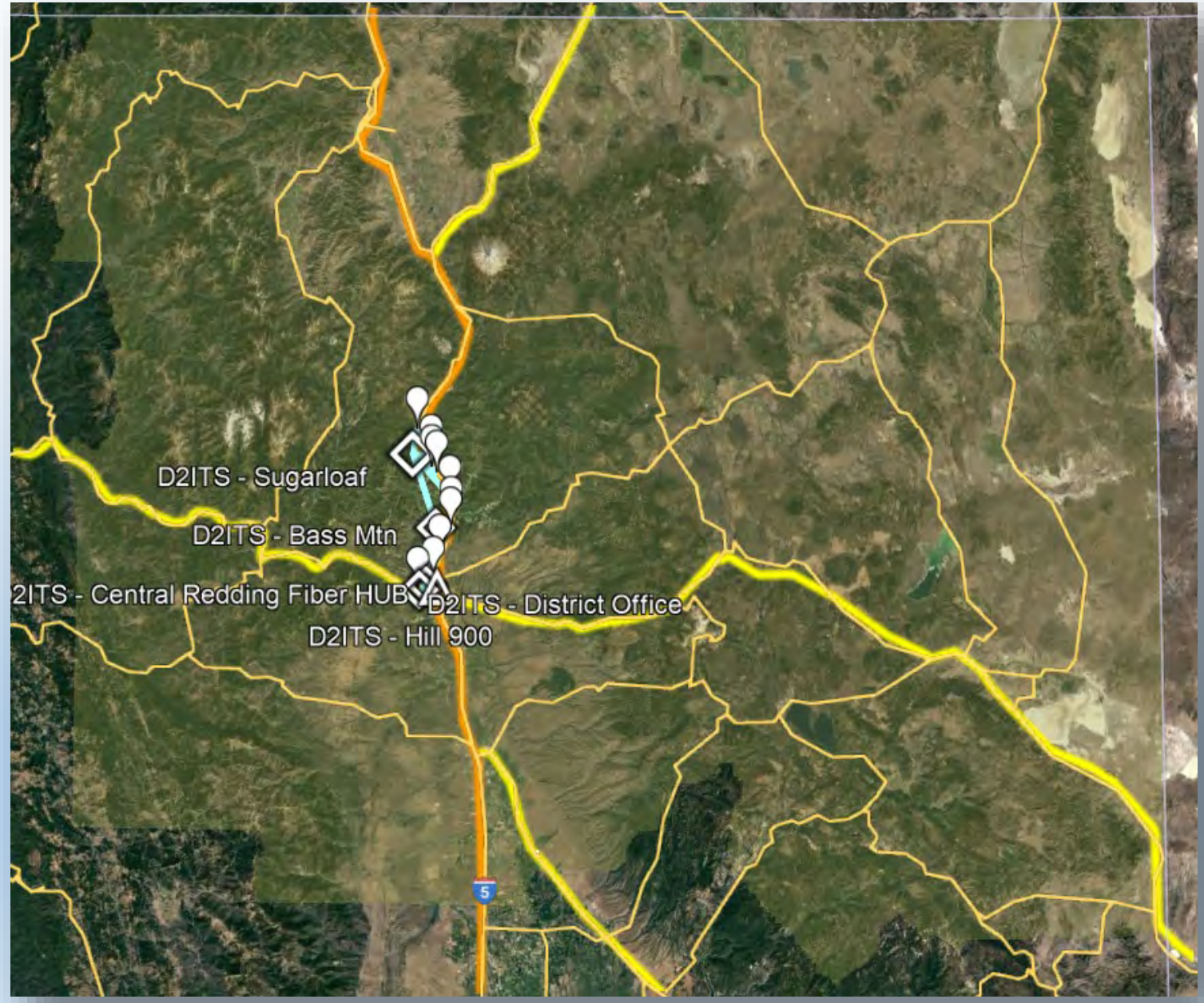
- Existing Microwave N
  - Redding Area
  - Bass Mtn Area
  - Sugarloaf Area

Background

Network Architecture Overview

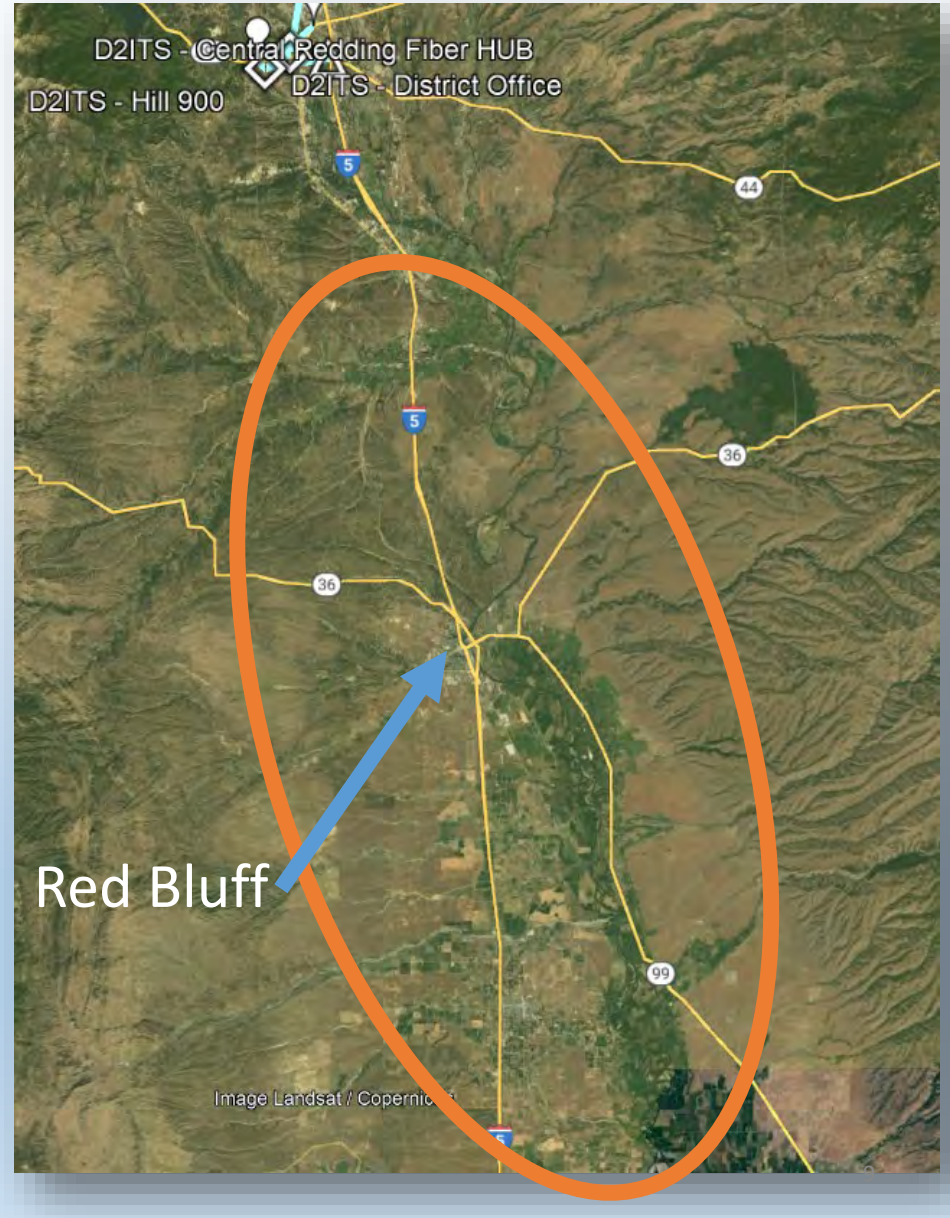


Red Bluff Wireless Expansion



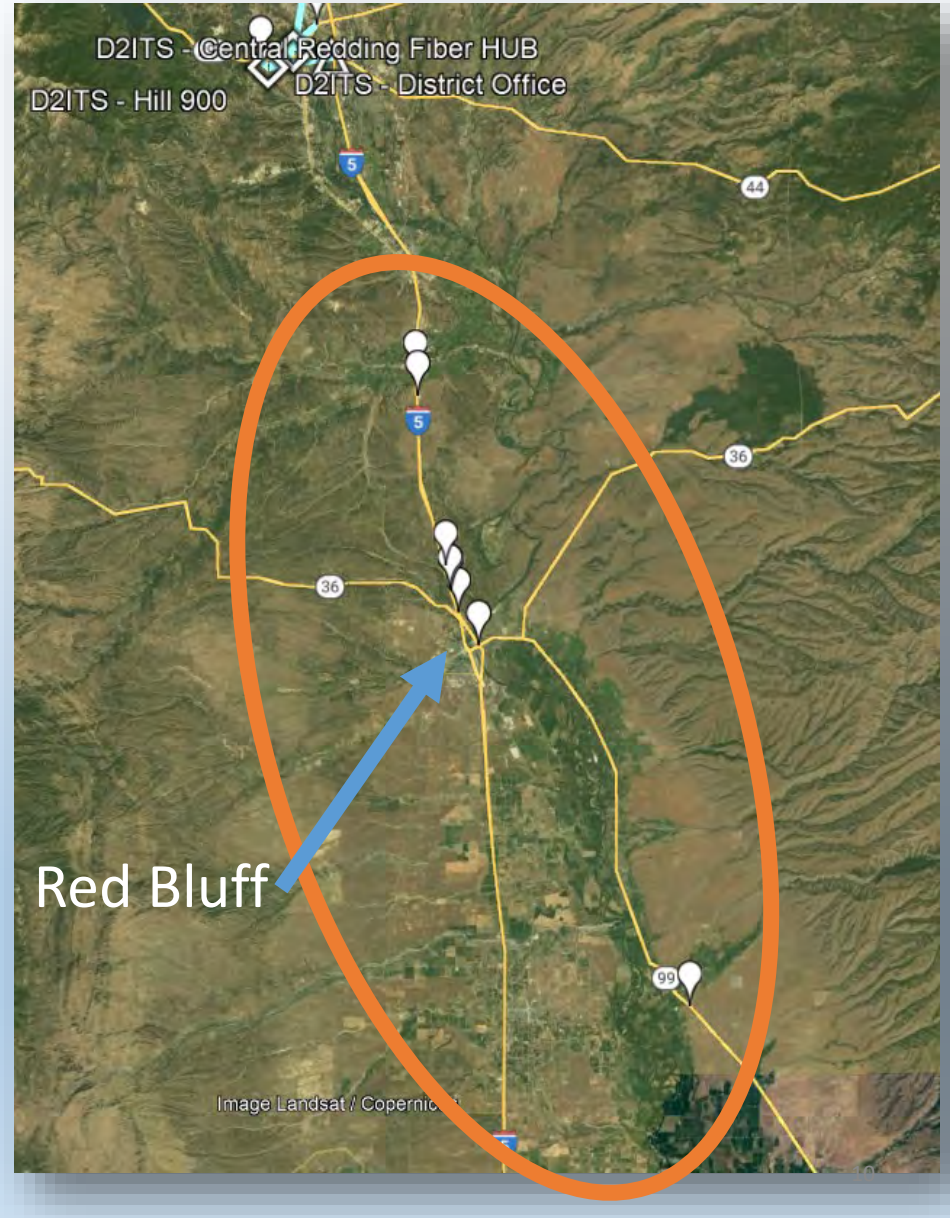
Red Bluff Wireless Expansion

- Reaches Southern portion of District 2
- Covers Approx. 35 miles of I-5
  - Cottonwood to Corning
- Covers Approx. 24 miles of SR-99
  - Red Bluff to SR-99/South Ave



Red Bluff Wireless Expansion

- Reaches Southern portion of District 2
- Covers Approx. 35 miles of I-5
  - Cottonwood to Corning
- Covers Approx. 24 miles of SR-99
  - Red Bluff to SR-99/South Ave
- 8 existing CCTVs within area
- 3 planned CCTVs within area
- 7 existing CMSs within area
- 4 planned CMSs within area



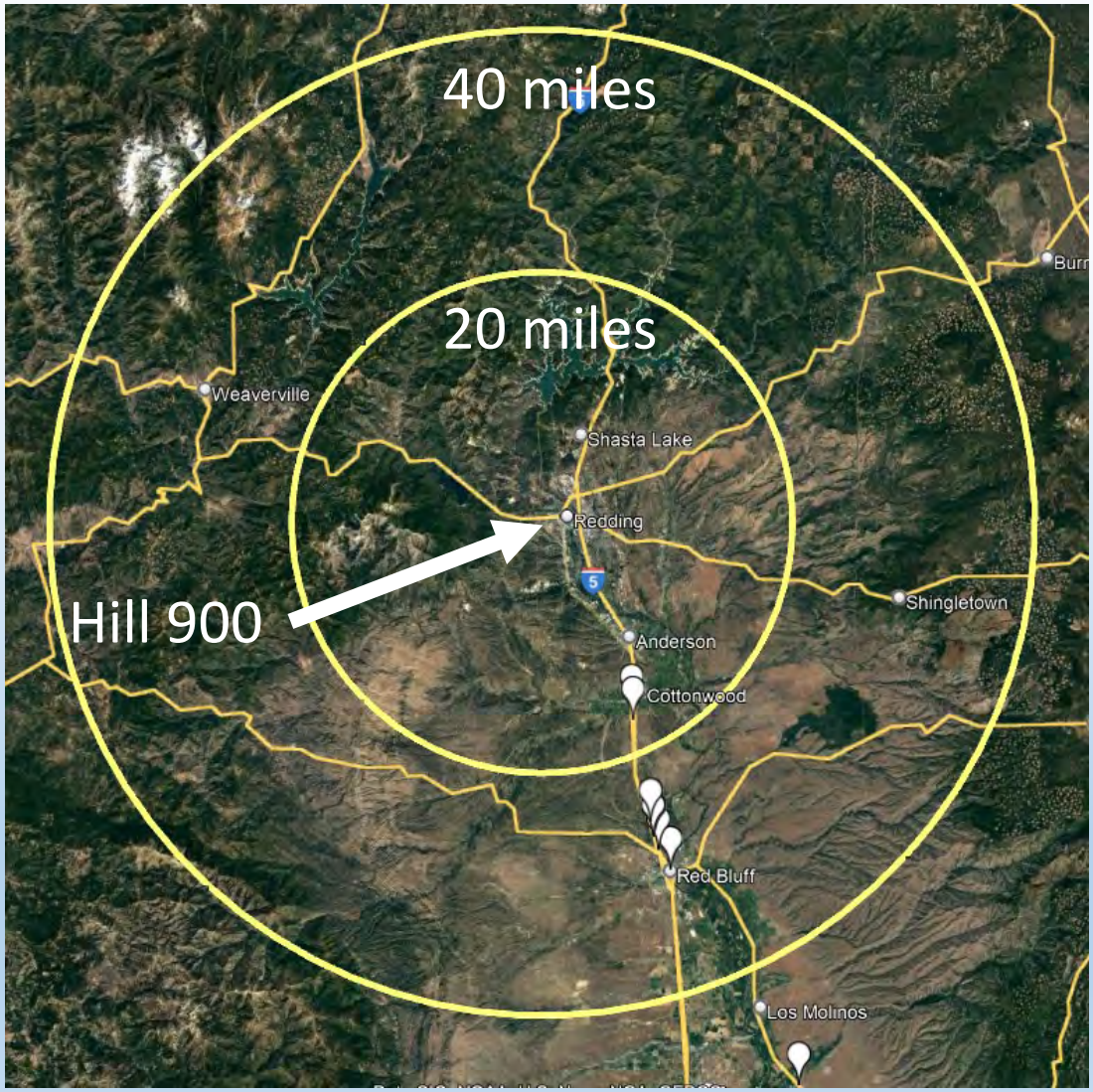
Red Bluff Wireless Expansion

Site Surveys

Red Bluff Wireless Expansion

Site Surveys

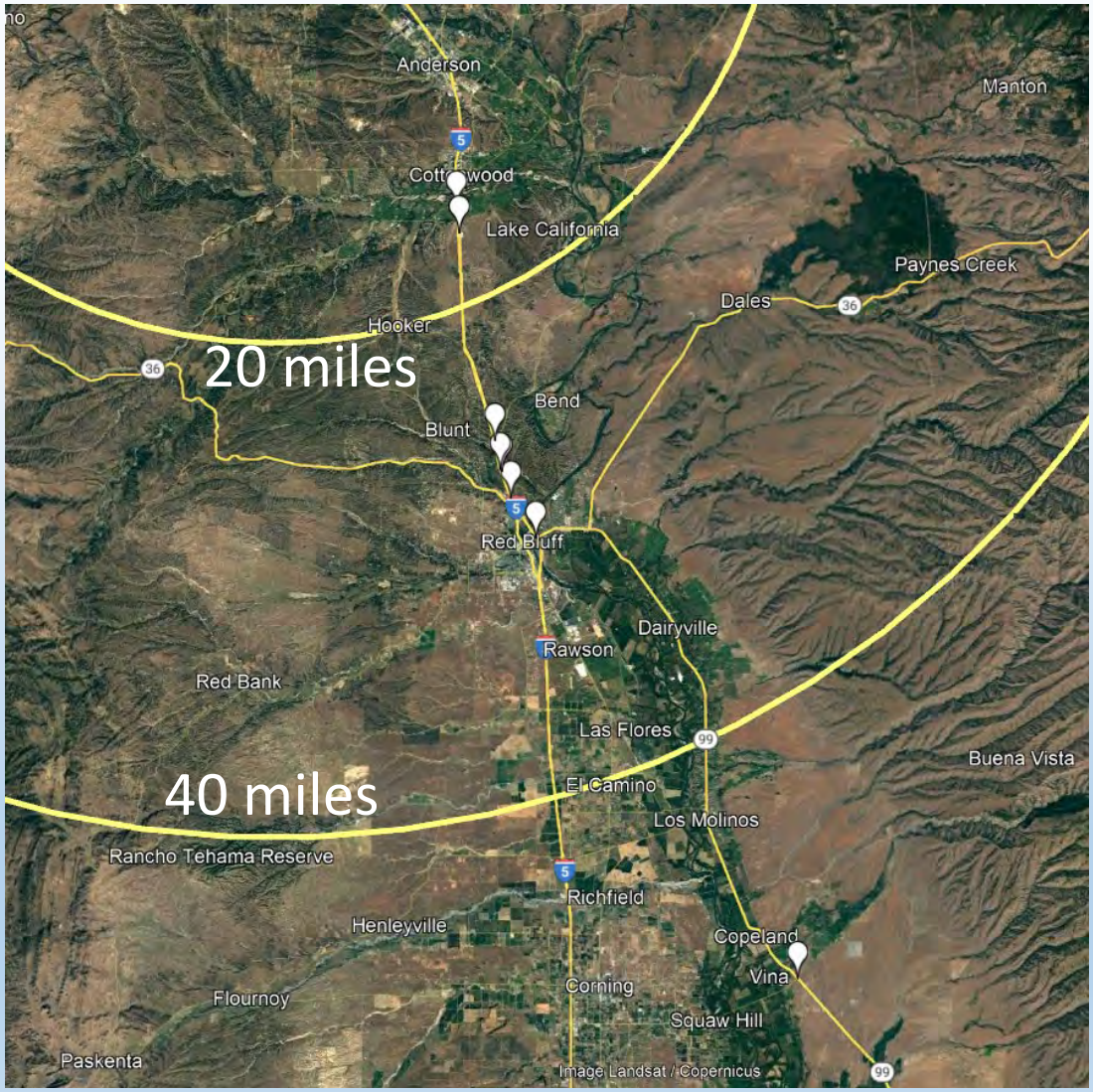
- Hill 900 Radio Site
  - 20-40 mile radius



Red Bluff Wireless Expansion

Site Surveys

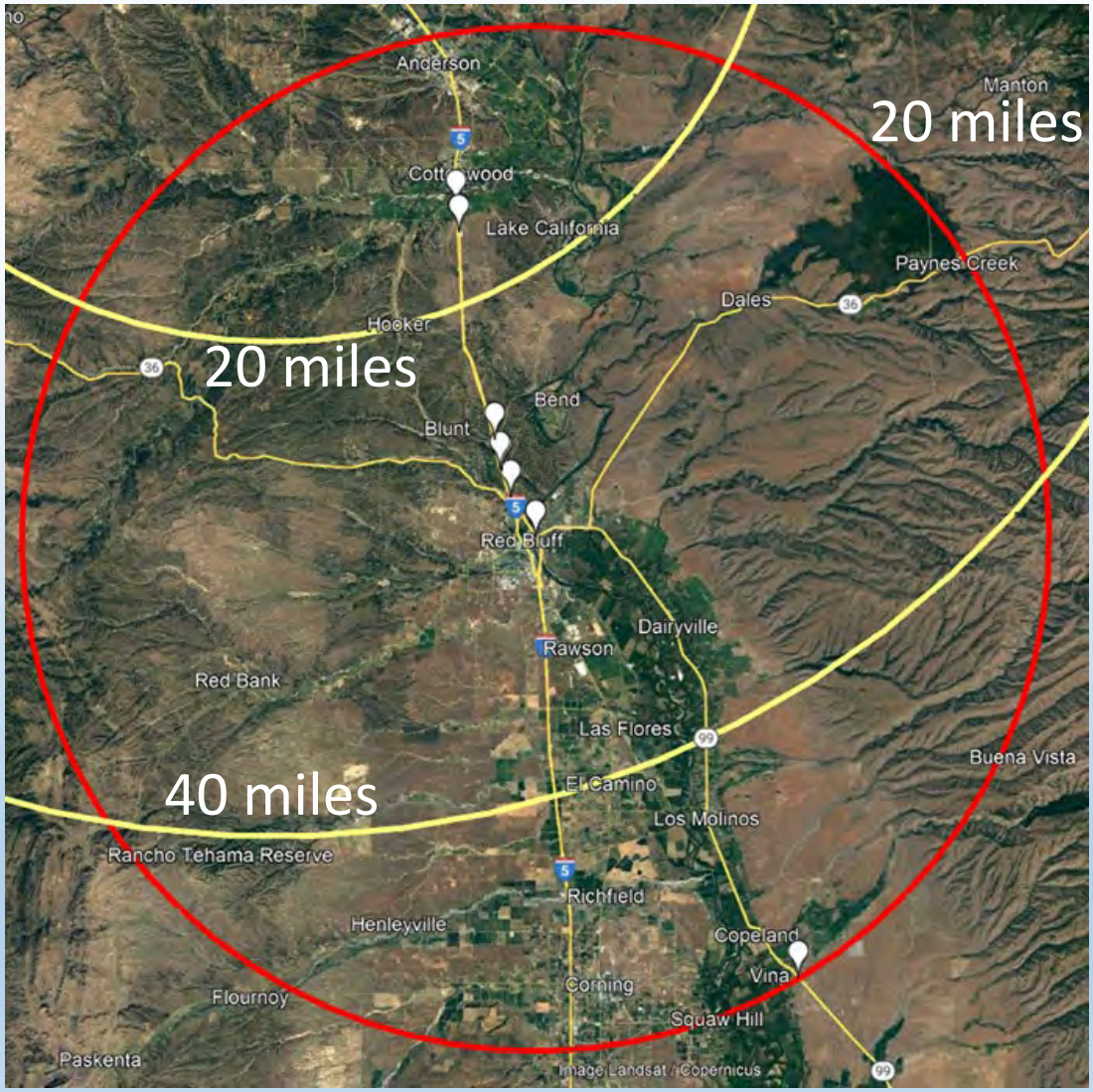
- Red Bluff Area
- Typical Link Requirements
  - Backhaul (6 GHz)
    - 20-50 miles



Red Bluff Wireless Expansion

Site Surveys

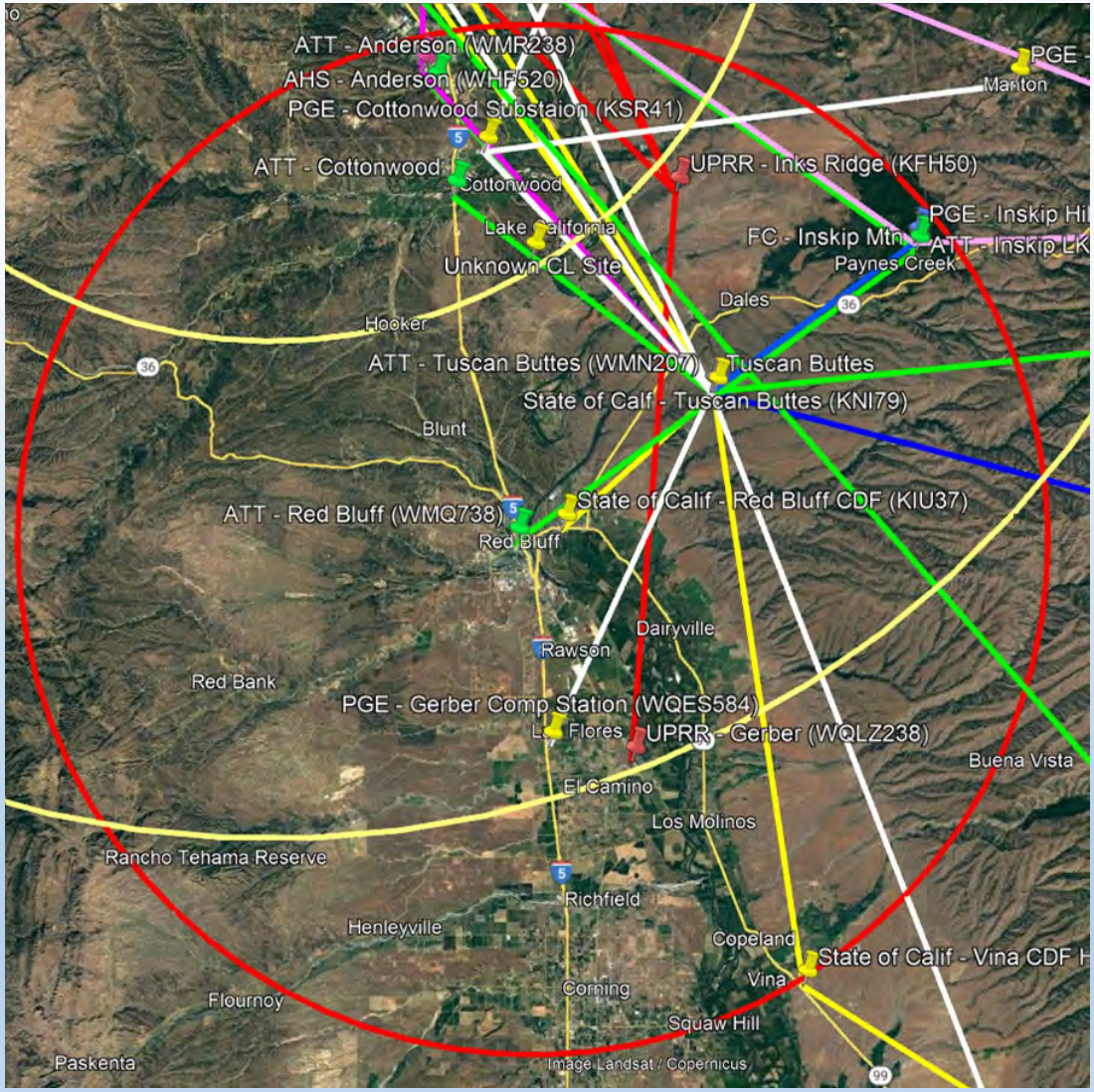
- Red Bluff Area
- Typical Link Requirements
  - Backhaul (6 GHz)
    - 20-50 miles
  - Roadside (4.9 GHz)
    - 20 miles or less



Red Bluff Wireless Expansion

Site Surveys

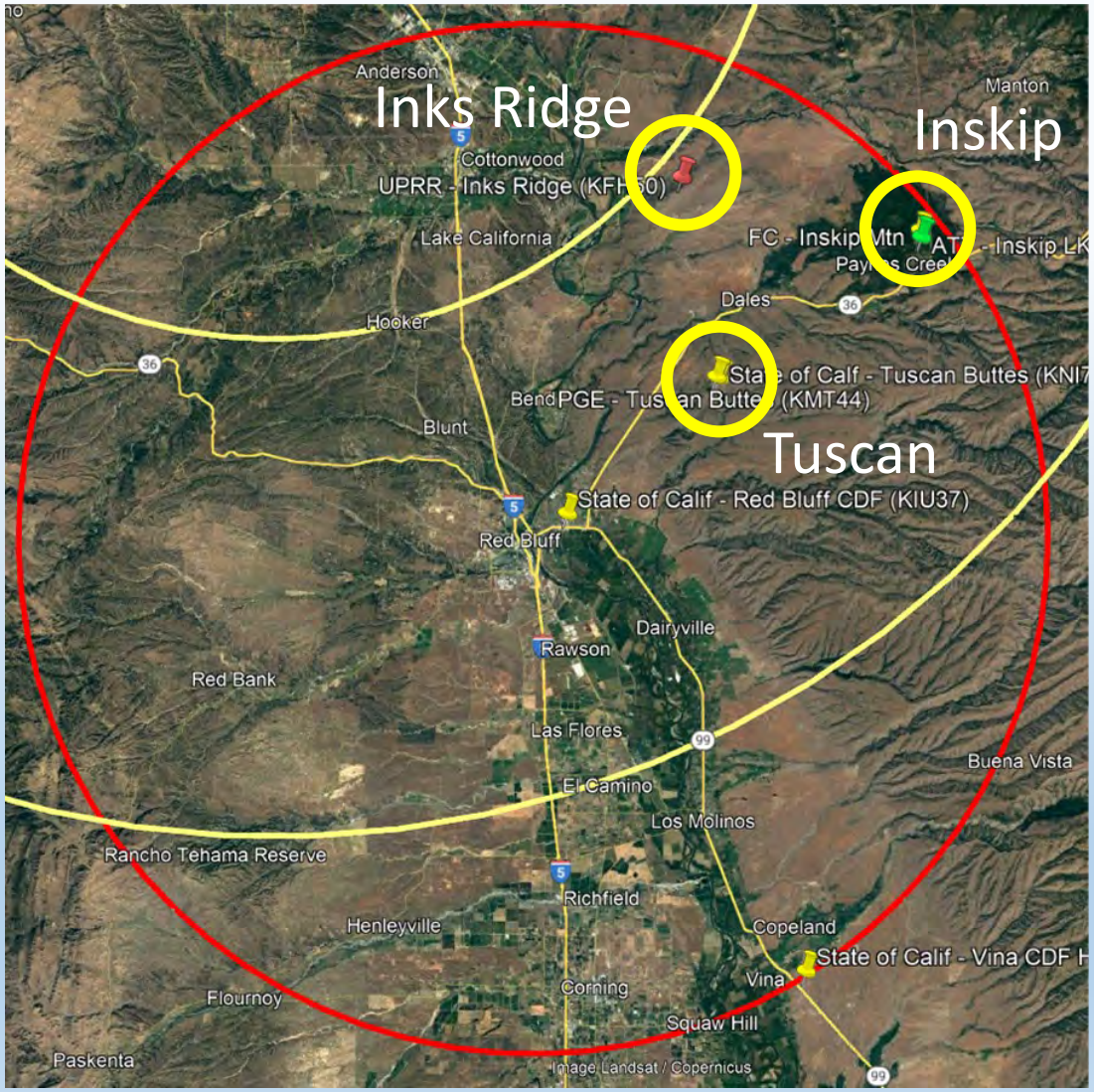
- Red Bluff Area
- Typical Link Requirements
  - Backhaul (6 GHz)
    - 20-50 miles
  - Roadside (4.9 GHz)
    - 20 miles or less
- Existing *Known* Links/Sites?



Red Bluff Wireless Expansion

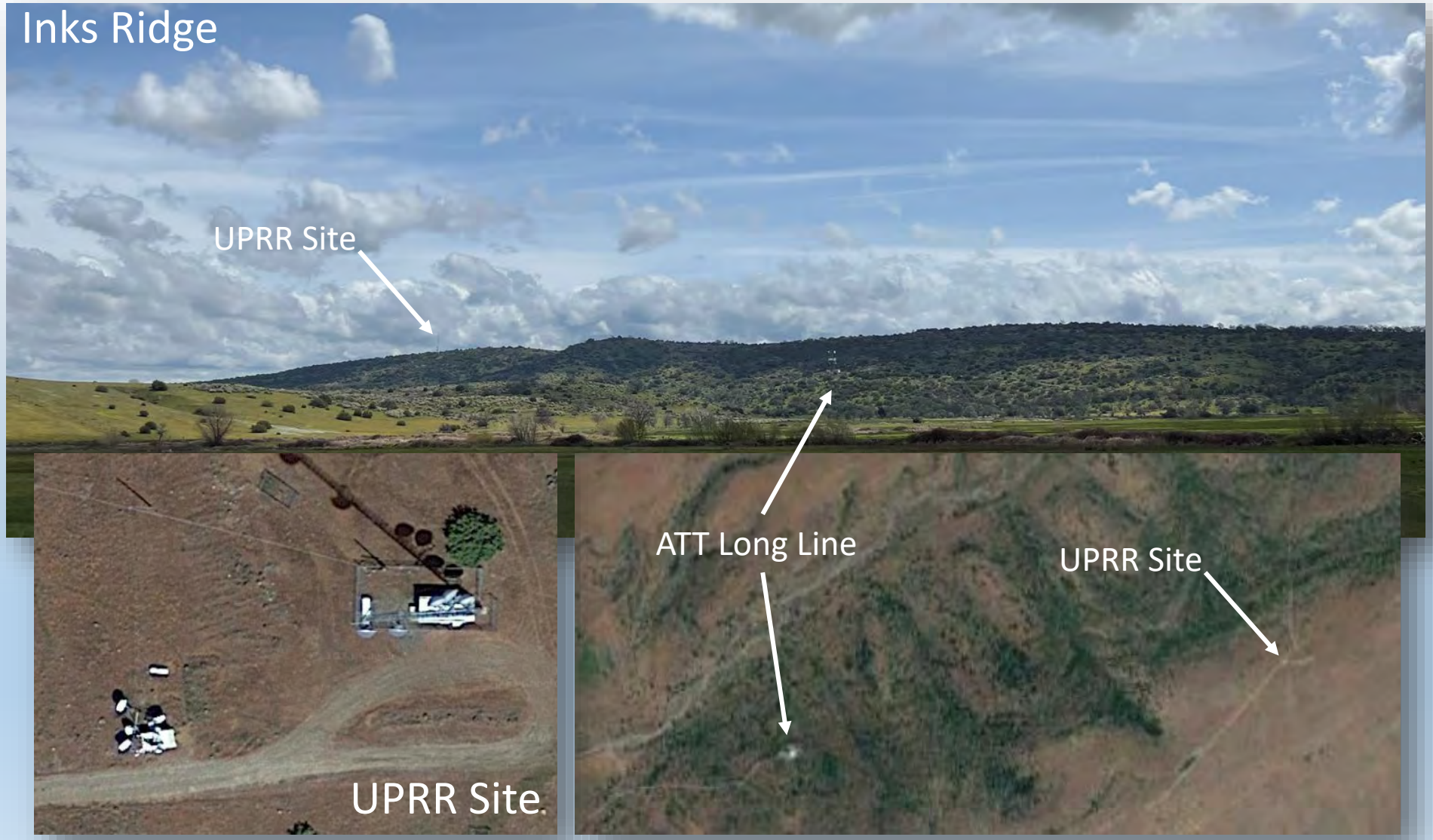
Site Surveys

- Red Bluff Area
- Typical Link Requirements
  - Backhaul (6 GHz)
    - 20-50 miles
  - Roadside (4.9 GHz)
    - 20 miles or less
- Existing *Known* Links/Sites?
  - Ink Ridge
  - Inskip
  - Tuscan Buttes



Red Bluff Wireless Expansion

Site Surveys – Inks Ridge



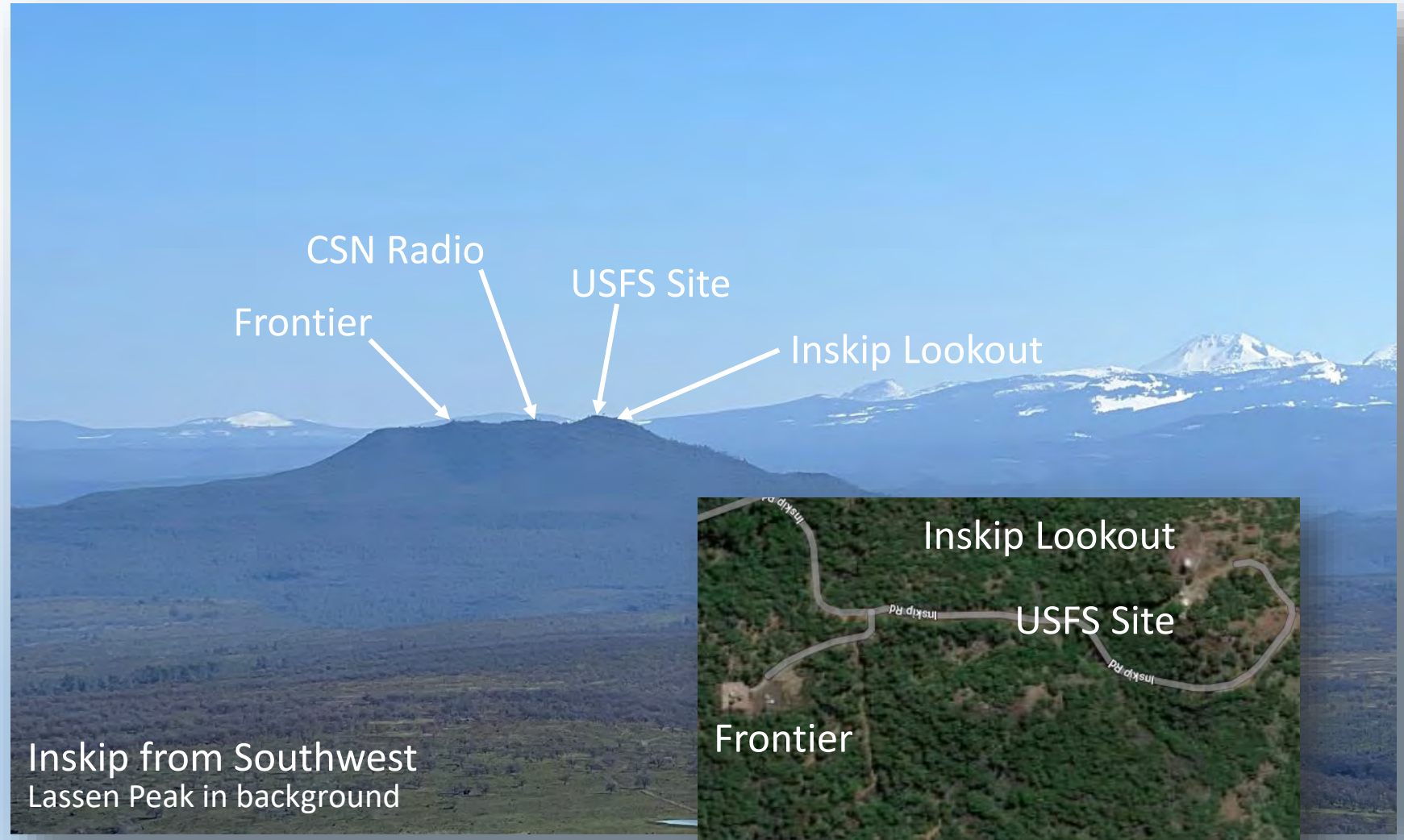
Red Bluff Wireless Expansion

Site Surveys – Inks Ridge

- Privately Owned Site
  - Radio Vault May be inadequate or not available to new users
- Alternatives may be
  - Acquire Land
  - Build radio vault and tower
- Relatively Close to I-5
  - 8-15 miles
- Overlooks North Red Bluff area
- Elevation is relatively low

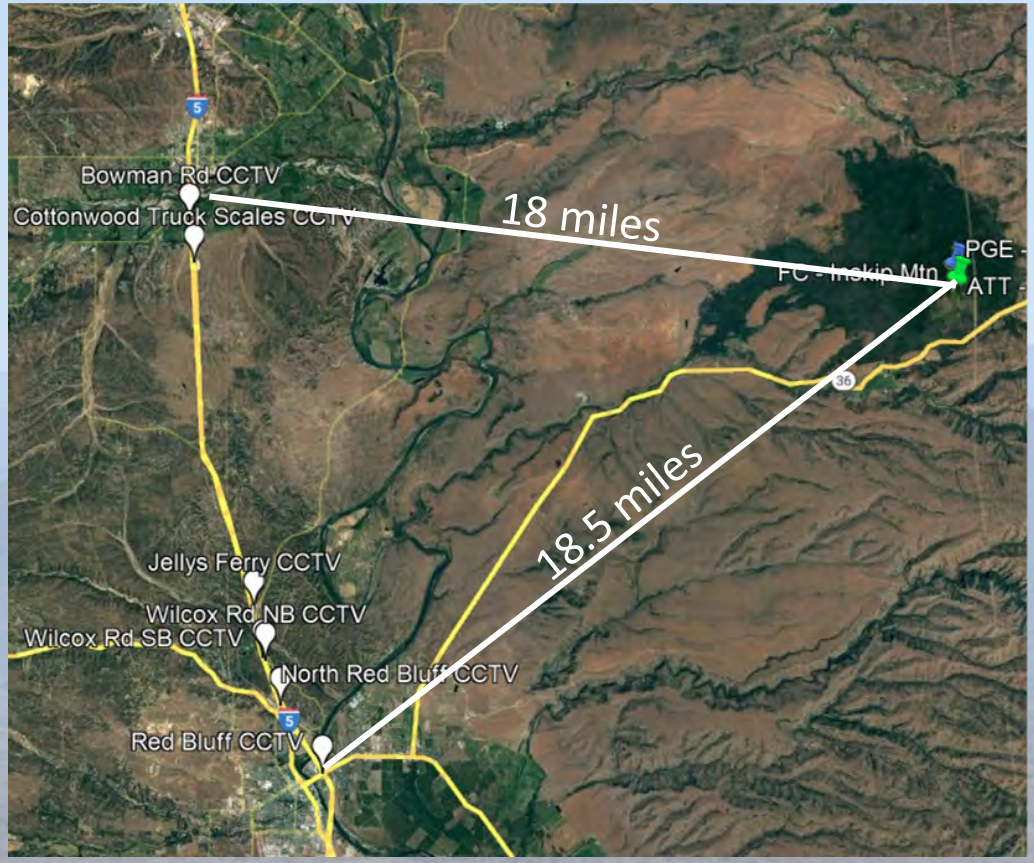
Red Bluff Wireless Expansion

Site Surveys – Inskip



Red Bluff Wireless Expansion

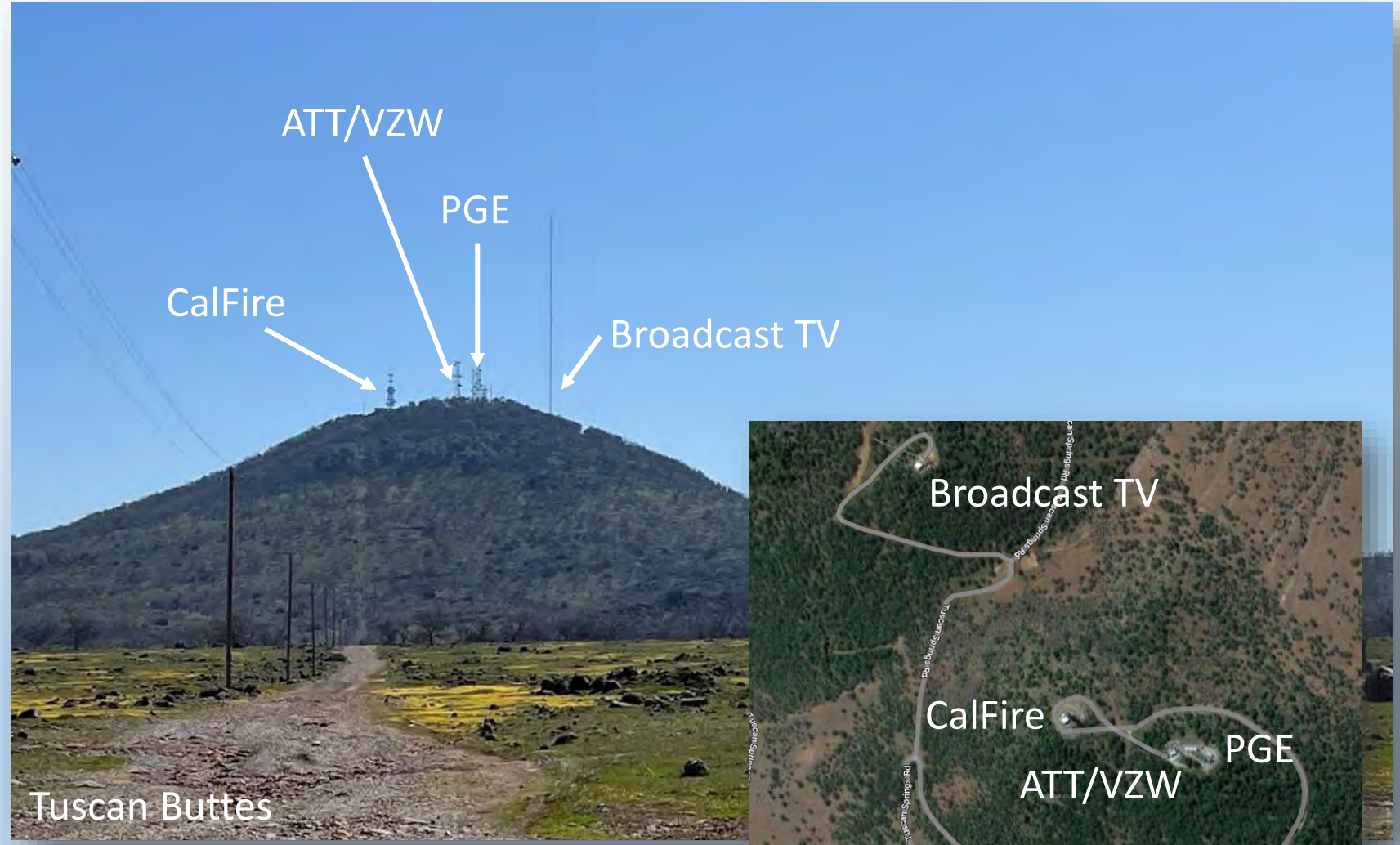
Site Surveys – Inskip



- Federally and Privately Owned Sites
  - Radio Vault May be inadequate or not available to new users
- Alternatives may be
  - Acquire Land
  - Build radio vault and tower
- Relatively far from I-5
  - +/-18 miles
- Overlooks Red Bluff area
- Elevation is relatively good

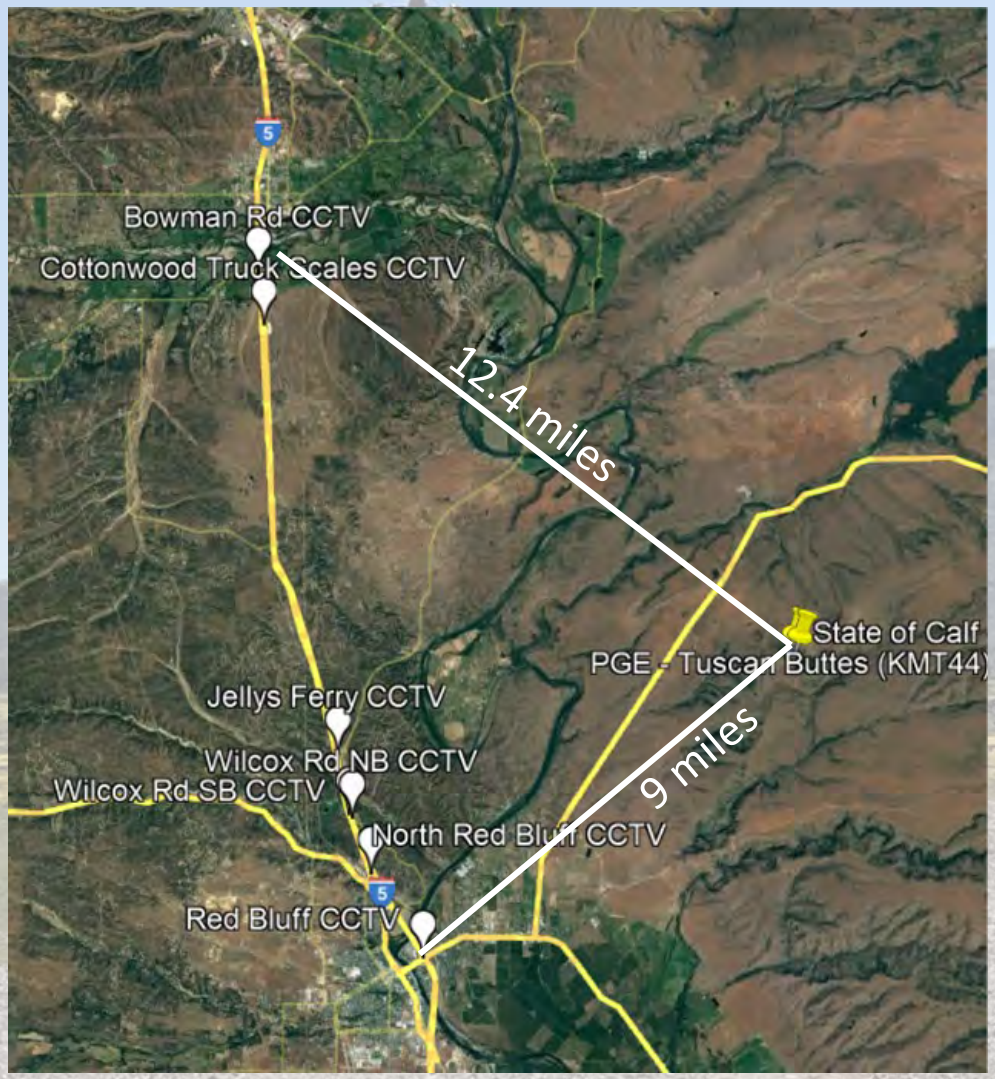
Red Bluff Wireless Expansion

Site Surveys – Tuscan



Red Bluff Wireless Expansion

Site Surveys – Tuscan



- State and Privately Owned Sites
  - CalFire Vault has capacity
- Relatively Close to I-5
  - 8-15 miles
- Overlooks Red Bluff area
- Elevation is relatively good
- Interagency Agreement possible

Red Bluff Wireless Expansion

Preliminary Path Analysis – Inks Ridge

Inks Ridge to Bowman Road
8.6 miles

Red Bluff Wireless Expansion

Preliminary Path Analysis – Inks Ridge

Inks Ridge to Cottonwood Truck Scales
8.6 miles

Red Bluff Wireless Expansion

Preliminary Path Analysis – Inks Ridge

Inks Ridge to Jellys Ferry Rd
11.9 miles

Red Bluff Wireless Expansion

Preliminary Path Analysis – Inks Ridge

Inks Ridge to Wilcox Rd NB
12.2 miles

Red Bluff Wireless Expansion

Preliminary Path Analysis – Inks Ridge

Inks Ridge to North Red Bluff
13.5 miles

Red Bluff Wireless Expansion

Preliminary Path Analysis – Inks Ridge

Inks Ridge to Red Bluff
14.5 miles

Red Bluff Wireless Expansion

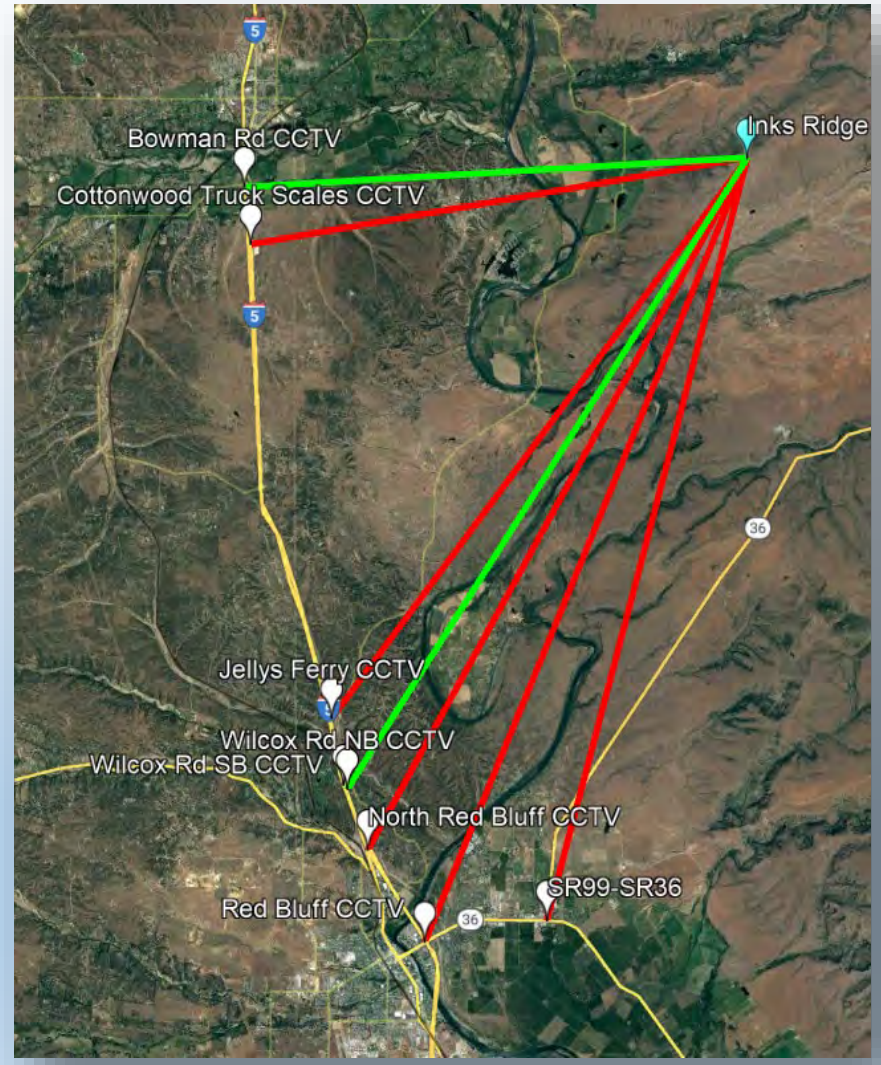
Preliminary Path Analysis – Inks Ridge

Inks Ridge to SR99-SR36
13.5 miles

Red Bluff Wireless Expansion

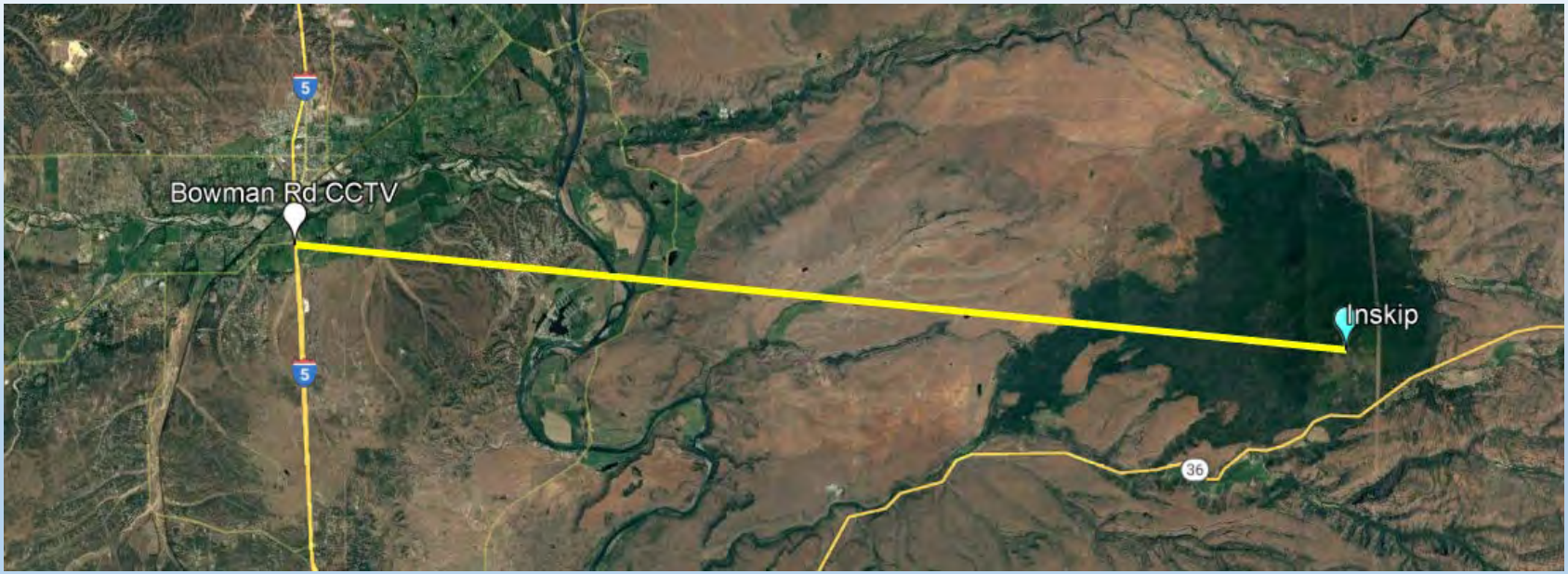
Preliminary Path Analysis – Inks Ridge

- Preliminary Path Summary
  - 2 likely point-to-point links



Red Bluff Wireless Expansion

Preliminary Path Analysis – Inskip



Inskip to Bowman
18.0 miles

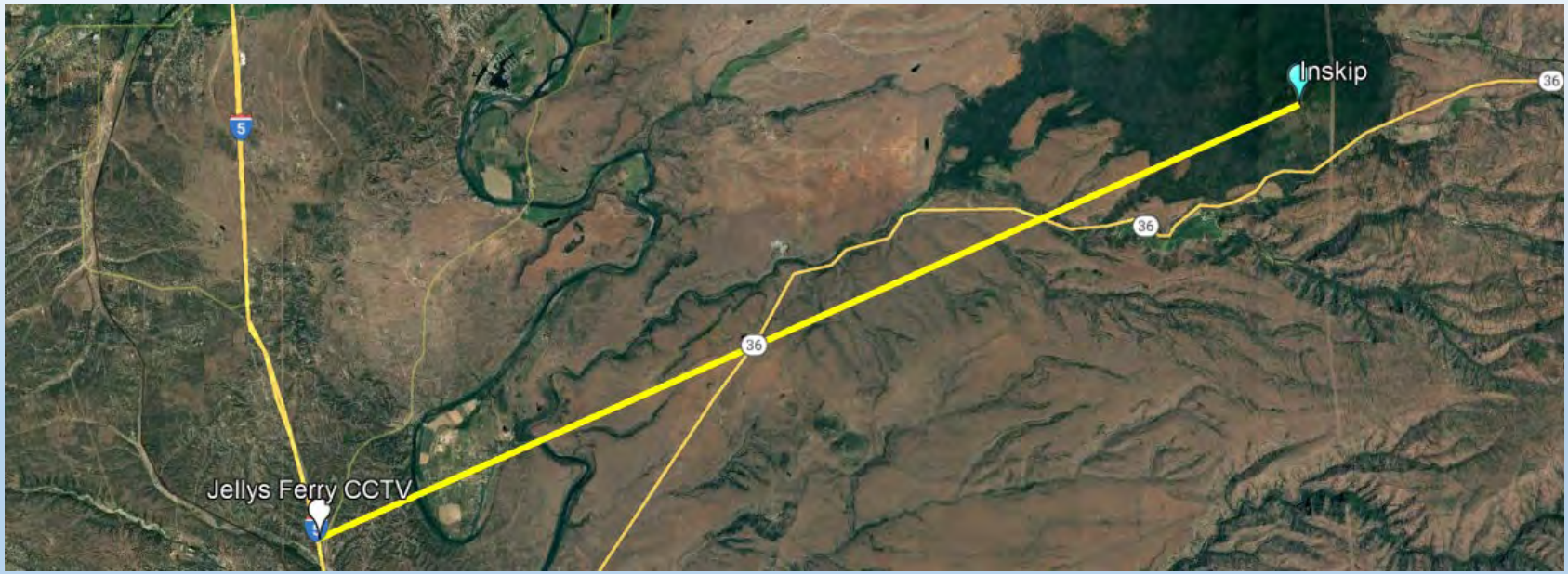
Red Bluff Wireless Expansion

Preliminary Path Analysis – Inskip

Inskip to Cottonwood Truck Scales
17.9 miles

Red Bluff Wireless Expansion

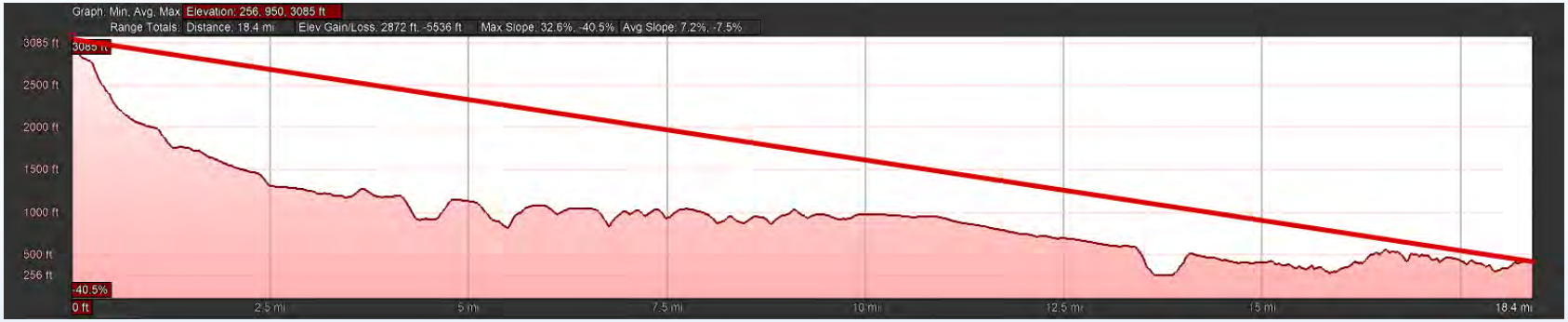
Preliminary Path Analysis – Inskip

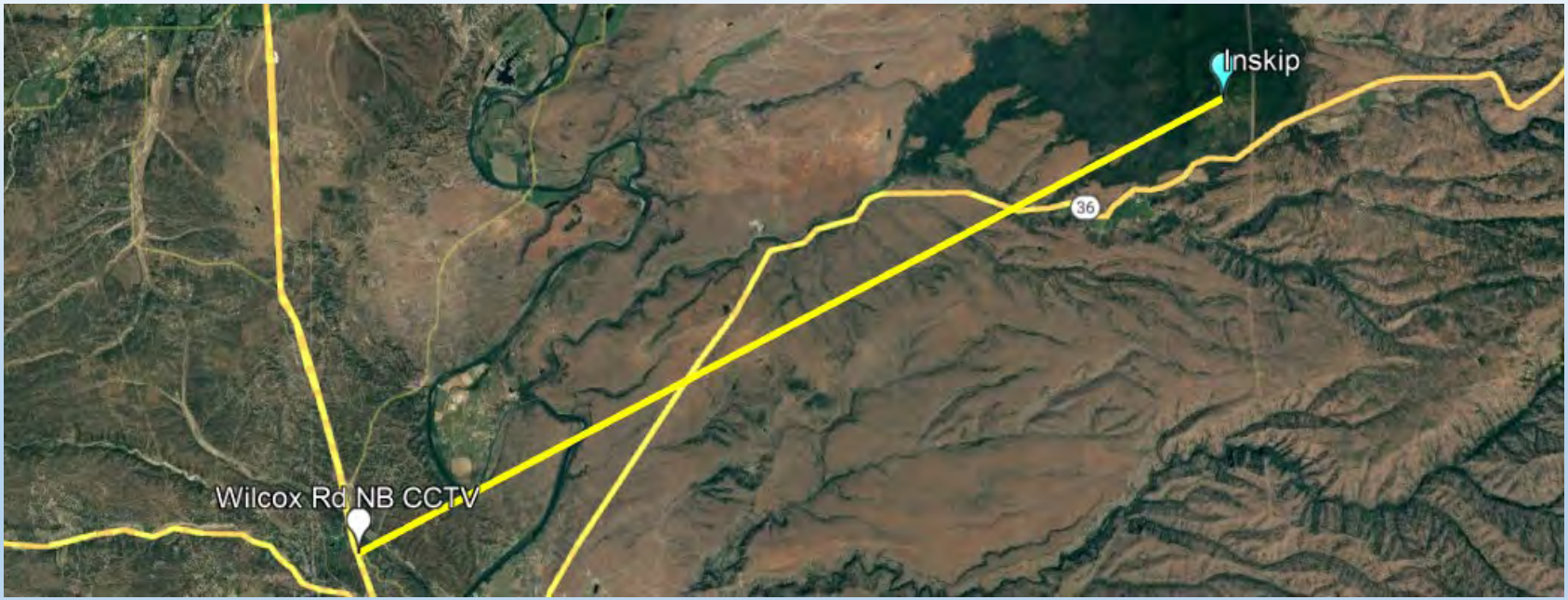


Inskip to Jellys Ferry
18.0 miles

Red Bluff Wireless Expansion

Preliminary Path Analysis – Inskip

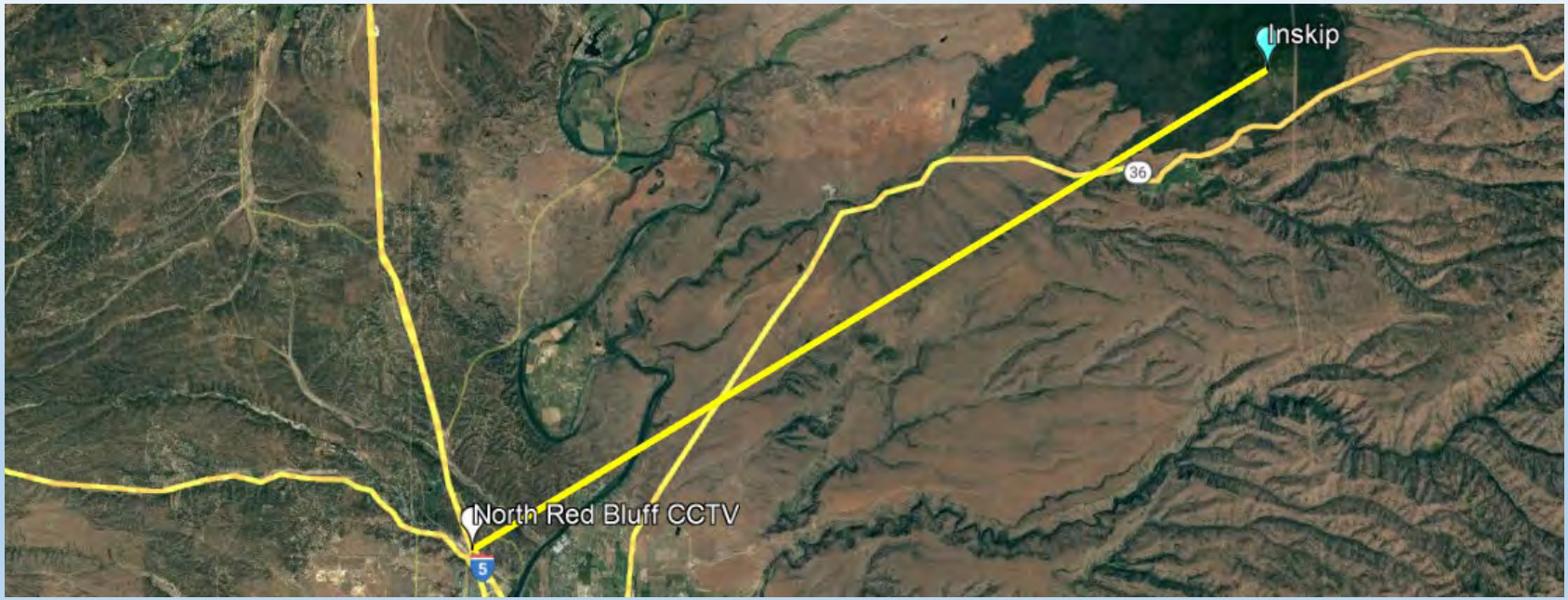




Inskip to Wilcox Rd NB
18.3 miles

Red Bluff Wireless Expansion

Preliminary Path Analysis – Inskip



Inskip to North Red Bluff
18.5 miles

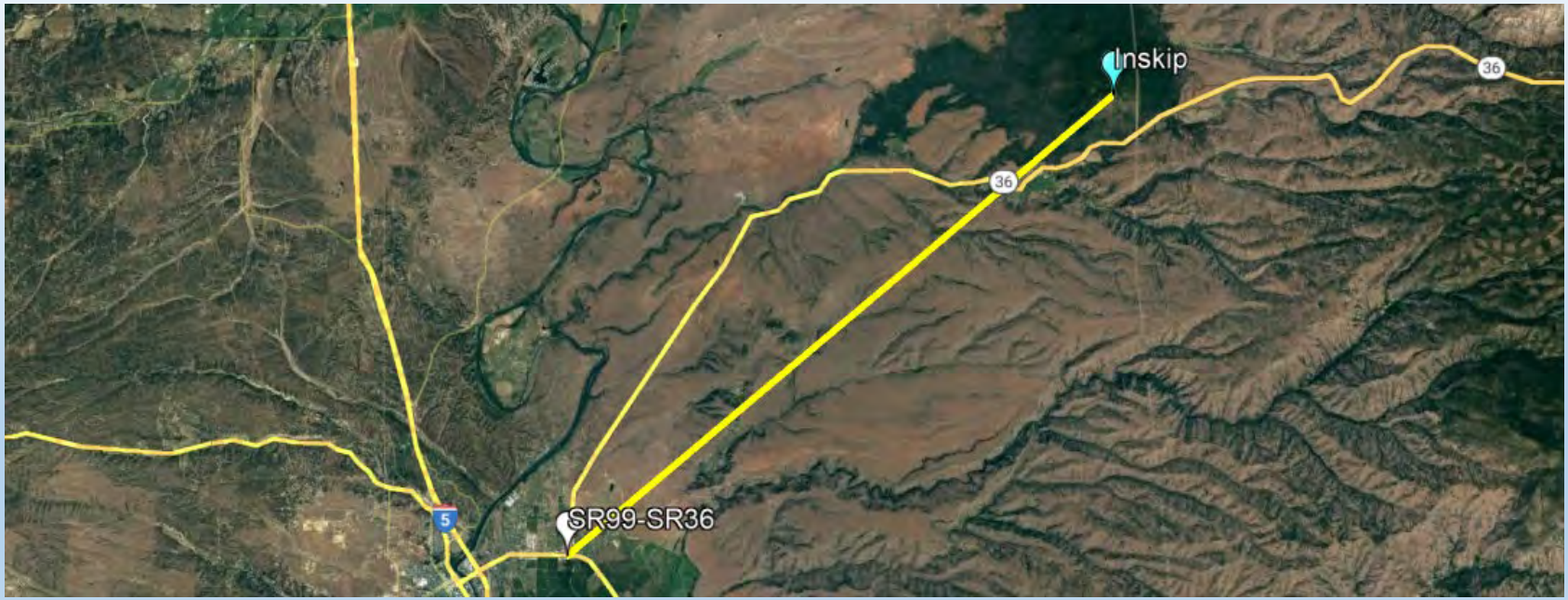
Red Bluff Wireless Expansion

Preliminary Path Analysis – Inskip

Inskip to Red Bluff
18.5 miles

Red Bluff Wireless Expansion

Preliminary Path Analysis – Inskip

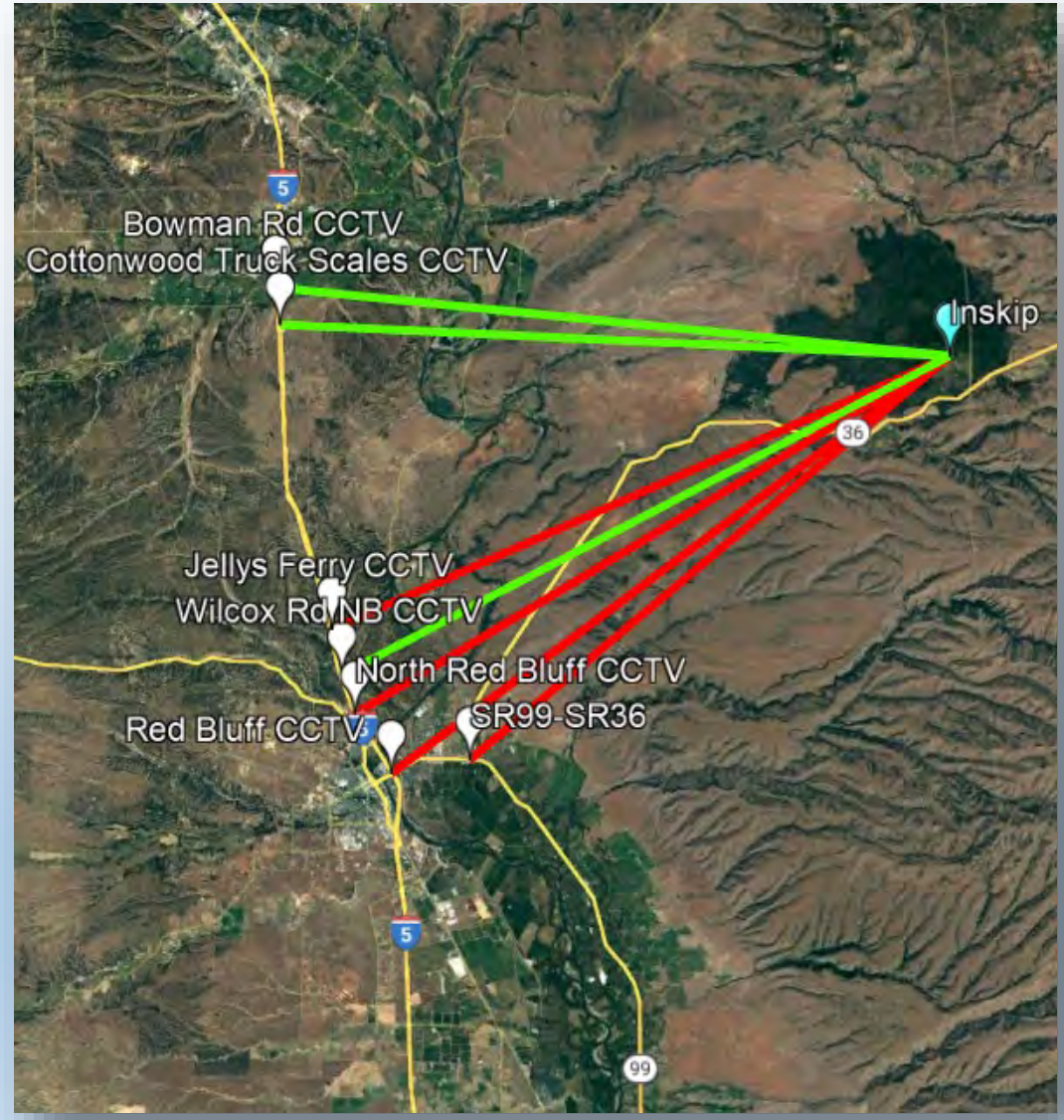


Inskip to SR99-SR36
16.7 miles

Red Bluff Wireless Expansion

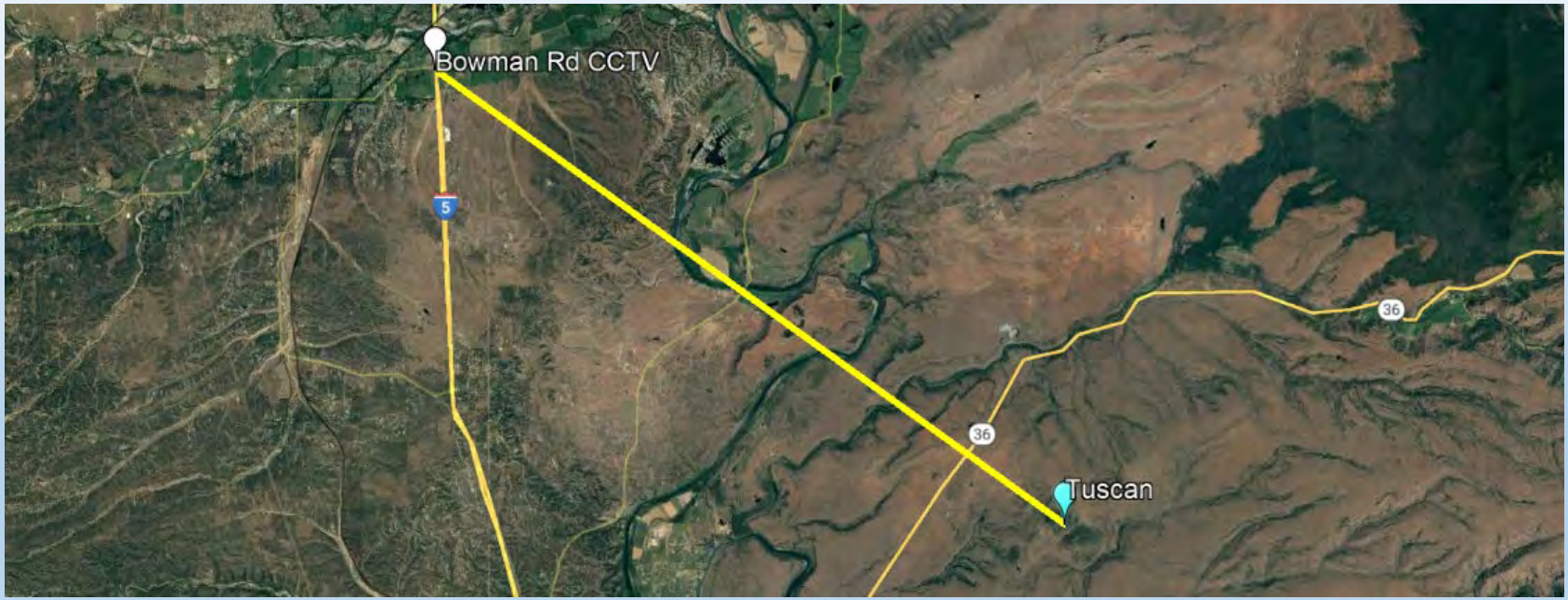
Preliminary Path Analysis – Inskip

- Preliminary Path Summary
  - 3 likely point-to-point links



Red Bluff Wireless Expansion

Preliminary Path Analysis – Tuscan



Tuscan to Bowman
12.5 miles

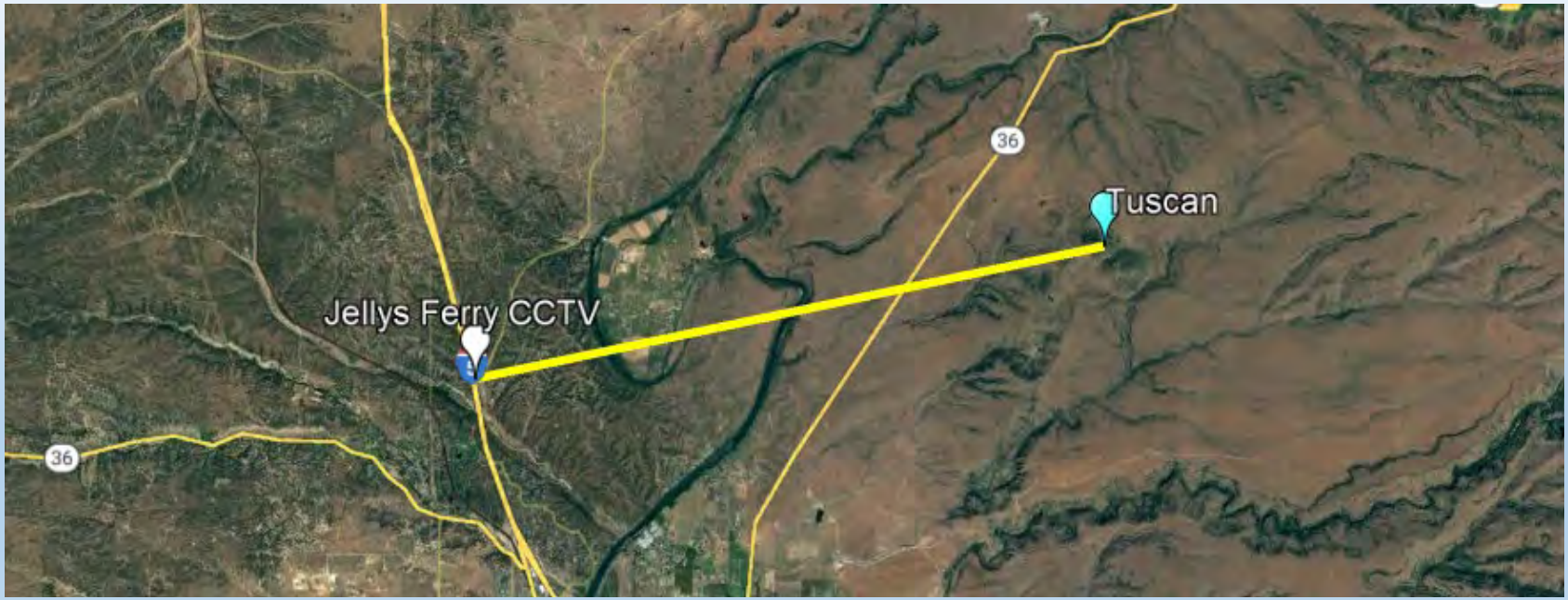
Red Bluff Wireless Expansion

Preliminary Path Analysis – Tuscan

Tuscan to Cottonwood Truck Scales
11.8 miles

Red Bluff Wireless Expansion

Preliminary Path Analysis – Tuscan



Tuscan to Jellys Ferry
8.8 miles

Red Bluff Wireless Expansion

Preliminary Path Analysis – Tuscan

Tuscan to Wilcox Rd NB
8.9 miles

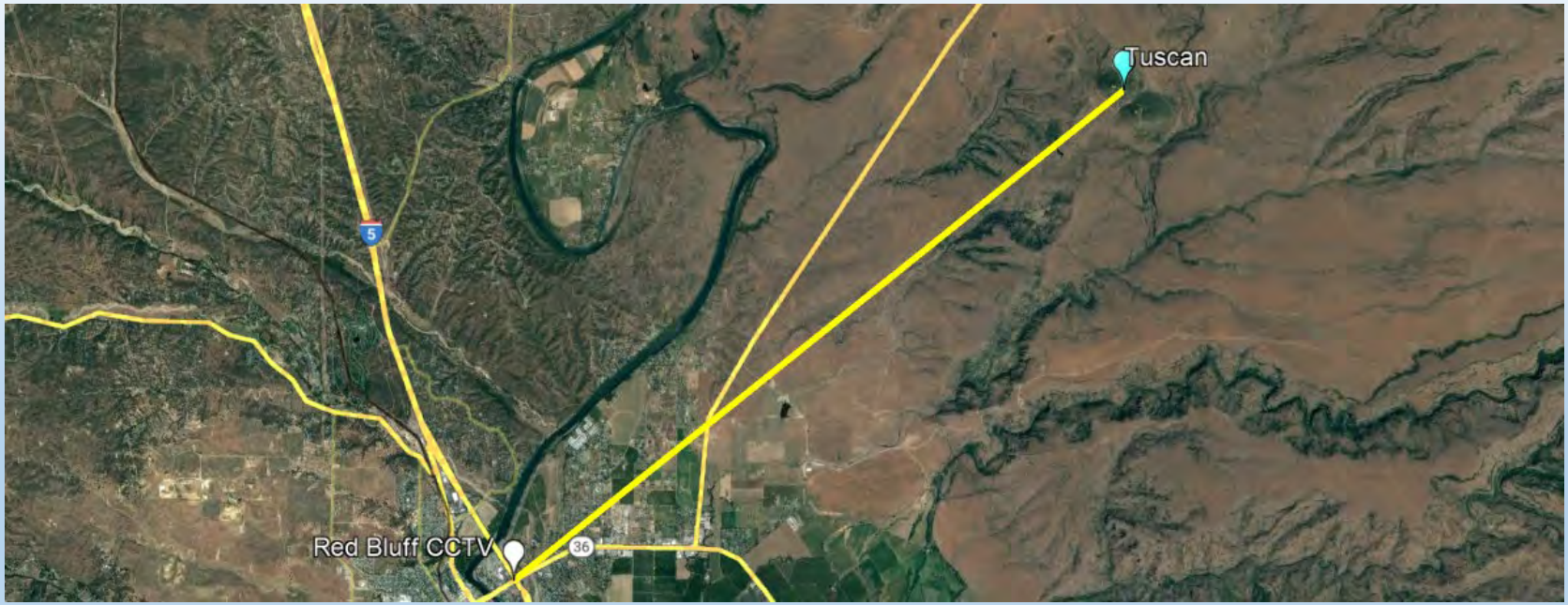
Red Bluff Wireless Expansion

Preliminary Path Analysis – Tuscan

Tuscan to North Red Bluff
8.9 miles

Red Bluff Wireless Expansion

Preliminary Path Analysis – Tuscan



Tuscan to Red Bluff
9 miles

Red Bluff Wireless Expansion

Preliminary Path Analysis – Tuscan

Tuscan to SR99-SR36
7.2 miles

Red Bluff Wireless Expansion

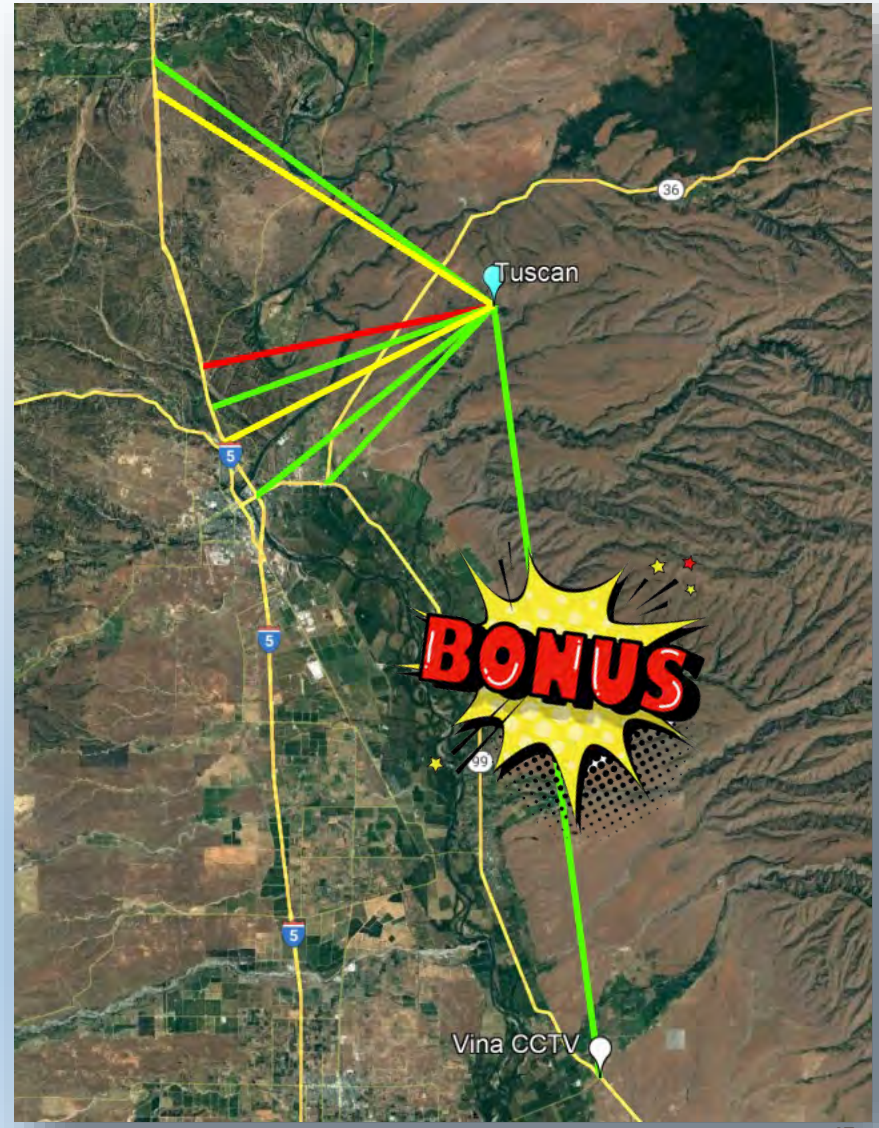
Preliminary Path Analysis – Tuscan

Tuscan to Vina
23 miles

Red Bluff Wireless Expansion

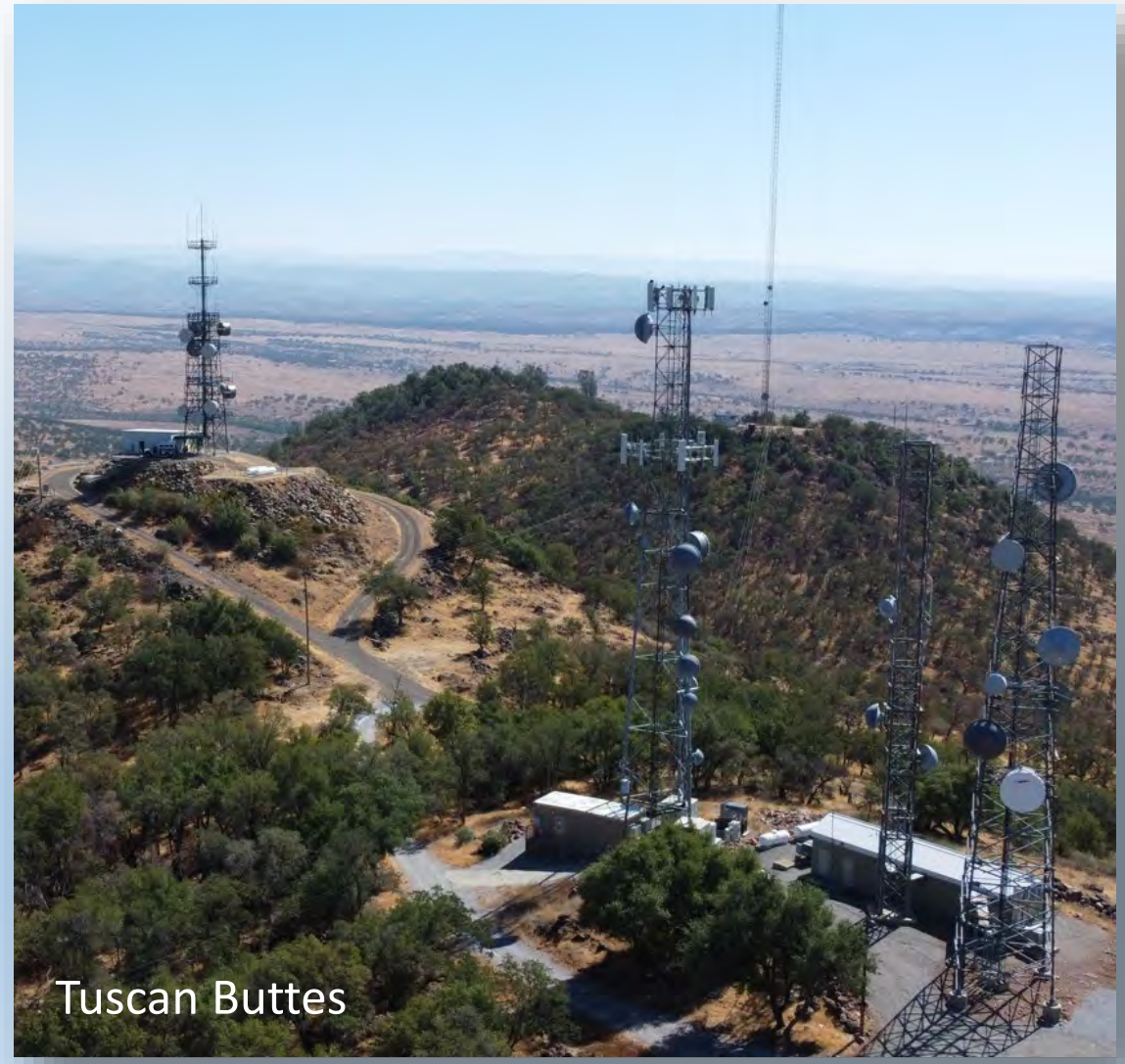
Preliminary Path Analysis – Tuscan

- Preliminary Path Summary
  - 7 likely point-to-point links



Red Bluff Wireless Expansion

Preliminary Site Prioritization

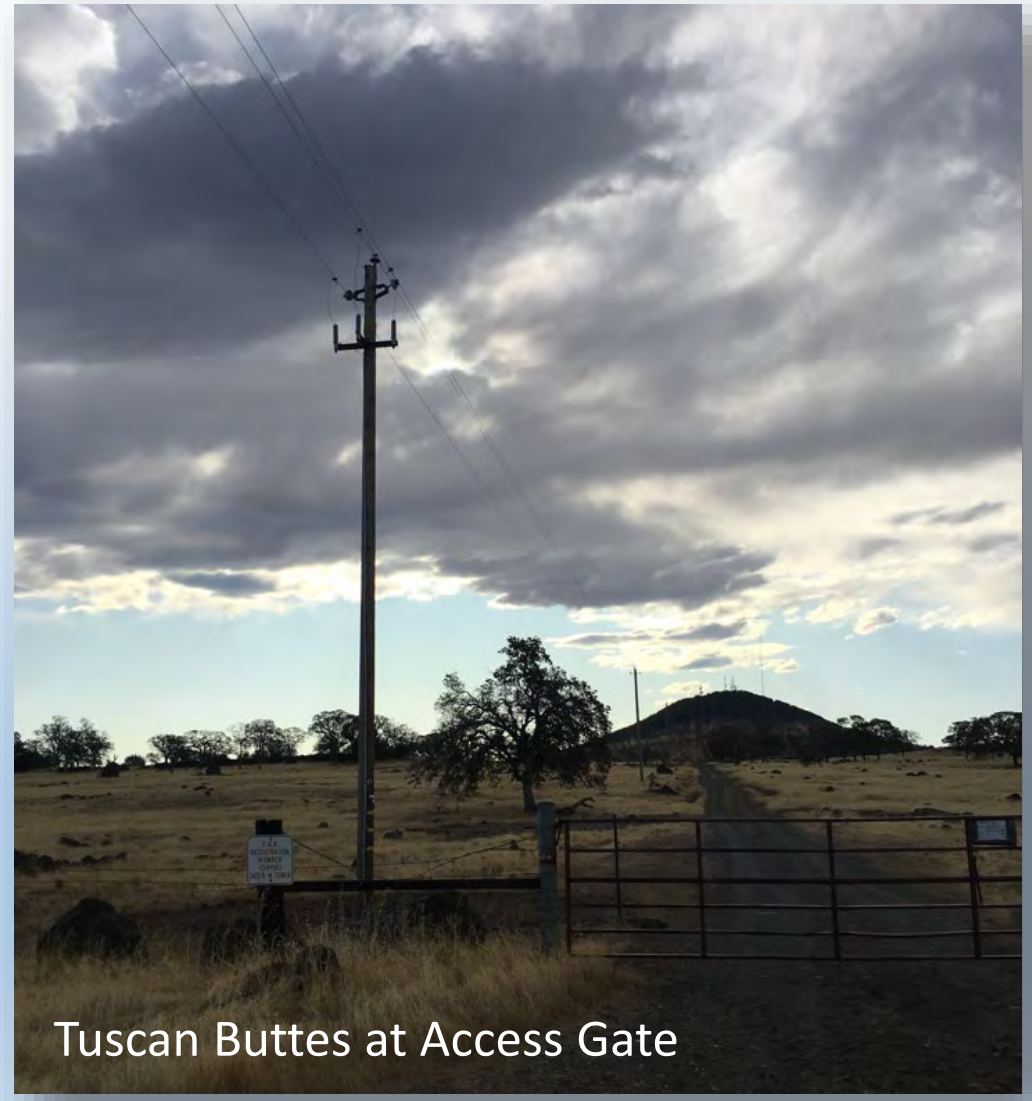

Tuscan Buttes

- Tuscan – 1st
  - 7 likely point-to-point links
- Inks Ridge – 2nd
  - 3 likely point-to-point links
- Inskip – 3rd
  - 2 likely point-to-point links

Red Bluff Wireless Expansion

Initial Field Site Visit (2017) – Tuscan

- Access
  - Locked Gate
  - Well maintained dirt road
  - 3 miles to site



Tuscan Buttes at Access Gate

Red Bluff Wireless Expansion

Initial Field Site Visit (2017) – Tuscan

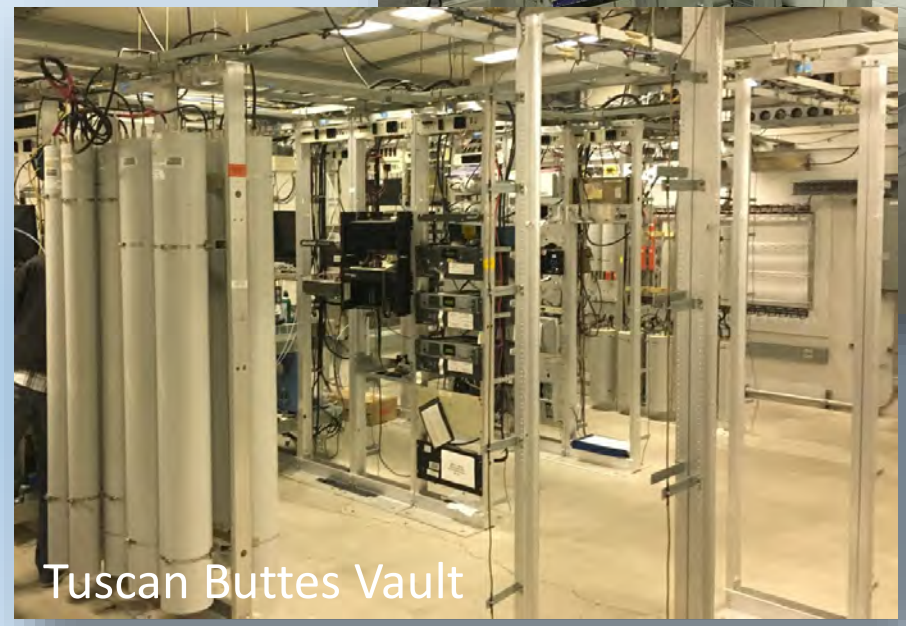
- Access
  - Locked Gate
  - Well maintained dirt road
  - 3 miles to site
- Tower
  - 80’ steel latus tower with 40’ nested monopole
  - Apparent available tower capacity

Tuscan Buttes Tower

Red Bluff Wireless Expansion

Initial Field Site Visit (2017) – Tuscan

- Access
  - Locked Gate
  - Well maintained dirt road
  - 3 miles to site
- Tower
  - 80’ steel latus tower with 40’ nested monopole
  - Apparent available tower capacity
- Vault
  - Apparent available racks

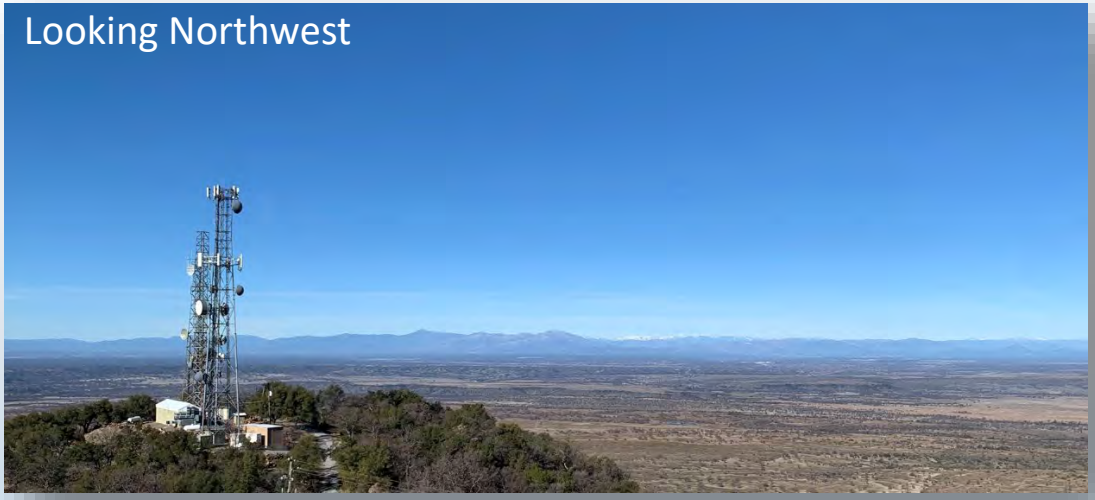


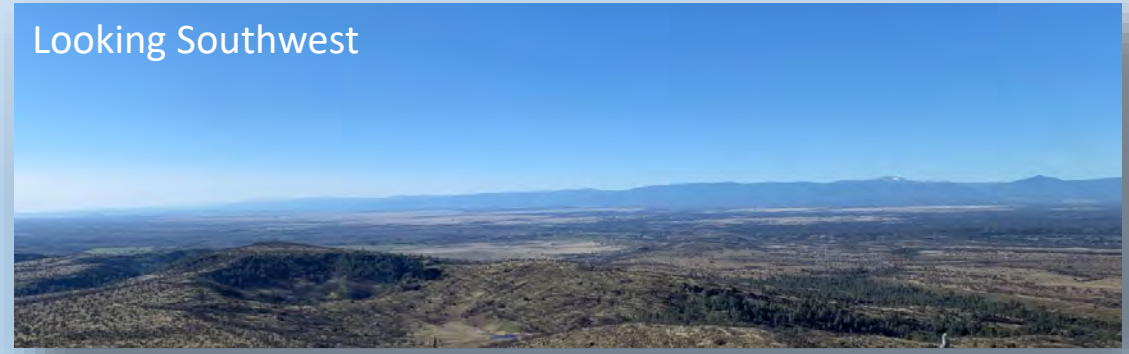
Tuscan Buttes Vault

Red Bluff Wireless Expansion

Initial Field Site Visit (2017) – Tuscan

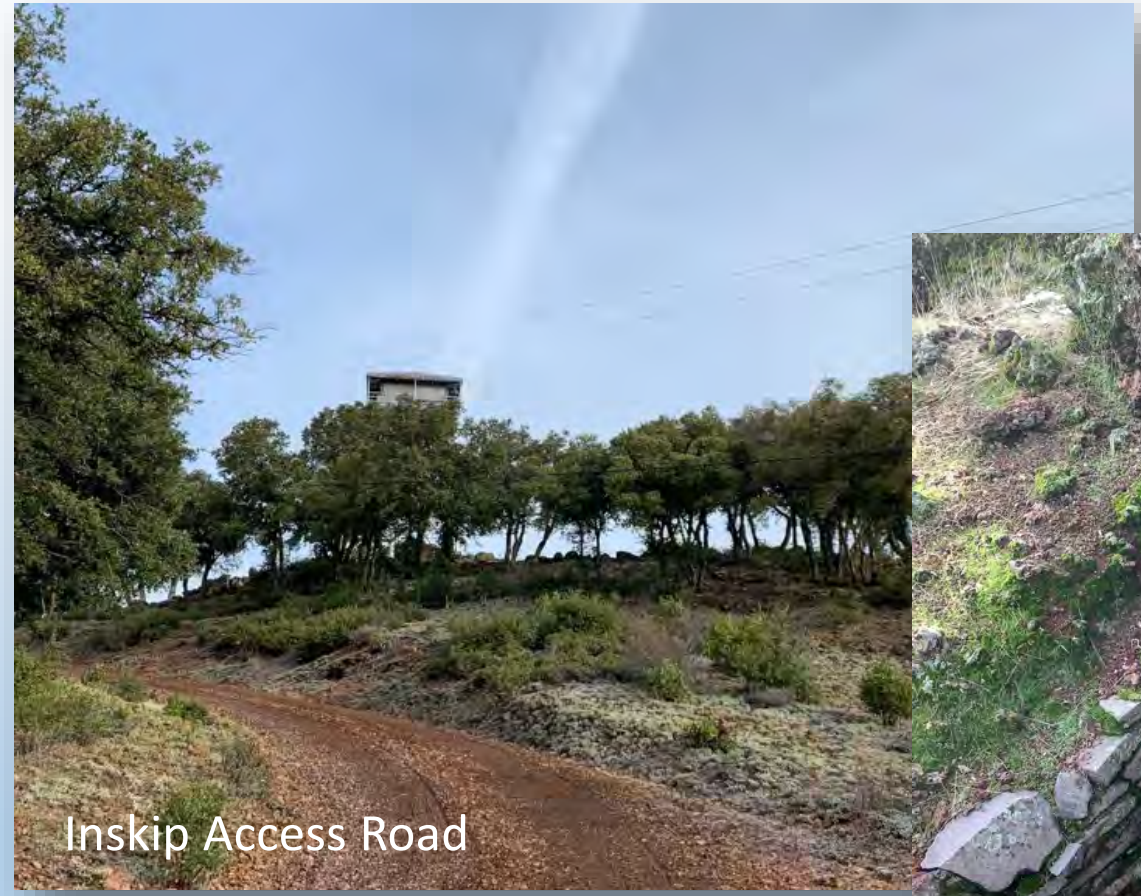
- Access
  - Locked Gate
  - Well maintained dirt road
  - 3 miles to site
- Tower
  - 80’ steel latus tower with 40’ nested monopole
  - Apparent available tower capacity
- Vault
  - Apparent available racks
- Line of site / RF Interference
  - No apparent usage of 5.8GHz
  - No apparent usage of 4.9GHz
  - Heavy usage of 6GHz



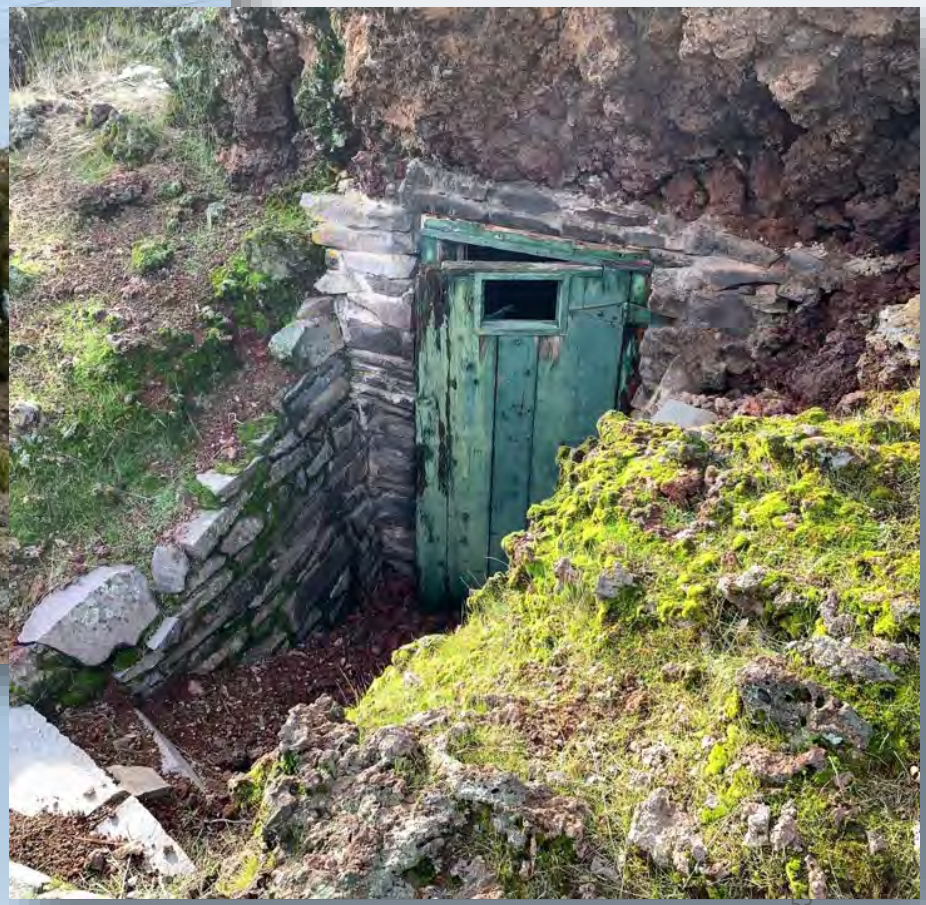


Red Bluff Wireless Expansion

Initial Field Site Visit (2019) – Inskip

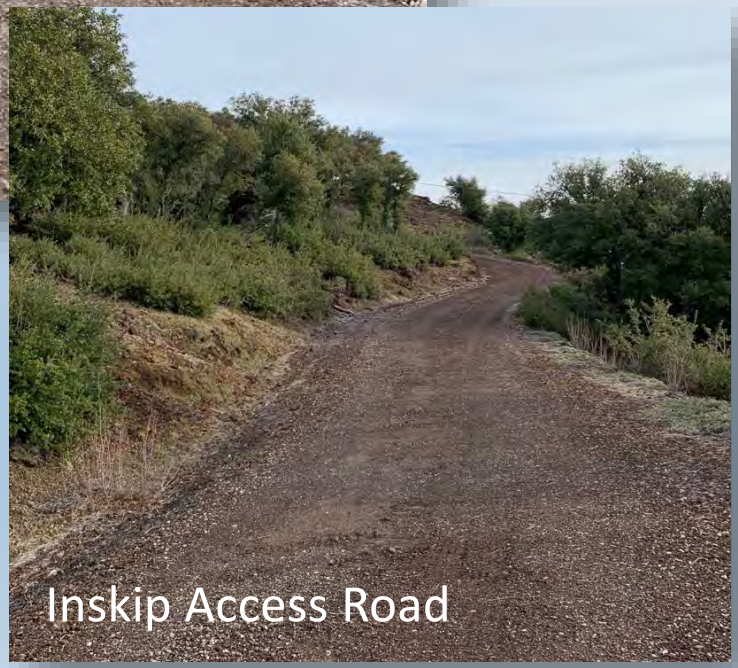


Inskip Access Road



Red Bluff Wireless Expansion

Initial Field Site Visit (2019) – Inskip



Inskip Access Road

- Access
  - Locked Gate at top
  - Well maintained dirt road
  - 4 miles to site

Red Bluff Wireless Expansion

Initial Field Site Visit (2019) – Inskip

- Access
  - Locked Gate at top
  - Well maintained dirt road
  - 4 miles to site
- Towers
  - Private towers
  - No apparent capacity
- Vaults
  - Looks in poor condition and unmaintained

Red Bluff Wireless Expansion

Initial Field Site Visit (2019) – Inskip

Inskip Vaults

- Access
  - Locked Gate at top
  - Well maintained dirt road
  - 4 miles to site
- Towers
  - Private towers
  - No apparent capacity
- Vaults
  - Looks in poor condition and unmaintained
- Line of site / RF Interference
  - No apparent usage of 5.8GHz
  - No apparent usage of 4.9GHz
  - Some usage of 6GHz

Red Bluff Wireless Expansion

Field Site Surveys – Bowman

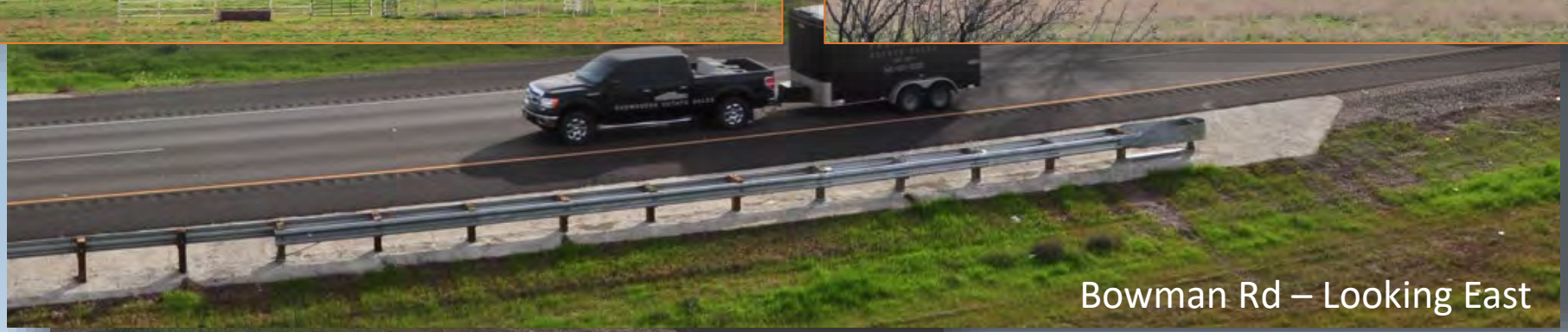
Bowman Rd CCTV

Red Bluff Wireless Expansion

Field Site Surveys – Bowman

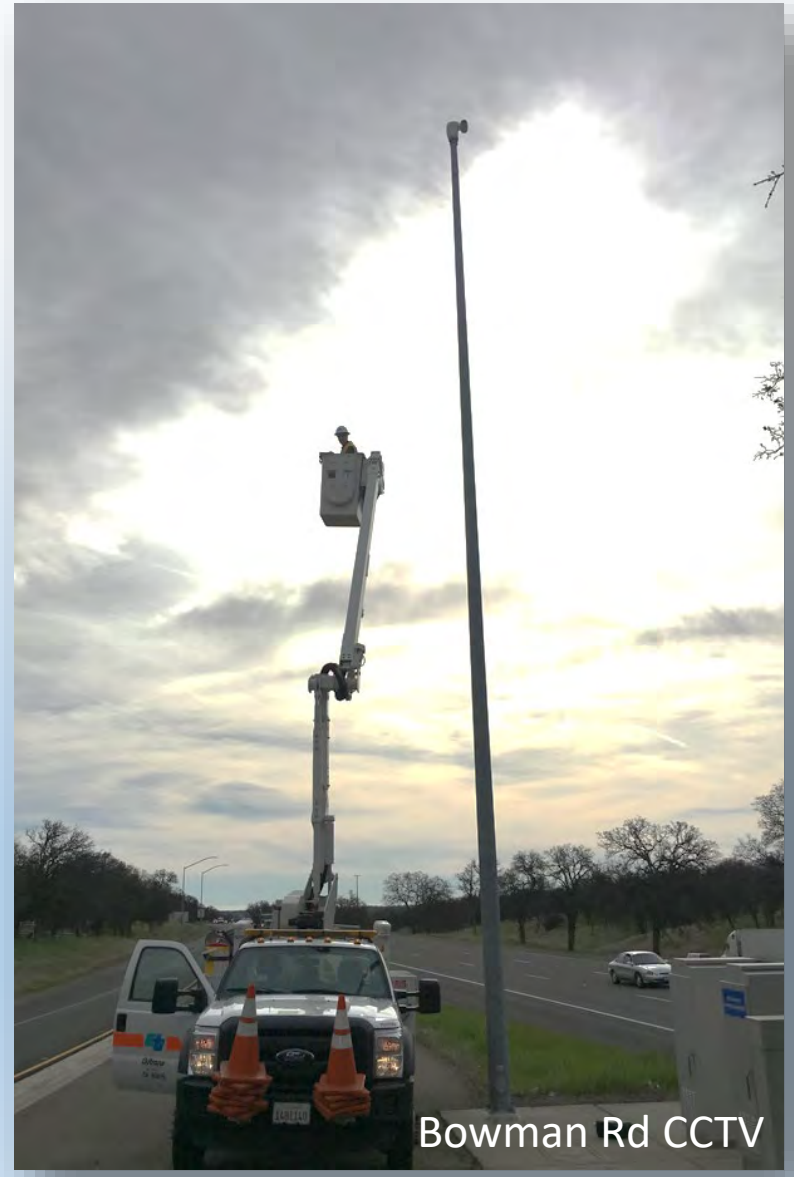
Red Bluff Wireless Expansion

Field Site Surveys – Bowman



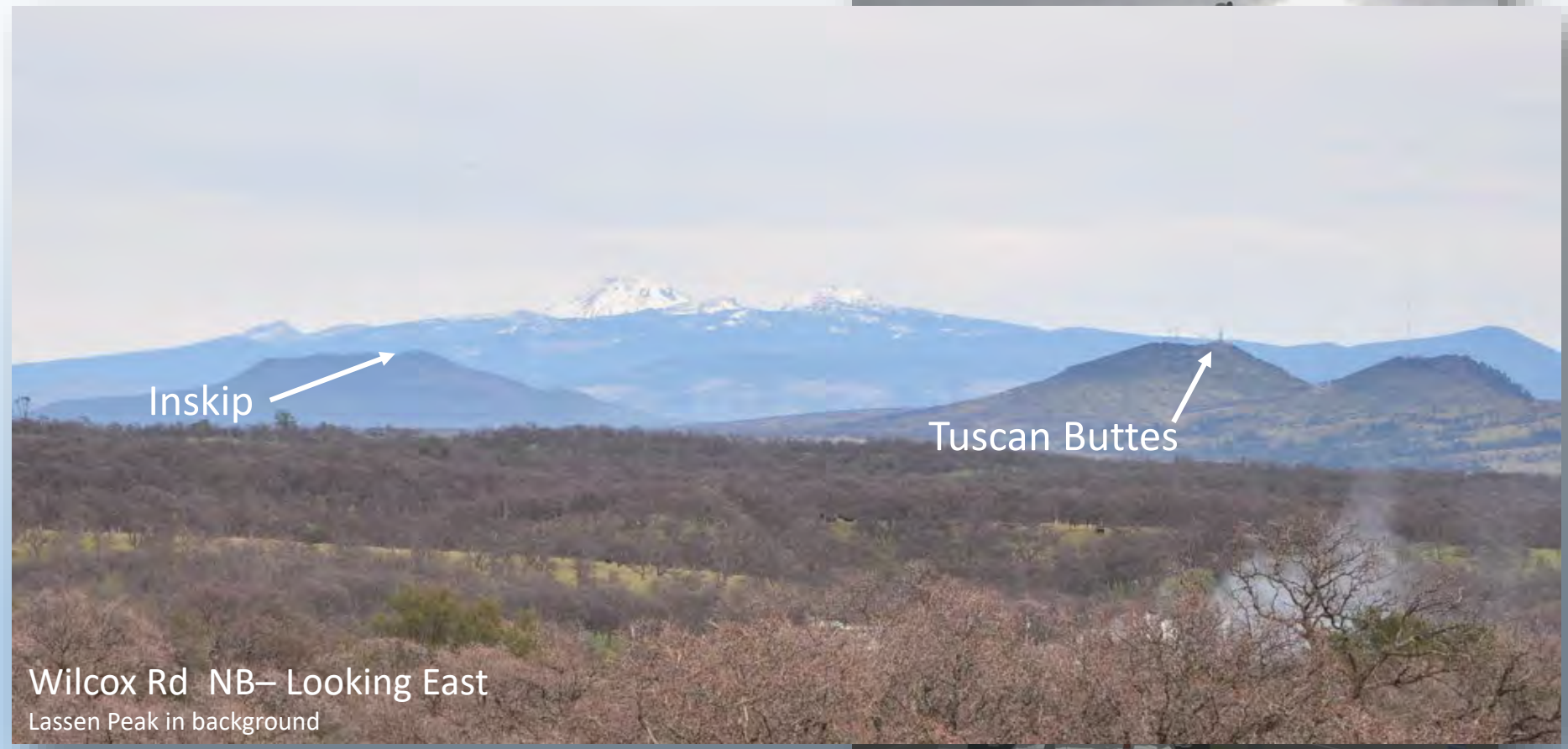
Red Bluff Wireless Expansion

Field Site Surveys – Wilcox RD NB



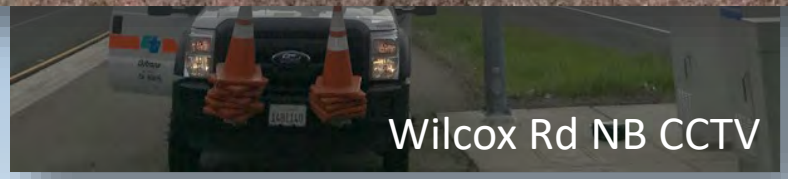
Red Bluff Wireless Expansion

Field Site Surveys – Wilcox RD NB



Wilcox Rd NB– Looking East

Lassen Peak in background



Wilcox Rd NB CCTV

Red Bluff Wireless Expansion

Field Site Surveys – Red Bluff

Red Bluff Wireless Expansion

Field Site Surveys – Red Bluff

Red Bluff Wireless Expansion

Field Site Surveys – Vina

Vina/South Ave – Looking North

Mt Shasta in background

Radio Specifications

Backhaul

Common Carrier Point-to-Point Considerations (6 GHz vs 11 GHz)

6 GHz

- More congested band
- More susceptible to thermal ducting
- Less susceptible to rain fade on longer links
- Generally used for 15-40 mile links

11 GHz

- Less congested band
- Less susceptible to thermal ducting
- More susceptible to rain fade on longer links
- Generally used for 10-15 mile links

Ra

Comm

6 GHz

- More congested band
- More susceptible to therr
- Less susceptible to rain f longer links
- Generally used for 15-40

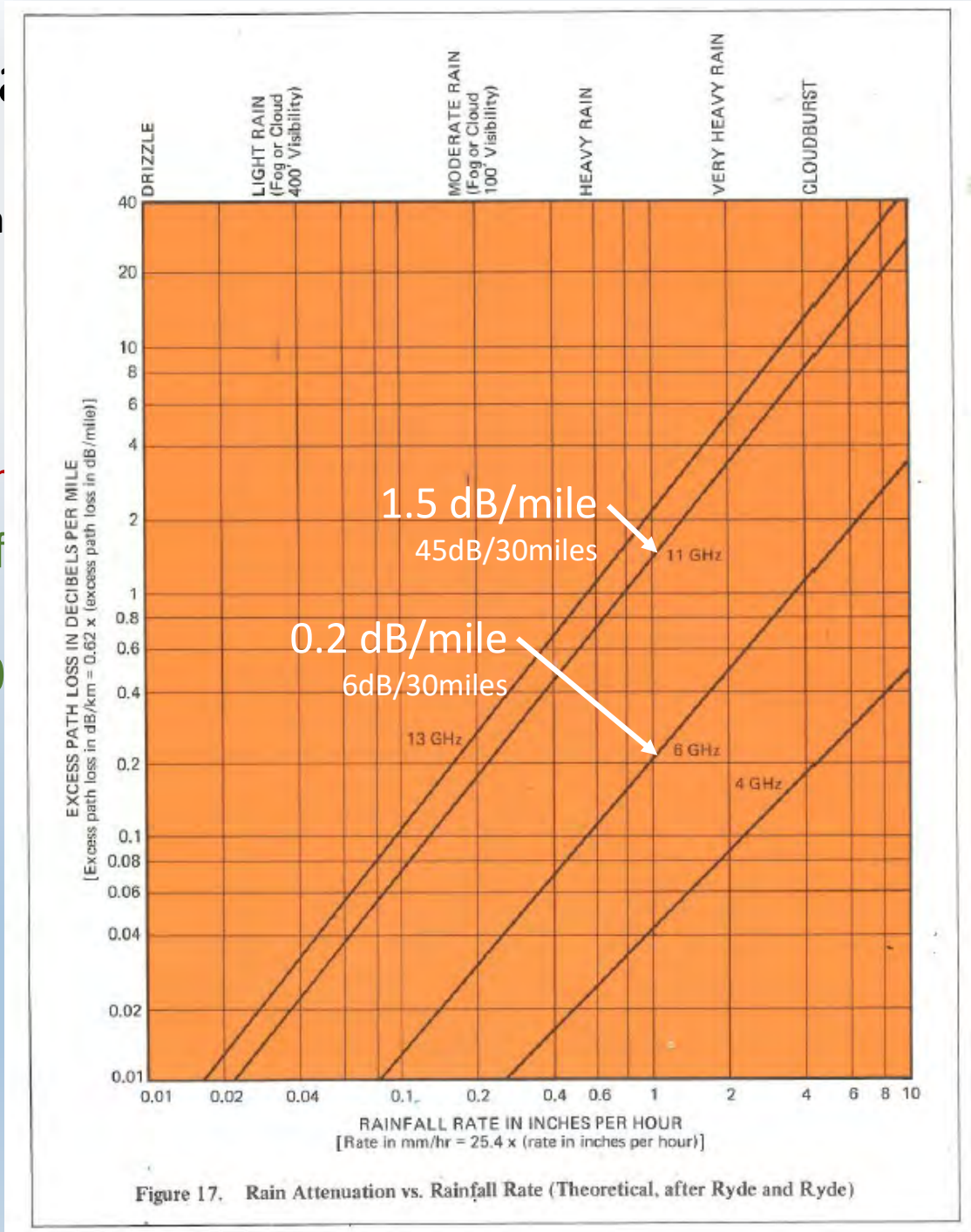


Figure 17. Rain Attenuation vs. Rainfall Rate (Theoretical, after Ryde and Ryde)

Radio Specifications

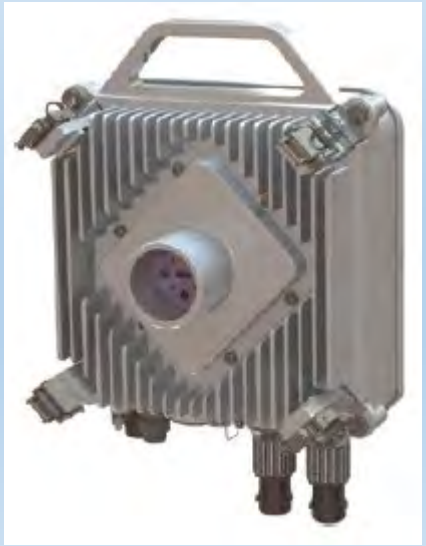
Backhaul – Requirements

- Approx. 30 mile link
- 99.999% Uptime (5 nines)
- 150 Mbps or more throughput
- Ethernet radios
- All indoor equipment
- Ease of installation
  - Installation done by state forces
- Ease of procurement
  - On existing state contract?

Radio Specifications

Backhaul – Evaluation

- Hardware specifications
- Ease of configuration
- Availability of support
- References from vendors
- Integration with existing system
- Vendor support



Radio Specifications

Backhaul – Selection

- Aviat Eclipse
  - All indoor radio
  - Three output power options
    - SP +29.5 dBm
    - HP +32.0 dBm
    - EHP +38.5 dBm
  - 155 Mbps Fixed throughput
    - 267 Mbps with ACM and 30 MHz Ch.

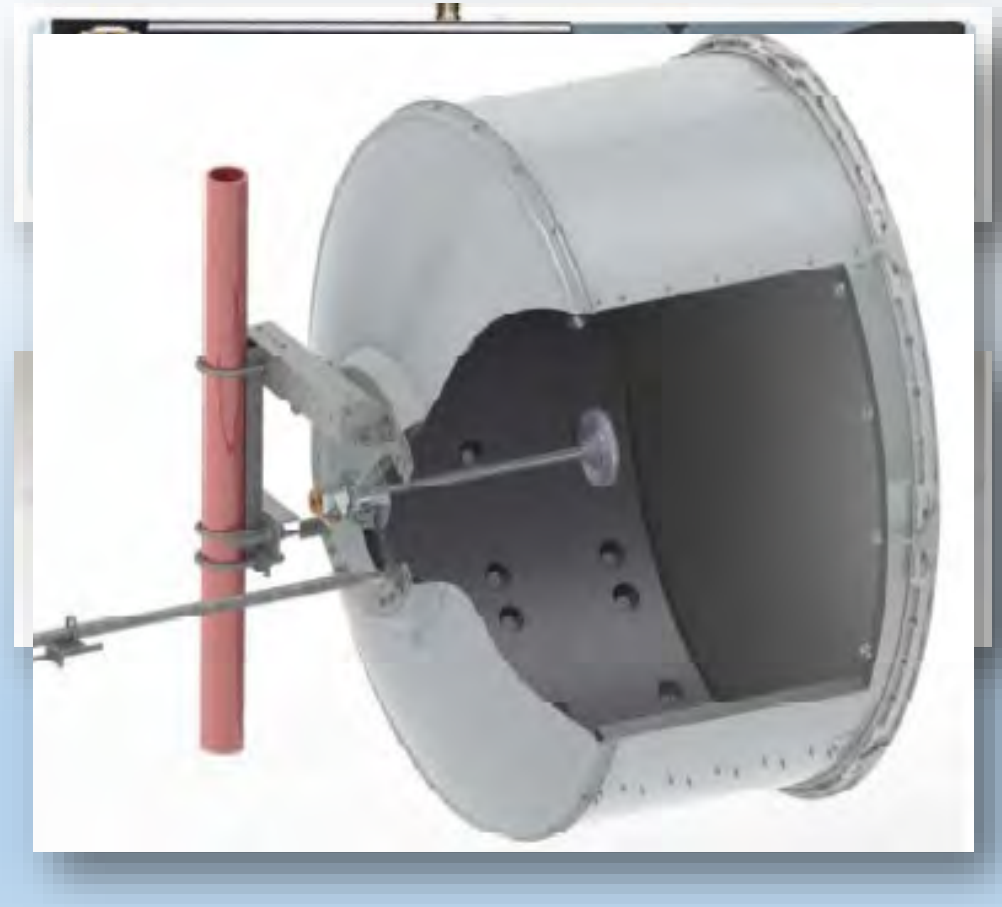
IRU400V4 – Transceiver

INU – Node Indoor Unit

Radio Specifications

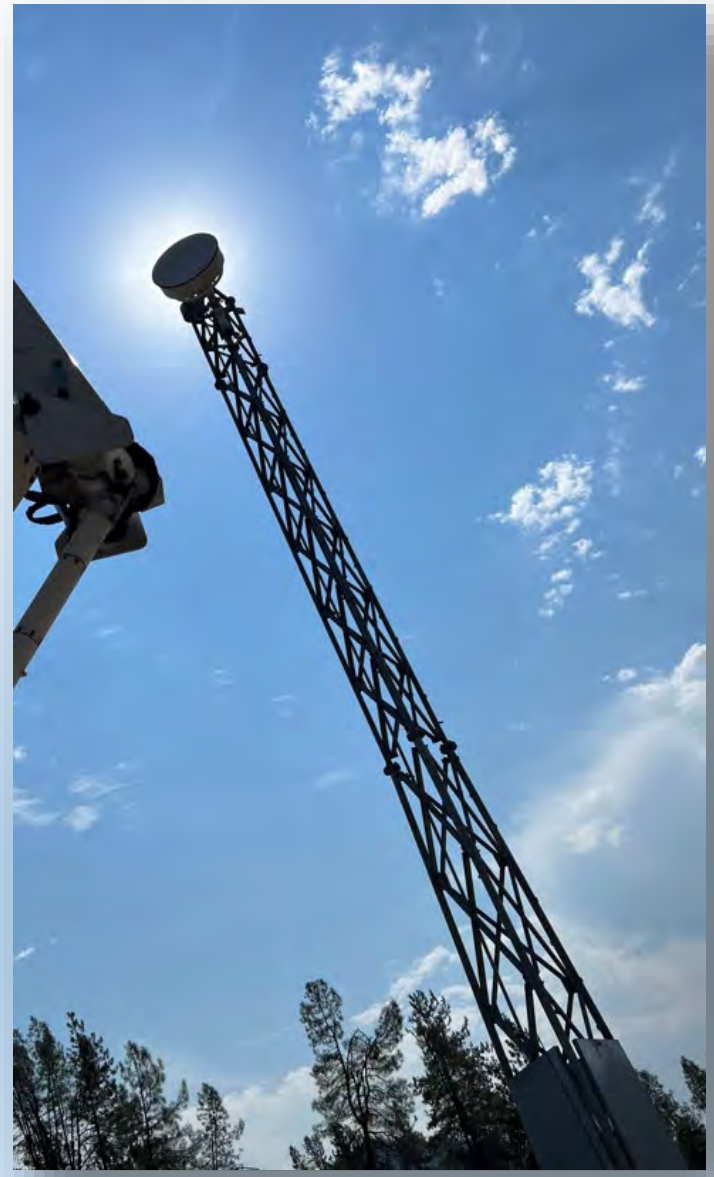
Backhaul – Selection

- Aviat Eclipse
  - All indoor radio
  - Three output power options
    - SP +29.5 dBm
    - HP +32.0 dBm
    - EHP +38.5 dBm
  - 155 Mbps Fixed throughput
    - 267 Mbps with ACM and 30 MHz Ch.
- CommScope (Previously Andrew)
  - ValuLine High Performance (HX series)
  - Lower quality than Andrew products



Radio Specifications

Roadside Link – Requirements



- Up to 23 mile link
- 99.999% Uptime (5 nines)
- 10 Mbps or more throughput
- Ethernet radios
- All indoor (cabinet) equipment
- Interoperability with existing roadside links

Radio Specifications

Roadside Link – Selection

RX Threshold (10E-6)

Data Rate (Mbps)	Channel Bandwidths 10	28	56
14	-93.1		
27	-85.8	-90.3	
36	-83.1	-89.1	
45	-79.6	-85.1	-88.1
54	-76.4	-84.4	-87.4
63	-70.2	-82.2	-85.2
100		-78.7	-81.7
125		-75.2	-80.7
150		-71.9	-79.9
175		-67.3	-76.3
200			-75.4
250			-72.2
300			-68.9
350			-64.3

Color Key		
QPSK	16-QAM	32-QAM
64-QAM	128-QAM	256-QAM

- Mosley NX-GEN-S
  - All indoor (cabinet) radio
  - Up to +37 dBm (frequency dependent)
  - Up to 350 Mbps throughput
  - -22°F to 131°F temperature range
  - Operates with existing roadside radios
- Radio Waves
  - 4.9-6 GHz

Coordination

Who talks to who?

Coordination

Interagency

ITS Engineering and Support

OCR

- Coordinating within Caltrans
  - District 2 ITS Engineering
  - Office of Radio Communications (OCR)

Coordination

Interagency

Caltrans

ITS Engineering and Support

- Coordinating within California
  - Caltrans
    - District 2 ITS Engineering
    - Office of Radio Communications (OCR)
  - CalOES
  - CalFire

OCR

Coordination

Interagency

Caltrans

ITS Engineering and Support

- Coordinating with the FCC
  - Caltrans
    - District 2 ITS Engineering
    - Office of Radio Communications (OCR)
  - CalOES
  - FCC

- Legislated by Law

OCR

Coordination

Drafting Proposal to CalFire

- Proposal to occupy the building
  - Narrative
  - Rack Locations
  - Defines the Scope of work in TDe-207

CalOES Telecommunications Work Authorization

Tuscan Buttes Microwave Upgrade
PRELIMINARY

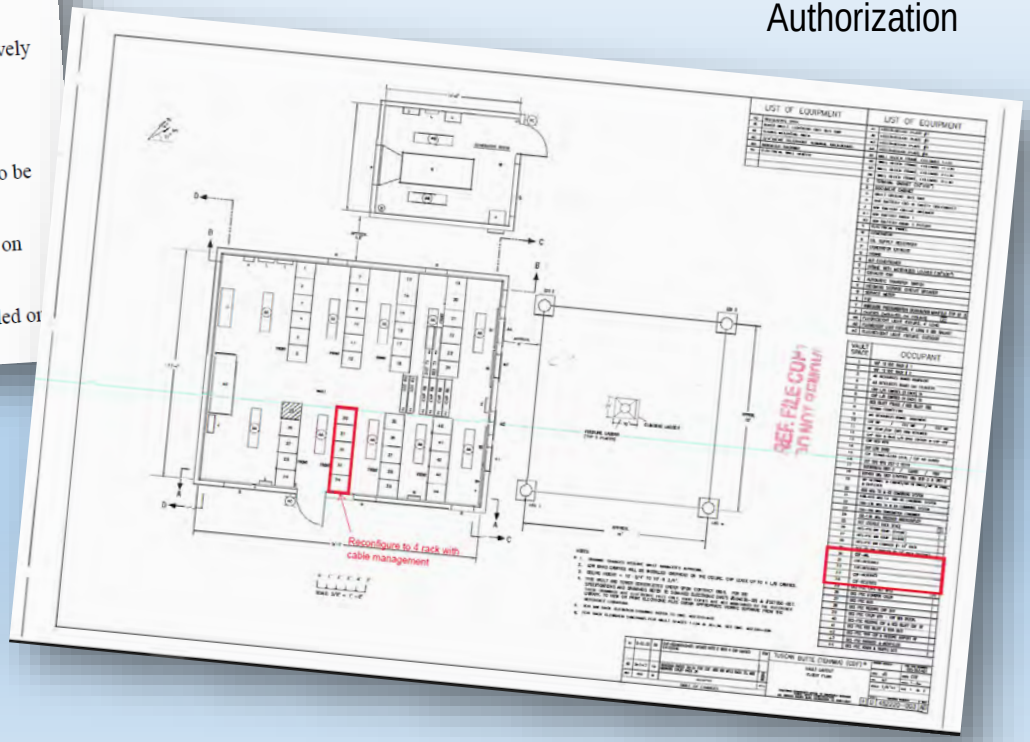
Caltrans
11/14/2019

System and Equipment Description
Caltrans District 2 Utilizes a Point-to-Point microwave system to transport video from Roadside CCTV's to the District Transportation Management Center (TMC). The network is used exclusively for our Transportation Management System, and allows TMC operators to monitor highway conditions via real-time video streams from the Roadside CCTV and other telemetry data.

Narrative of proposed changes:
New proposed, Link 1 (Hill 900), 5725-6425 MHz 8 foot high performance parabolic antenna to be installed on the North Face of the tower at approximately 25 feet AGL.

New proposed, Link 2 (Bowman Rd), 4940-4990 MHz 4 foot parabolic antenna to be installed on North Face Leg 1 of the tower at approximately 40 foot AGL.

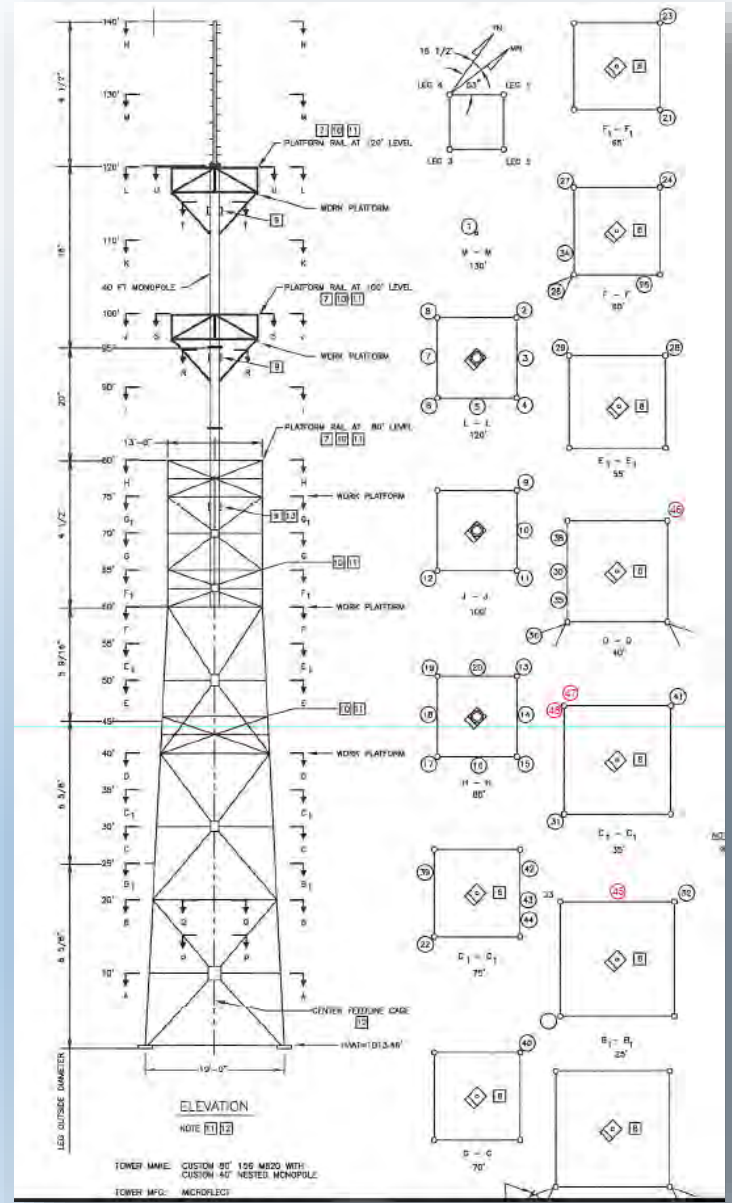
New proposed, Link 3 (Wilcox Rd NB), 4940-4990 MHz 2 foot parabolic antenna to be installed on North Face Leg 4 of the tower at approximately 35 foot AGL.



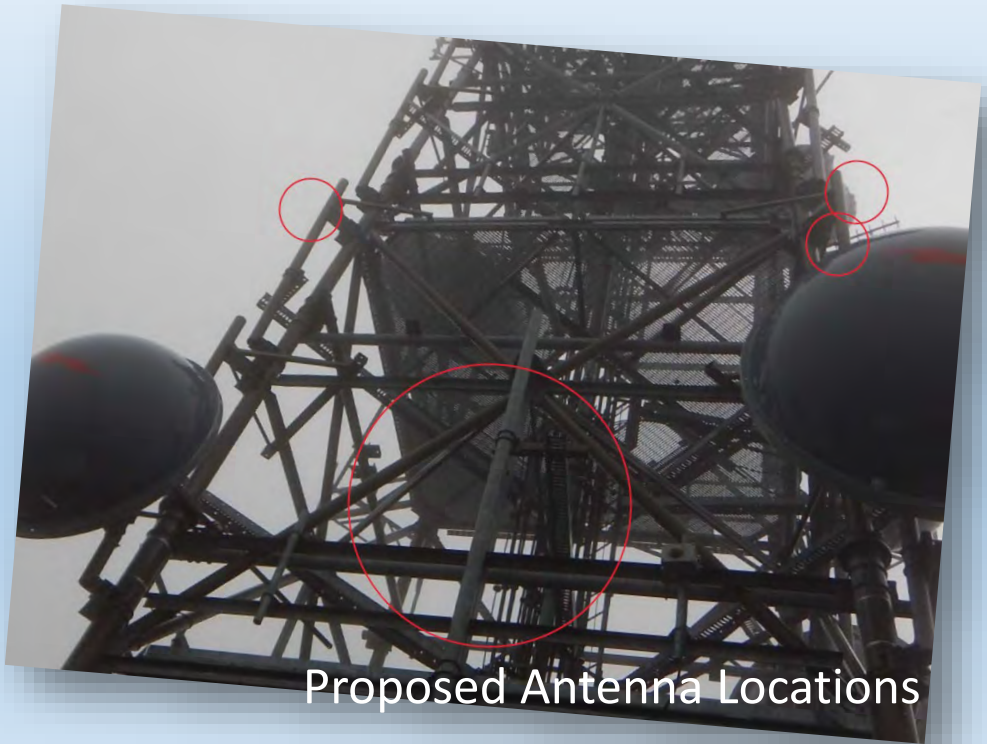
Caltrans ↔ CAL OES ↔ Other Users

Coordination

Drafting Proposal to CalOES



- Proposal to CalOES
  - Vault and Tower Drawings
  - Rack Layouts
  - Antenna sizing / locations

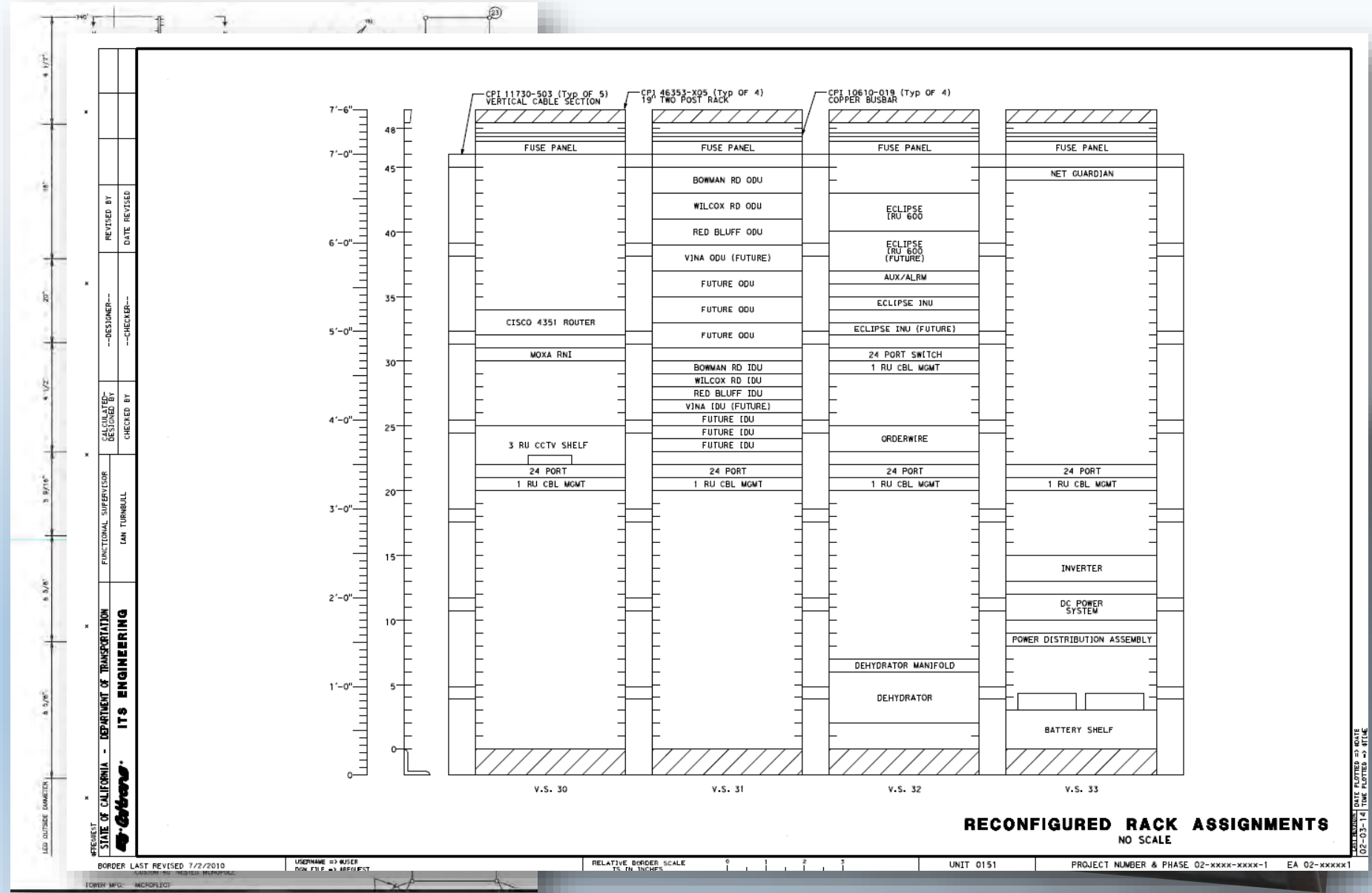


Proposed Antenna Locations

Other Users

Coordination

Drafting Proposal to CalOES

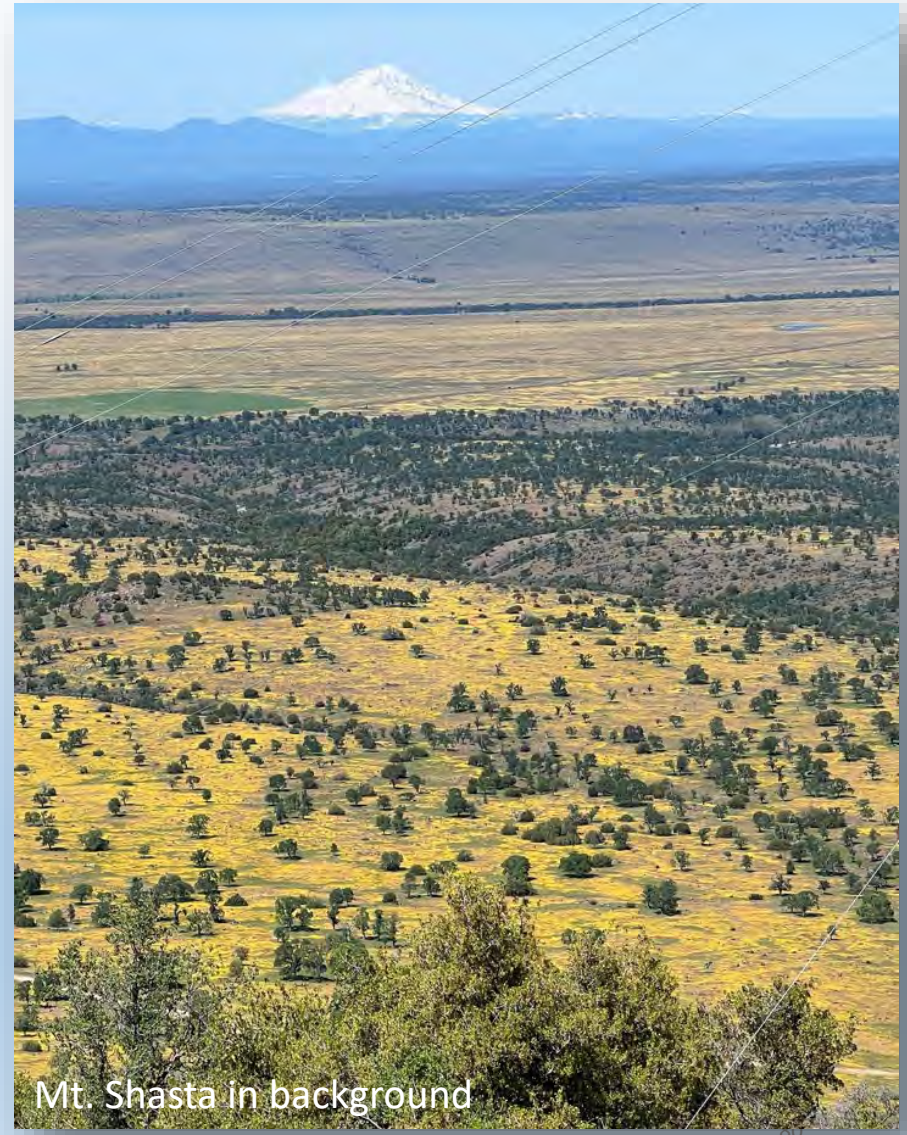


Caltrans ↔ CAL OES ↔ Other Users

Coordination

Issues

- Desired Rack Space/Locations
  - Designated as future by other agencies
- Essential services designation by State Architect
  - Stricter Installation methods
  - Stricter requirements
  - Considered changing location to Inskip
  - Added delay due to uncertainty in guidelines



Mt. Shasta in background

Coordination

Drafting Proposal to CalOES

- Frequency Coordination
  - CommSeach to Coordinate 6 GHz backhaul link

Microwave Path Data Sheet Page 1 of 2

COMSEARCH

19700 Janelia Farm Boulevard, Ashburn, VA, 20147
(703)636-5234 www.comsearch.com

PCN Date: 11/14/2019 — New Path
Job Number: 191114COMSDS02 — RCN Number: 19111443

Administrative Information	**HILL 900 CA**	**TUSCAN AVIAT CA**
City/County	Redding/Shasta	/Tehama
Status / License Basis	Engineering Proposal / PRIMARY OPERATION	Engineering Proposal / PRIMARY OPERATION
Call Sign	WQYJ992	
Licensee Code	S00141	S00141
Licensee Name	California, State of	California, State of
Radio Service / Station Class	MW -- Microwave Public Safety Pool	FXO -- Fixed
Site Information		
Latitude (NAD 83)	40 ° 34' 44.2" N	40 ° 15' 43.5" N
Longitude (NAD 83)	122 ° 25' 12.0" W	122 ° 5' 33.9" W
Ground Elevation (m/ft-AMSL)	272.00 / 892.4	562.57 / 1845.7
Antenna Structure Registration #	1018172	
Path Azimuth (°)	141.608	321.821
Path Length (km / miles)	44.825 / 27.853	
Transmit Antenna	77376A	67389A
Manufacturer	Commscope	Commscope
Model	HX6-6W	HX8-6W
Gain(dBi) / Beamwidth(°) / Tilt(°)	39.1 / 1.80 / 0.22	41.6 / 1.30 / -0.52
Centerline (m / ft - AGL)	7.62 / 25.0	7.62 / 25.0
Receive Antenna	Same As Transmit	
Manufacturer		
Model		
Gain (dBi) / Beamwidth (°)		
Centerline (m / ft - AGL)		

Coordination

Drafting Proposal to CalOES

- Frequency Coordination
  - CommSeach to Coordinate 6 GHz backhaul link
  - District 2 coordinated 4.9 GHz

Links	Channel	Polarization	Key
Wilcox Rd->Tuscan Buttes	9	Vertical	
Tuscan Buttes->Wilcox Rd	4	Vertical	
Bowman Rd->Tuscan Buttes	7	Vertical	
Tuscan Buttes->Bowman Rd	2	Vertical	
Red Bluff->Tuscan Buttes	8	Vertical	
Tuscan Buttes->Red Bluff	3	Vertical	

	CH 1	CH 2	CH 3	CH 4	CH 5	CH 6	CH 7	CH 8	CH 9	CH 10
Low/High	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90
Center	4942.50	4947.50	4952.50	4957.50	4962.50	4967.50	4972.50	4977.50	4982.50	4987.50
Vertical										
Horizontal										

Coordination

Drafting Proposal to CalOES

- Frequency Coordination
  - CommSeach to Coordinate 6 GHz backhaul link
  - District 2 coordinated 4.9 GHz
- Frequency Licensing
  - All submittals are sent to the CalOES FCC group.

Links	Channel	Polarization	Key
Wilcox Rd->Tuscan Buttes	9	Vertical	
Tuscan Buttes->Wilcox Rd	4	Vertical	
Bowman Rd->Tuscan Buttes	7	Vertical	
Tuscan Buttes->Bowman Rd	2	Vertical	
Red Bluff->Tuscan Buttes	8	Vertical	
Tuscan Buttes->Red Bluff	3	Vertical	

	CH 1	CH 2	CH 3	CH 4	CH 5	CH 6	CH 7	CH 8	CH 9	CH 10
Low/High	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90
Center	4942.50	4947.50	4952.50	4957.50	4962.50	4967.50	4972.50	4977.50	4982.50	4987.50
Vertical										
Horizontal										

Procurement

Backhaul Link

- Leveraged existing NASPO non-mandatory agreement
  - RFOs are not required for select categories of equipment
  - Expedited procurement
- Caltrans' Department of Procurement and Contracts (DPAC) requires authorization from Office of Radio Communication

Procurement

Roadside Links

- Completive Bidding
- 4.9 GHz band
  - FCC issued freeze on the band in September 2020
  - Ordered 5.8 GHz ISM Band Radios
  - FCC partially releases freeze on band in September 2011
  - Ordered 4.9 GHz Band Radios
- Supply Chain issues
  - Long delays on radio components

Installation

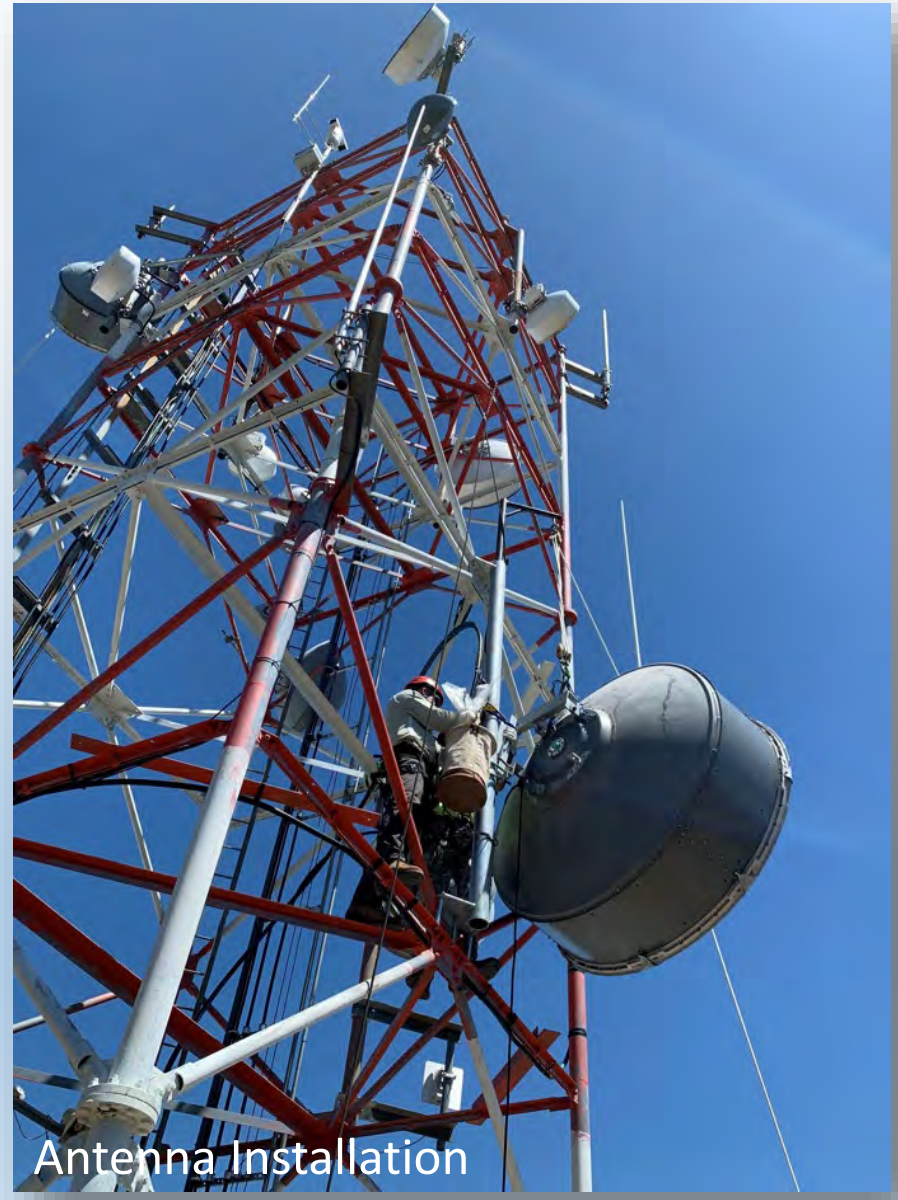
Backhaul Link – Hill900

6’ Antenna Construction

Waveguide Termination

Installation

Backhaul Link – Hill900

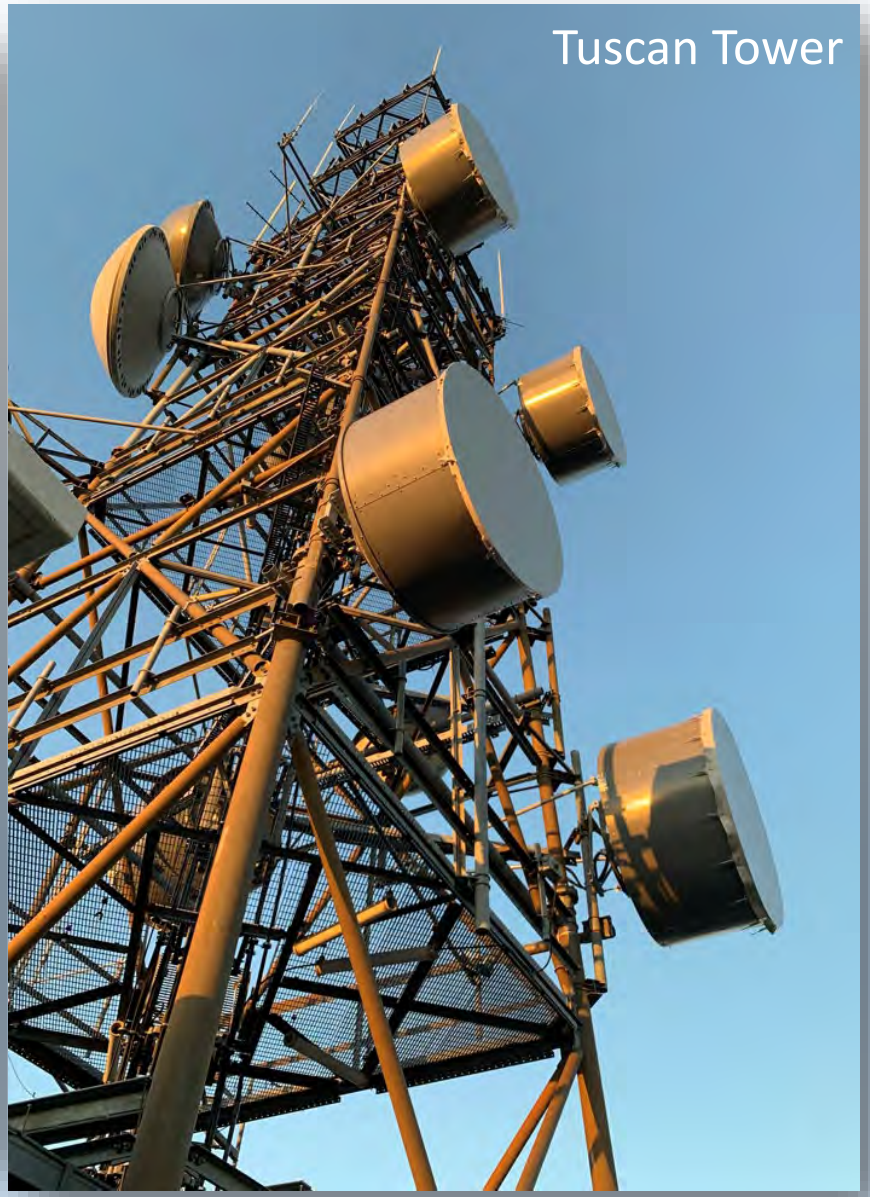


Antenna Installation

Installation

Backhaul Link – Tuscan

Antenna Construction



Tuscan Tower

Installation

Backhaul Link – Tuscan

Installation

Backhaul Link – Tuscan

Tuscan Tower

- Hoisting
  - Largest antenna office has hoisted
- Location
  - Ease of working on antenna
- Peaking
  - Narrow beamwidth
  - Long Link

Installation

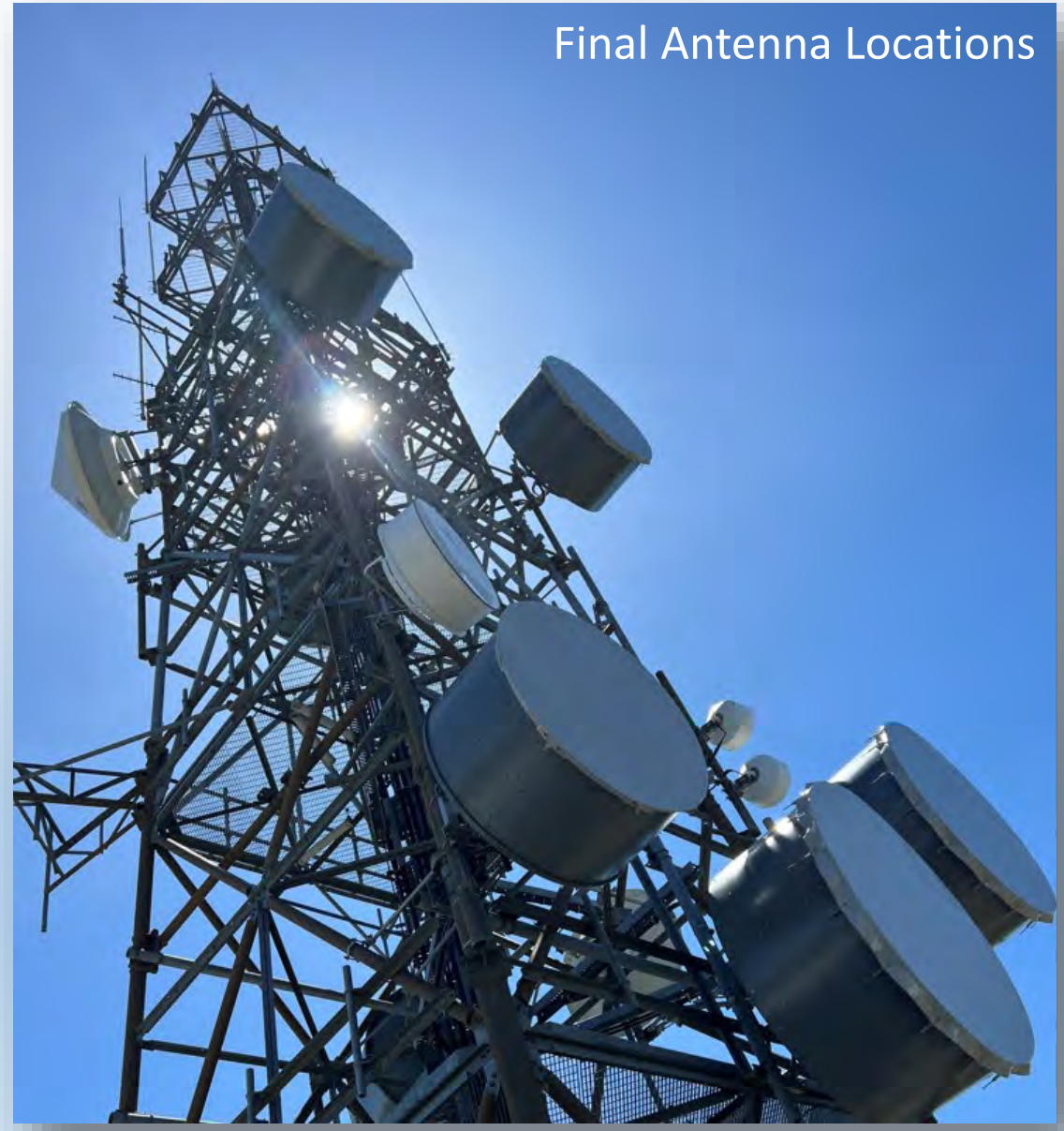
Roadside Links

Installation

Roadside Links

Installation

Roadside Links



Lessons Learned

- Time (expect it)
  - Inter/Intra-Agencies
    - Coordinating
  - Changing Reequipments
    - DSA
    - FCC
  - Manufacturing (Supply Chain)
    - Radio
    - Networking Equipment

Lessons Learned

- Access protocols
  - Vault owner had stringent protocols
    - Checking out vault key
  - Gate access with via Adjacent Users Combination

- Rapport
  - Local OES Technicians
  - Adjacent Users

Questions?