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Analysis of Fixed Wireless Options with Case Studies

Prepared for the Georgia Technology Authority

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1 Executive Summary

CTC conducted a technical and cost analysis of fixed wireless broadband options to reach areas in Georgia unserved by broadband, defined as 25 Mbps download and 3 Mbps upload. We focused on using Citizens Broadband Radio Service (CBRS), Educational Broadband Service (EBS), and other emerging, available spectrum and technologies that can deliver broadband performance.

This report documents CTC's analysis of fixed wireless broadband solutions using the available spectrum and technologies on a statewide basis, using available mapping and other resources, as well as our analysis of three representative counties (Glascock, Miller, and Gordon) selected by the State. We have also captured the associated capital and operational costs. We offer a short introduction to fixed wireless network connectivity in Section 2 to describe the different spectrum, fixed wireless network characteristics, and the major factors that impact cost to inform the rest of the report.

1.1 Key Findings

The primary cost driver for a fixed wireless broadband solution is spectrum, predominantly due to its technical characteristics. The farther a certain radio frequency can reach, the more locations it can cover lowering overall cost. The lower the frequency, the better it will penetrate or go around obstacles. Other cost drivers include the power authorized by the FCC for users in the band, the density of locations within a given coverage area, tower availability (building a new tower adds expense), tower lease costs (for available towers), and the service adoption rate.

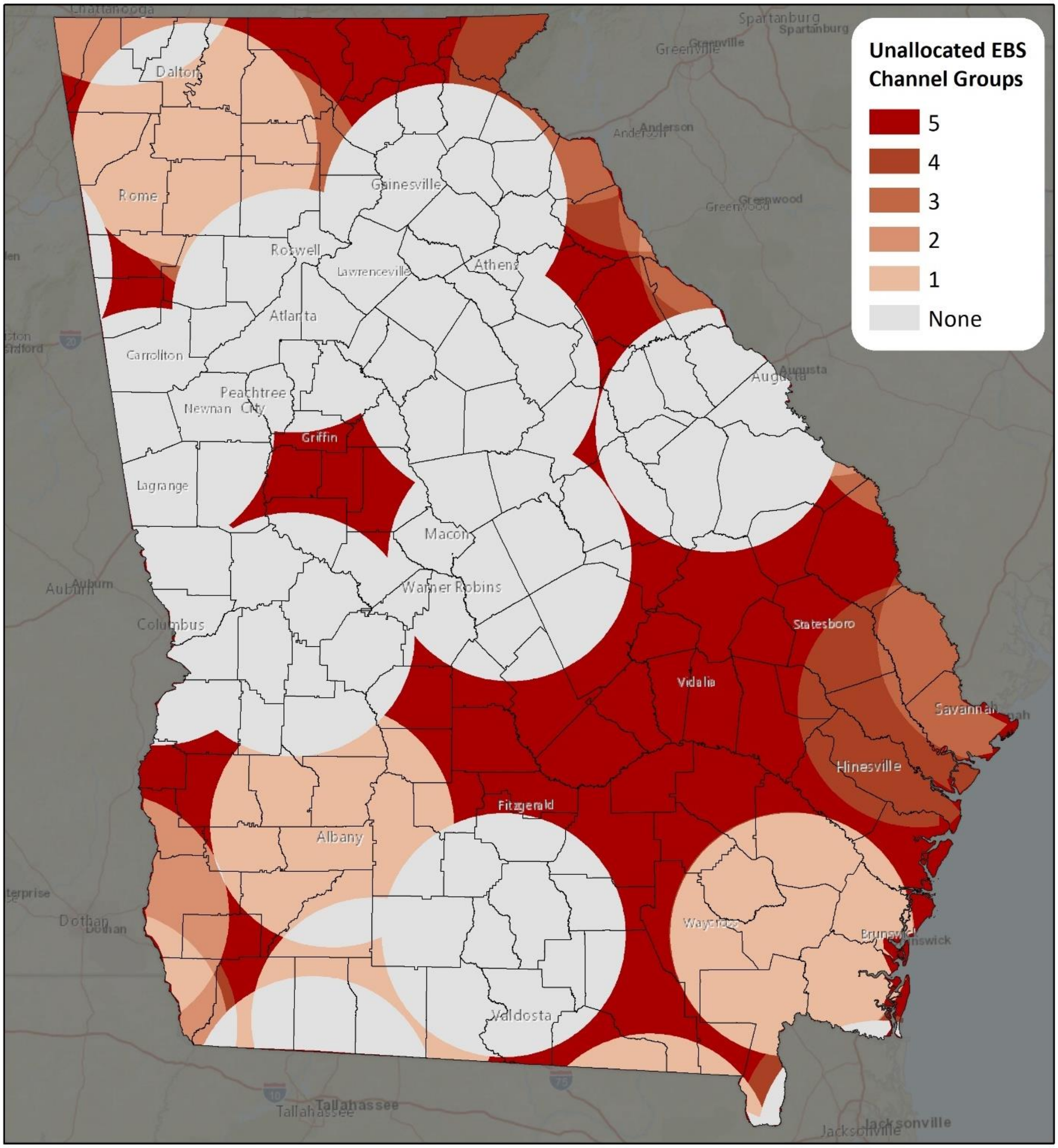
The Educational Broadband Service (EBS) technology and spectrum is the best technological and financial fit for a fixed wireless broadband network and has channel groups available in some areas of the State.

The technological fit is due to the higher allowed operational power and the superior signal propagation, including through foliage and over challenging terrain. EBS spectrum is now available for purposes other than education, and many entities, such as mobile carriers, are taking advantage of its availability. EBS spectrum is allocated in 20 MHz "channel groups"; one channel group is sufficient providing broadband service.

Due to the aforementioned technological advantages over other spectrum such as CBRS and unlicensed 5 GHz, EBS is also a more cost-effective spectrum solution. EBS's superior signal propagation translates to more locations served from each tower (or other vertical structure used for service distribution in an area) and higher speeds.

Figure 1 indicates where unallocated channel groups are at present.

Figure 1: Unallocated EBS Channel Groups in Georgia



We anticipate T-Mobile will seek to use the spectrum for 5G deployments, including expanding in-home broadband offerings[1] and we recommend the State follow the deployment of this service in the event it is a viable option for connectivity for unserved locations and unserved students. We also anticipate that other entities, including new entrants, may be able to acquire

[1] https://www.t-mobile.com/news/network/new-t-mobile-fixed-broadband-alternative

spectrum in a new band plan of unallocated EBS spectrum that is expected to be auctioned in 2021.

Although the State may choose not to participate in the EBS auction, there are other ways to take advantage of EBS. To deploy fixed wireless networks, the State could partner with WISPs that would be willing to participate in the auction and that are interested in either expanding a current network or deploying a new network in the State's area of interest. The State could also research incumbent license and license sublease holders to see whether there is an opportunity for using that spectrum.

Where EBS is not available, CBRS provides the next-best performance option. Although CBRS does not propagate as far as EBS and thus is not as optimal for rural broadband, it is still an effective option for rural broadband. It is especially a viable, affordable solution for urban and suburban areas and campuses such as some low-income housing complexes.

Unlicensed 5 GHz frequencies can be used to augment EBS and CBRS when needed. To reach more unserved locations, a 5 GHz solution will supplement an EBS, CBRS, or combined EBS/CBRS solution.

The Rural Digital Opportunity Fund (RDOF) reverse auction recently conducted by the FCC was designed to support deployment of broadband in many currently unserved parts of the country. In Georgia, many unserved parts of counties received awards, but some did not. However, RDOF awardees have years until they are required to build their networks, so unserved locations in RDOF-awarded areas may have a long wait until they receive service.

In addition, many RDOF awardees placed extremely low bids for the areas, in many cases, too low to build and operate a sustainable network.[2] Therefore, many awardees may default on their obligations, or may need to scale back their commitments in service area or performance. A fixed wireless network may provide connectivity sooner in RDOF-awarded areas while awardees address any problems in deployment.

Based on our analysis, **a fixed wireless solution using existing towers would provide service to 58.8 percent, 93.5 percent, and 92.2 percent of all unserved locations in the case-study counties of Glascock, Miller, and Gordon, respectively.** The lack of unassigned EBS channel blocks in Glascock County forced the use of CBRS and unlicensed 5 GHz only, with propagation areas much smaller than EBS, so fewer unserved locations were reached using existing towers.

Based on our analysis, **a fixed wireless solution using existing towers would provide service to 44 percent, 91 percent, and 86 percent of all unserved student locations in the case-study**

[2] https://www.ctcnet.us/blog/

counties of Glascock, Miller, and Gordon, respectively. Again, the lack of unassigned EBS channel blocks in Glascock County forced the use of CBRS and unlicensed 5 GHz only whose propagation areas are much smaller than EBS, thus fewer unserved student locations were reached using existing towers.

Based on our analysis of the three case-study counties, the capital costs for building a fixed wireless network that provides broadband to a large percentage of the unserved population of a more populous county such as Gordon County (see Table 8 for a comparison of county populations in Georgia), assuming a take-rate of 60 percent, will be in the $10 million range for all unserved locations and $3 million to $5 million for unserved students locations. In Miller and Glascock Counties, capital costs will be in the $1.5 million to $3 million range to all unserved locations and $600,000 to $1 million for unserved student locations. Of note, however, operating costs are greater for the counties with a lower number of unserved locations since the tower to served location ratio is higher.

The capital cost per location served varies based on the scale of the network (Table 1). This is due to the cost of tower equipment, backhaul, and other fixed costs for the distribution network independent of the customer premises equipment (CPE) and installation. The distribution network includes the core equipment and backhaul and radio equipment, including antennas located on towers, poles, or other structures that distribute service to a CPE; the distribution cost per served premises ranges from $234 for more-populated Miller County to $875 per premises for less-populated Glascock County. Distribution costs per premises were more than twice as high when the network is built only for the unserved students. In contrast, the cost of the CPE and installation for each location are consistent across any proposed network. The cost of a new tower would likely be between $100,000 and $300,000, depending on the terrain and height needed.

Our design and resulting estimates only consider the use of existing towers and we assumed that space is available at a certain height on each. We assumed that backhaul is provided by fiber optic cabling where it already exists and microwave links otherwise; assumption is that 10 percent of the sites require an additional microwave hop. Capital costs also include engineering and design, RF path analysis, structural analysis, site acquisition, and permitting.

Table 1: Estimated Fixed Wireless Capital Costs

County - Locations	Number of Existing Towers	Locations Served	Percent of Locations Served	Capital Cost	Average Distribution Network Cost per Served	Installation and CPE Cost per Location Served
Glascock – All	8	973	59%	$1,410,000	$875	$955
Glascock– Students	3	228	44%	$581,000	$1,950	$1,000
Gordon – All	12	3,451	94%	$2,850,000	$350	$785
Gordon - Students	5	706	91%	$952,000	$880	$785
Miller – All	39	15,031	92%	$10,600,000	$235	$785
Miller – Students	20	3,364	86%	$3,500,000	$555	$785

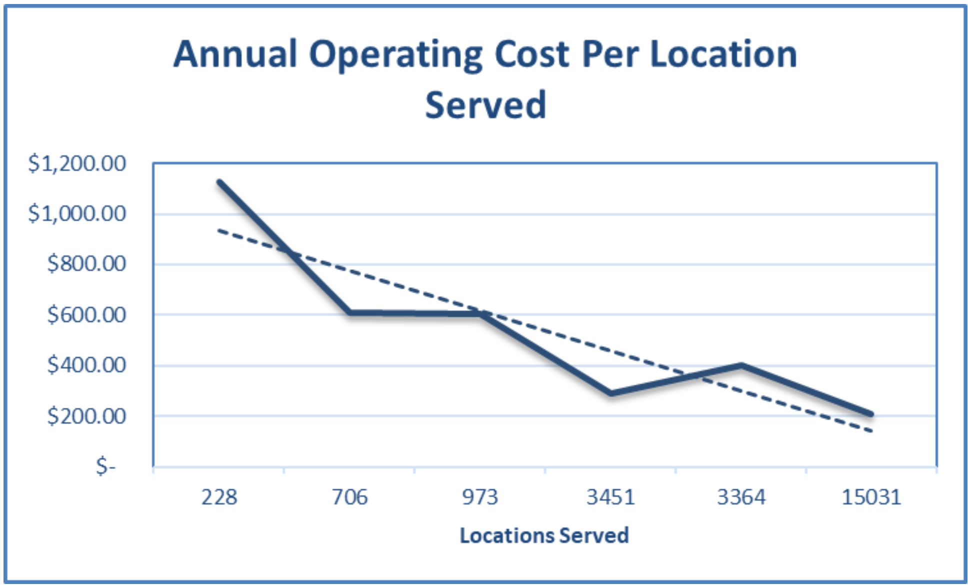
Note: The capital cost model assumes a penetration rate of 60%, which is feasible for an area with no other broadband internet option.

Operating costs also vary across the three counties based on the number of towers required and the number of locations or student locations predicted to be served by the analysis model, primarily the number of locations served. As shown in Table 2 and Figure 2, the more locations served, the lower the annual operating cost per location—the estimated cost per location served by our model for a student-only network is just over $1,100 in Glascock County to serve 228 students while in Gordon County it is just under $400. This range is due primarily to the sharing of the tower lease costs over different numbers of locations. In addition, the ability of the network to be sustained highly depends on the adoption rate and the number of locations in a particular area. As the adoption rate and number of locations decrease, the monthly operating costs per location increase.

Table 2: Estimated Fixed Wireless Operating Costs

Description	Number of Towers	Locations Served	Annual Cost	Annual Cost per Location Served
Glascock County – All	8	973	$588,185	$605
Glascock County – Students	3	228	$256,550	$1,125
Gordon County – All	39	15,031	$3,130,800	$208
Gordon County – Students	20	3,364	$1,343,100	$400
Miller County – All	12	3,451	$1,000,022	$290
Miller County – Students	5	706	$430,412	$610

Figure 2: Operating Cost per Location Served



1.2 What Could $1 Million Do?

When considering and explaining policy options for various levels of funding, it is useful to consider the potential impact from $1 million of capital funding. As shown in Table 1, $1 million can fund the capital costs of the distribution (non-premises) portion of a fixed wireless network to a significant percentage of unserved students in a relatively small rural county. In the case studies in Section 4, we find that 44 percent of currently unserved Glascock County students would be served as would 91 percent of unserved Gordon County students. The shortfall in Glascock is due to the distribution of the students, many of whom are far from tower locations and would require additional towers to serve, significantly decreasing the per-location impact of the funds.

A solution that maximizes the number of locations served by $1 million is to focus on larger, more densely populated counties and use the funds both for distribution equipment and premises CPE. To maximize the number of locations you would purchase as many CPE devices as possible because each CPE device represents another connected location. You would also minimize spending in other areas as much as possible.

One way to do this is to share the cost of the network core among adjacent or nearby counties. Core network costs are approximately $200,000 and have been included in the cost for each of the solutions. Another way is to focus on towers that serve the largest number of locations e. In the three counties we studied, the tower that covered the most people could reach more than 1,200 locations.

If a network is able to leverage an existing network core, approximately 1,000 locations could be connected for a $1 million capital expenditure.

Note, however, that ongoing operating costs must be considered as well. Operating costs for a network with one tower and 1,000 CPE are estimated to be close to $200,000 per year or approximately $200 per user per year.

Extrapolating the capital and operating cost analyses of the three counties to other individual counties is difficult, because costs depend on the specific distribution of unserved locations and the towers, among other factors. However, it would be possible to create a single statewide model using the methodologies used in this study for the three case study counties, and then re-examine the statewide model on a county-by-county basis. This approach may be instructive, in that it could also explore the synergies and economies of scale that would come from a unified or broader regional approach to core networking and operations.

2 Introduction to Fixed Wireless Network Connectivity

Broadband speeds in compliance with the FCC's definition (i.e., 25 Mbps download, 3 Mbps upload) are now more technically feasible using fixed wireless networks than in the past, owing to increased available spectrum and new wireless technologies.

Unallocated 2.5 GHz Educational Broadband Service (EBS) spectrum is scheduled to be available in many parts of Georgia to entities through a planned 2021 auction and, more immediately, to those who apply to the FCC for Special Temporary Authority during the COVID epidemic. The Citizens Broadband Radio Service (CBRS) spectrum can be obtained via registration with a dynamic spectrum assignment system, with DISH, Windstream, cable operators and some smaller providers having obtained priority CBRS licenses in an auction earlier this year. Other unlicensed spectrum is obtainable—the 900 MHz, 2.4 GHz, and 5 GHz bands are classified as unlicensed spectrum—but only the 5 GHz band has channel widths capable of delivering broadband speeds to a reasonable number of simultaneous users on a broadband network.

Current wireless internet service providers (WISP) typically do not build their networks to provide connection speeds to each premises that are comparable to cable broadband or fiber networks; they find they would not be able to attain a sustainable return on investment if they were to do so. Subsidies would be helpful to these firms to boost speeds, expand their networks, or both.

However, a fixed wireless connection may be a desirable solution if cable or fiber is not available or cost-effective. If adequate care in the design such that the network is not overloaded and uses spectrum capable of broadband speed, subscribers will enjoy a high-quality signal. Fixed wireless is particularly cost-effective in low-density rural areas where there are few homes and businesses per mile, and therefore the cost of building wired networks is often high. Many Georgia counties fall into this category.

2.1 Fixed Wireless Spectrum and Architecture

Fixed wireless networks typically use the following spectrum and associated frequencies:

Table 3: Fixed Wireless Spectrum

Spectrum	Frequency Band
TV White Space (TVWS)	500 MHz
Unlicensed	900 MHz, 2.4 GHz, and 5 GHz
Educational Broadband Service (EBS)	2.5 GHz
Citizens Broadband Radio Service (CBRS)	3.5 GHz

Of these bands, CBRS, EBS, and 5 GHz unlicensed technology have channel widths capable of delivering 25 Mbps down and 3 Mbps up—so those are the three primary bands we considered. If spectrum is available and obtainable, we believe the 2.5 GHz band is technically optimal for most of rural Georgia, due to the allowance for higher broadcast power and frequency characteristics.

Fixed wireless broadband is delivered via access point antennas mounted on towers (or rooftops) to a subscriber antenna. Subscriber antennas can be located indoors or outdoors depending on the distance to the access point and the amount of "clutter" between the subscriber antenna and the access point. Outdoor antennas may be attached to a building or a mast on the premises (Figure 3).

Figure 3: Sample Indoor and Outdoor Customer Antenna Configurations for a Fixed Wireless Network

2.1.1 Educational Broadband Service (EBS)

Educational Broadband Service (EBS) is the 2.5 GHz band that was formerly licensed for educational-only purposes but recently was reconsidered for broader use by the FCC. Originally only educational institutions, government, or nonprofit organizations could acquire licenses for educational purposes, but with provisions allowing license holders to lease their spectrum to commercial entities. However, in October 2019 the FCC authorized EBS licenses to be opened for commercial use.[3]

EBS was originally established as Instructional Television Fixed Service (ITFS). ITFS spectrum was granted to educational institutions to provide educational television over microwave. ITFS did not see large adoption, and the FCC eventually relaxed the rules and allowed the educational

[3] https://www.federalregister.gov/documents/2019/10/25/2019-22511/transforming-the-25-ghz-band

entities to sublease the spectrum to commercial entities with some provisions that require a minimum amount of educational content. To spur the growth of 5G and broadband in rural areas, the FCC has relaxed the rules even further, eliminating the educational requirements. Anyone is eligible to bid on spectrum in an upcoming auction.

A new band plan was recently developed with the intent of providing access to more entities to spur the growth of broadband and 5G initiatives, but with existing EBS licensees grandfathered into the new rules. Consideration was also given to the technology, including private 4G LTE networks, now being more affordable, and equipment more readily available.

Rural Tribal Nations were provided a priority window in 2020 to directly access unassigned EBS spectrum and with a service area comprised of Tribal Land (as defined in Section 27.1204(b)(3) of the FCC Order). Because the FCC opted *not* to grant a priority window for organizations seeking spectrum for educational use, educational entities, commercial companies, and any other entities will bid together in an upcoming FCC auction for the remaining EBS channel groups. This remaining spectrum is predicted to be auctioned in the first half of 2021.[4]

However, there is also an option for an entity to apply for Special Temporary Authority (STA) license for unallocated EBS spectrum during the COVID emergency. STAs requested for periods longer than 60 days require 30 days of public review which can delay deployment, so it is recommended to instead apply for a 60-day STA and then apply for extensions as needed. Typically, STAs cannot be longer than 180 days, but it may be possible to obtain longer periods due to COVID.[5]

The 2.5 GHz band ranges from 2496 MHz to 2690 MHz and the scheme for how this band is divided for licensing recently changed. Currently, the 2.5 GHz band is separated into eight channel groups named alphabetically (A through G) with EBS comprising channel groups A, B, C, D, and G (E, F, and H are allocated to the Broadband Radio Service (BRS)). Each of the A through G channel groups contained four channel bands of 5.5 MHz each, one channel band of 6 MHz, and interleaved guard channels. Channel group licenses were issued for a 35-mile radius around a fixed point, called a Geographic Service Area (GSA).[6]

The new 2.5 GHz band plan utilizes the same frequency range, but the grouping of spectrum and the process for licensing is different, removing interleaved channels and creating channel groups for different types of operation. The spectrum is now separated into three channel groups.

[4] https://www.ruralspectrumscanner.com/close-of-2-5-ghz-tribal-window-opens-door-for-auction-in-2021/

[5] STAs are temporary by nature, so this does not work as a permanent solution. If, in the upcoming auction, an entity obtains a license to spectrum in use by the STA, there will always be the possibility they could object to extensions. The FCC may also choose not to renew STAs in advance of the auction, a possibility that grows more likely as the epidemic recedes.

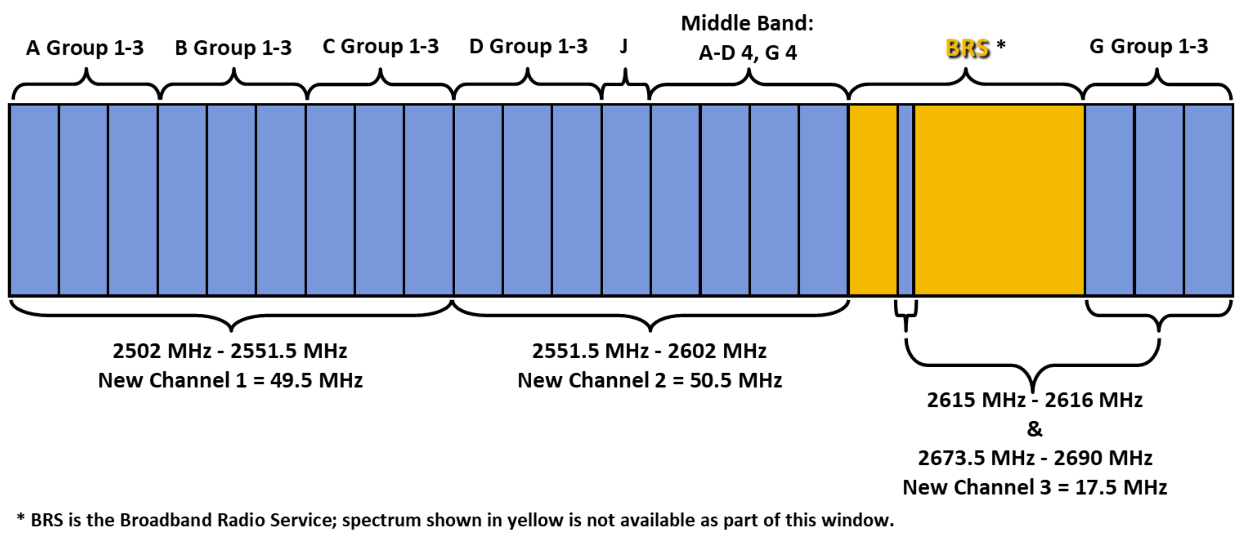
[6] https://www.nebsa.org/index.cfm/regulatory/ebs-spectrum-and-band-plan/

Channel 1 spans from 2502 MHz to 2551.5 MHz for a total of 49.5 MHz. Channel 2 spans from 2551.5 MHz to 2602 MHz for a total of 50.5 MHz. Channel 3 splits its spectrum into two group spans, one from 2615 MHZ to 2616 MHz and another from 2673.5 MHz to 2690 MHz, for a combined total of 17.5 MHz.

Under the new band plan, the FCC will auction spectrum rights for an entire county (the new GSA), as opposed to a 35-mile range. This will be an overlay license, that is, although the winning bidder will obtain a license to spectrum for an entire county, there will effectively be a spatial and spectrum cut-out for incumbent license holders who will retain their license for existing GSAs and spectrum channel groups under the current assignments.

Figure 4 displays the current (top) and new (bottom) band plans showing where the channel groups from the old band plan coincide with the new band plan.

Figure 4: Current and New Band Plan for EBS Spectrum[7]



As noted previously, BRS is another classification of spectrum within the 2.5 GHz band that exists in both the current and new band plans. BRS was previously assigned channel blocks F, E, and H for use for wireless cable, which will now coincide with New Channels 2 and Channel 3.

2.1.2 Citizens Broadband Radio Service (CBRS)

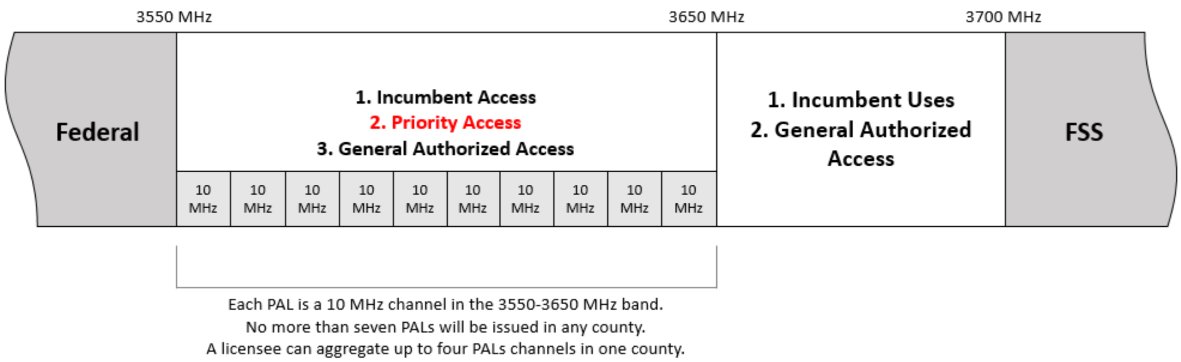
Citizens Broadband Radio Service (CBRS) is a band of spectrum in the 3.5 GHz range authorized for both licensed and unlicensed use by the FCC in 2015. Extending between 3550 MHz to 3700 MHz, CBRS provides spectrum to a broad audience of potential users, from government entities to small businesses. The FCC has divided access to the CBRS band into three tiers with different

[7] https://www.fcc.gov/25-ghz-band-plan

levels of interference protection (Figure 5). Access to the CBRS band is managed by a cloud-based dynamic frequency coordination system called a Spectrum Access System (SAS).

Access is divided into three tiers: Incumbent Access, Priority Access [Licenses] (PAL), and General Authorized Access (GAA) and is managed by the SAS. Each tier spans the ten 10 MHz channels; the remaining spectrum remains available for incumbent uses and is available for GAA.

Figure 5: CBRS Tiers (Source: FCC)



- Tier 1 – Incumbent Access grants access to the 3550 MHz to 3650 MHz band to existing license holders, primarily U.S. Navy radar systems and commercial fixed satellite stations.[8] Users in Tier 1 have the highest priority for their licensed frequencies and have a GSA of 35 miles. The SAS continuously monitors the channels and will prioritize a Tier 1 transmission over a Tier 2 or Tier 3 transmission on the Tier 1 incumbent's frequency.[9]
- Tier 2 – Priority Access channels were auctioned off as through competitive bidding. PAL licenses were granted for 10 MHz channels in the 3550 to 3650 MHz band in individual counties (as opposed to the 35-mile GSA that incumbents have) and must be renewed every 10 years. A total of 70 MHz, and thus seven PALs, are available in each county; however, no single licensee may operate more than 40 MHz (four PALs) in a single county. The SAS will prioritize a Tier 2 transmission over a Tier 3 transmission on the Tier 2 frequency licensed to that provider.
- Tier 3 – General Authorized Access (GAA) allows open, unlicensed access to the full CBRS band. This spectrum is available for use by anyone using certified equipment and who has

[8] "What is CBRS?" *Fierce Wireless*, June 23, 2020, https://www.fiercewireless.com/private-wireless/what-cbrs#:~:text=The%20incumbent%20tier%20is%20reserved,as%20commercial%20fixed%20satellite%20stations. In Georgia, Navy radar systems may potentially be activated from time to time at Kings Bay Naval Submarine Base inland of the eastern coast, and the Naval Reserve training center on the western border with Alabama.
[9] There also exists grandfathered users who had already been using this band before CBRS was created, but these users were supposed to have migrated to GAA in 2020.

registered with the SAS. However, Tier 3 users have the lowest priority of the three Tiers and are granted access on a first-come, first-served basis.

As noted, the SAS coordinates use of the band, ensuring Tier 2 and Tier 3 users do not interfere with incumbents. The SAS is responsible for databasing spectrum users and prioritizing and granting access requests based on users' access tiers and the spectrum load of a given area. As CBRS usage grows, the SAS will be responsible for efficiently managing the user load to ensure access rules are enforced and interference is minimized.

In late January, the FCC authorized full commercial deployment of OnGo[10] service in the 3.5 GHz CBRS band. This allows OnGo-certified antennas and devices to use the band as General Authorized Access (GAA) by unlicensed users. Currently GAA users have access to the full 150 MHz in the CBRS band, but as PAL holders build out their networks, the SAS will give PAL licensees priority on the spectrum they have been allocated. In areas where all of the PAL holders make use of their channels, GAA users will only be able to share 80 MHz of the band.

The SAS monitors the spectrum through the internet and provides a temporary license to that spectrum in its area to a user. This temporary license must be renewed at regular intervals. The SAS checks its national database and verifies the user's access priority (tier). In an extremely congested situation where spectrum channels may not be available, the SAS will reduce or revoke access to existing users to accommodate a new request from a higher tier user, with the Tier 1 users having the highest priority. Because the CBRS band is in the early days of use, there is no public record of congestion or spectrum availability, but anecdotal reports in urban and rural areas are reporting the ability to access GAA spectrum.

2.1.3 Other Unlicensed Spectrum

Unlicensed spectrum in the 900 MHz, 2.4 GHz, and 5 GHz bands is available for open use by any entity. Of these unlicensed bands, only 5 GHz has channel widths capable of delivering 25 Mbps down and 3 Mbps up to a reasonable number of simultaneous users on a broadband network. Despite its bandwidth capabilities, the 5 GHz band is limited in power and thus provides service over a much smaller coverage area than the CBRS and EBS bands. It can be effective at increasing capacity at shorter distances from an antenna but less so for longer-range coverage.

Unlicensed channel users share the spectrum without a frequency coordination system such as the CBRS' SAS. Wi-Fi devices have been using 5 GHz frequencies for some time now and mobile carriers recently began aggregating unlicensed 5 GHz channels with their licensed spectrum which creates a larger "pipe" enhancing performance. 5 GHz spectrum devices use a listen-before-talk (LBT) mechanism to detect channel availability.

[10] OnGo is a brand name that represents the networks and devices in the CBRS band.

TV White Space (TVWS) refers to recently vacated, unused, and unlicensed television frequencies. TVWS has much better non-line-of-sight transmission qualities than other bands; but, due to narrower channel bandwidth, TVWS does NOT reliably deliver 25 Mbps downstream on a large-scale network. Therefore, its use should only be considered when other connectivity or spectrum is not available or feasible. In addition, because white space technology is not widely deployed, compatible equipment is far more expensive than other wireless equipment.

2.2 Fixed Wireless Network Characteristics and Considerations

Most fixed wireless network solutions require the antenna at the subscriber location to be in or near the line-of-sight of the base station antenna. Line-of-sight can be especially challenging in mountainous regions where the terrain and trees and other plants ("clutter") can obstruct. It is also a problem in areas with dense vegetation or multiple tall buildings.

As a result, WISPs often need to lease space at or near the top of radio towers; even then, some customers may be unreachable without the use of additional repeaters. Climate conditions like rain and fog can also impact the quality of service.

When designing and deploying a fixed wireless network, there is a tradeoff in spectrum between capacity and the ability to penetrate obstructions such as clutter and terrain. Higher frequencies have wider channels and are therefore able to provide more capacity. However, higher frequencies are those most easily blocked by obstructions.

Wireless equipment vendors offer a variety of point-to-multipoint and point-to-point solutions. Point-to-multipoint is more suited to a residential or small business network while large or medium-sized business connections and backbone connectivity between wireless sites would use a point-to-point solution. Point-to-point connectivity enables dedicated bandwidth needed for these applications, but at a higher cost per user than a point-to-multipoint design.

2.3 Fixed Wireless Network Deployment Cost Factors

Fixed wireless network deployment costs depend on a range of factors including the following:

- **Wireless equipment used.** Spectrum selected, required capacity, and required coverage range for a solution defines what equipment will be required. Access point (tower) equipment costs for EBS, CBRS and 5 GHz are relatively similar, approximately $3,500 to $4,000 per installation. Using 10 MHz of bandwidth, an access point can potentially support up to 64 locations for CBRS, EBS, or 5 GHz unlicensed spectrum.

- **Backhaul connection**. This is the connection between two towers via a point-to-point wireless microwave link or a fiber connection between the wireless equipment on the tower and core network. If a wireless backhaul connection is required, equipment is estimated to cost close to $15,000. Ongoing, operating expenses for this equipment includes maintenance and replacement fees. Fiber connection costs vary as to whether or not fiber is close to the access point and, if fiber will need to be built to the access point, the length of fiber installed. The cost to build fiber ranges from $25,000 to $150,000 per mile, depending on installation method, terrain, and other factors. If fiber is available, there may be an ongoing lease cost to use the fiber to connect to the core.

- **Future capacity and lifespan of investment.** Wireless equipment generally requires replacement every five to ten years—exposure to the elements causes deterioration and technology continues to advance at a rapid pace, making older equipment obsolete.
- **Placement on towers.** Fixed wireless networks work best when the line of sight between tower and subscriber antennas is optimized. Therefore, space near the top of a tower is most desirable, and therefore potentially more expensive, to minimize obstruction and reach the maximum number of premises. Cluttered and hilly areas will require higher antenna placement and potentially the need for additional towers.

3 Statewide Analysis

3.1 Spectrum and Capacity

For most rural counties in Georgia, EBS is the most desirable spectrum option. It is cost-effective and high-performance because of the propagation characteristics and spectrum channel sizes. However, EBS availability may be challenging in many parts of the State. As discussed in more detail in Section 3.1.1, 65 percent of Georgia counties have some EBS spectrum unallocated and 50 percent of counties have a full channel group available (unallocated), providing adequate spectrum to deliver broadband-speed service. However, as discussed in Section 2, the spectrum is not available "off the shelf," and new entrants must obtain spectrum through a temporary STA or compete in the upcoming auction.

CBRS is considered as a viable option, but because much of the CBRS PAL spectrum in Georgia is already licensed to mobile wireless carriers, cable companies, telecommunications companies, and other broadband companies, CTC's analysis considers the use of Tier 3 GAA spectrum, that is readily available to new entrants.

Operators in each Georgia county will have access to the CBRS GAA spectrum, as available and coordinated by the SAS. GAA frequencies can be used as the primary spectrum where EBS spectrum cannot be readily obtained or to augment EBS channels where additional capacity is needed. Although CBRS is more susceptible to clutter and terrain relative to EBS, and CBRS frequencies are limited to lower-power use than EBS, CTC ideally recommends targeted augmentation of EBS with CBRS GAA spectrum to increase capacity in areas where EBS alone could not provide broadband service for all possible locations.

Unlicensed 5 GHz spectrum is, by definition, available in all counties. However, it has inferior propagation characteristics relative to both EBS and CBRS, so it is best suited to augment service where capacity demand is so great that EBS and CBRS together cannot serve all possible locations.

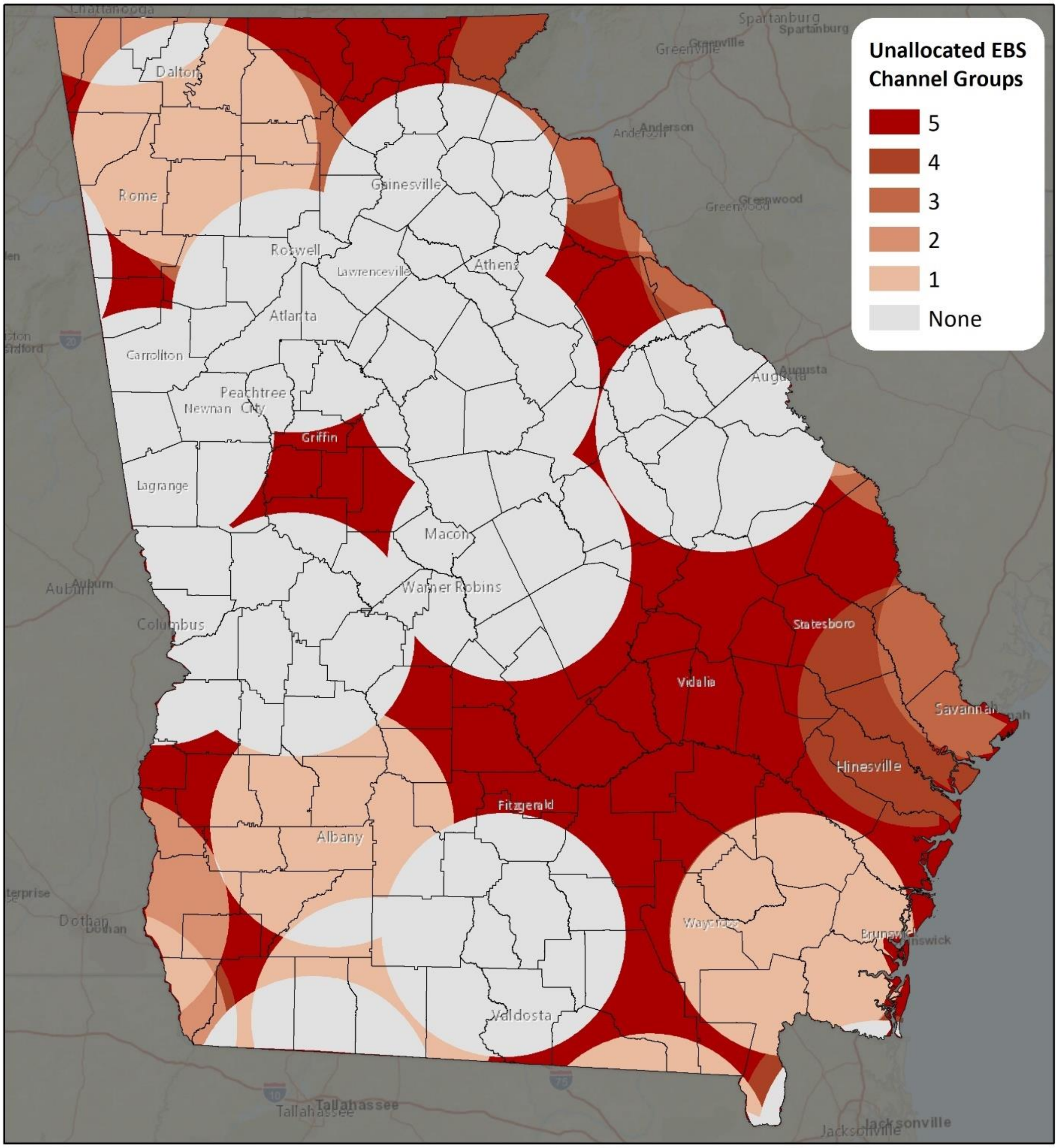
Each block of FCC-controlled spectrum comes with its own set of technical characteristics, licensing processes, and eligible uses. Although this process seems somewhat cumbersome, it does provide a clear path for designing a viable solution with the available resources.

3.1.1 EBS in Georgia

3.1.1.1 EBS Spectrum Availability

Much of the EBS spectrum in Georgia is already licensed under the current band plan, but some spectrum is unallocated in most parts of the State. Figure 6 illustrates the number of channel groups out of five that are unallocated in any given location.

Figure 6: Unallocated EBS Channel Groups in Georgia



As the map illustrates, less EBS spectrum is currently assigned in southern Georgia. There is a large pocket in southern Georgia where no EBS spectrum has been licensed at all. An entity could potentially bid on this area in the upcoming auction with less concern about losing area and spectrum to "cut-outs" from incumbent providers. In other areas of the State, where incumbent users occupy most of the spectrum, there may only be limited channel groups available to a new entrant.

T-Mobile is the main EBS spectrum holder in Georgia, having acquired most of its access through their merger with Sprint (and Sprint's lease of EBS capacity from educational license holders) T-Mobile has stated its intention to use this band to deploy 5G in more areas.[11]

In counties where incumbents hold licenses to EBS channel groups, potential bidders for the unassigned channel groups cannot interfere with an incumbent's spectrum. Bidders will need to assess whether the unassigned areas of the county (under the current coverage areas) are large enough to justify a bid. However, there are many counties in Georgia which have at least one channel group available throughout the entire county, and thus have an opportunity to acquire spectrum at auction.

Due to the rules around interference with incumbents when obtaining an EBS overlay license, there are several variables to consider when looking at EBS use in each county. If all EBS channel groups from the current band plan are available in a county, an entrant could bid for any of the three new channels to establish a broadband network. If channel groups have been licensed by an incumbent within a county, this does not necessarily mean one could not acquire an EBS license in the new auction, but consideration must be made as to how much a channel group could cover without interfering with an incumbent's service and whether it is worth the cost.

CTC's detailed analysis found that 65 percent of Georgia counties have some unassigned EBS spectrum, with a significant concentration in southeastern Georgia, as noted above. Thirty-seven counties have at least one channel group available and 43 counties have no channel groups available countywide but have a large area of the county unallocated to existing licenses. EBS bids in these counties may still be viable but usage will need to respect the boundaries of the incumbent licenses. Together these two categories account for 50 percent of the State.

Twenty-three counties only have a small area unassigned in existing GSAs; 56 counties have no unassigned channel groups and thus cannot be served using EBS spectrum.

Table 4 lists the counties based on how many channel groups are unassigned within the county, and how large of a space in those counties is not covered by existing GSAs.

[11] https://www.t-mobile.com/news/network/fast-mid-band-5g-new-cities-towns-location-coverage

Table 4: Number of Unassigned EBS Channel Groups in Each County

Channel Group Assignments	Counties
No channel groups assigned	Candler, Jeff Davis, Lamar, Montgomery Rabun, Telfair, Toombs, Towns, Treutlen, Union, Wheeler, Wilcox
At least one channel group unassigned	Appling, Bacon, Brantley, Bryan, Bulloch, Chatham, Chattooga, Clay, Crisp, Dade, Dougherty, Effingham, Evans, Fannin, Gilmer, Glynn, Gordon, Lee, Liberty, Long, McIntosh, Pickens, Pierce, Screven, Seminole, Tattnall, Wayne
No channel groups unassigned countywide but some available in a substantial part of the county	Atkinson, Bartow, Ben Hill, Butts, Catoosa, Cherokee, Clinch, Coffee, Dawson, Decatur, Dodge, Dooly, Early, Echols, Elbert, Emanuel, Floyd, Haralson, Hart, Jenkins, Johnson, Laurens, Lincoln, Lumpkin, Miller, Monroe, Murray, Pike, Polk, Pulaski, Quitman, Randolph, Spalding, Taliaferro, Terrell, Turner, Upson, Walker, Ware, White, Whitfield, Wilkes, Worth
No channel groups unassigned countywide but some available in a small part of the county	Baker, Brooks, Burke, Calhoun, Camden, Carroll, Charlton, Colquitt, Forsyth, Grady, Habersham, Hancock, Houston, Irwin, Meriwether, Mitchell, Paulding, Stephens, Stewart, Sumter, Thomas, Walton, Washington
No channel groups and no space available	Baldwin, Banks, Berrien, Bibb, Bleckley, Chattahoochee, Clarke, Clayton, Cobb, Columbia, Cook, Coweta, DeKalb, Douglas, Fayette, Franklin, Fulton, Glascock, Greene, Gwinnett, Hall, Harris, Heard, Jackson, Jasper, Jefferson, Jones, Lanier, Lowndes, Macon, Madison, Marion, McDuffie, Morgan, Muscogee, Newton, Oconee, Oglethorpe, Peach, Putnam, Richmond, Rockdale, Schley, Talbot, Taylor, Tift, Troup, Twiggs, Warren, Webster, Wilkinson

3.1.1.2 EBS License Holders

Georgia currently has 66 active EBS licenses, with 60 held by educational organizations such as school districts and educational associations and the rest held by small wireless operators. Of these 66 licenses, there are 60 subleases to other companies to use the licensed spectrum. Fortynine of the leases are held by entities related to T-Mobile (Sprint, Clearwire Spectrum Holdings, Clearwire Spectrum Holdings II, Clearwire Spectrum Holdings III, Fixed Wireless Holdings, WBSY Licensing, NSAC, and TDI Acquisition Sub).[12] We anticipate T-Mobile will primarily use the spectrum for 5G mobile and in-home deployments.[13]

The remaining 10 leases are held by Paladin Wireless, Gallatin Wireless Internet, Spectrum Holdings, UW-Charing, SoniqWave Networks, and Antilles Wireless. These companies may be seeking to expand their wireless capabilities in Georgia or may be sub-leasing their spectrum to other companies.

3.1.2 CBRS in Georgia

3.1.2.1 CBRS GAA Spectrum Use

CBRS GAA spectrum is the only available CBRS tier option for new entrants in the State. Any operator may use up to 80 MHz of CBRS Tier 3 GAA spectrum, sharing the allocation with other providers and entities that may be in proximity, as well as incumbent users, such as the U.S. Navy. This will be the preferred choice for an emerging provider and will literally be available off-the-shelf, requiring only registration with the SAS.

The exact amount of spectrum available at a particular location and a particular time will depend on the current and future local use. There is not yet a public record of GAA spectrum availability; there is no public access to the SAS database. We estimate that, on average, 40 MHz of spectrum will be available in most rural areas, enabling the spectrum to be used to complement an EBS-centered wireless deployment (a minimum of 10 MHz in bandwidth is needed).

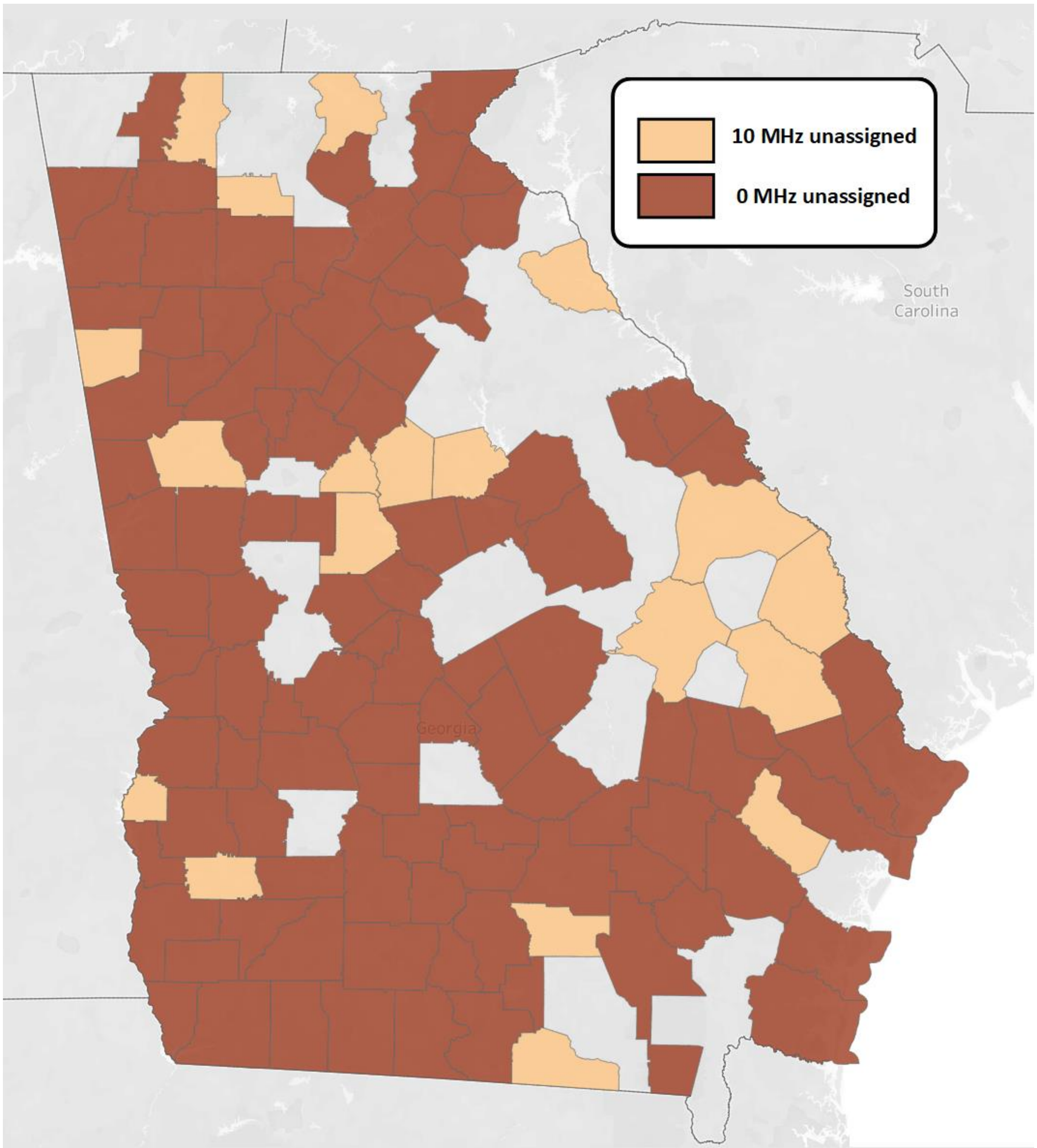
3.1.2.2 CBRS Priority Access License (PAL) Spectrum Availability

The auction for the Tier 2 Priority Access License (PAL) CBRS spectrum has already taken place and is therefore not an option for providers not already awarded a license. We analyzed the PAL awards in order to identify entities who could use this spectrum in particular counties to provide service, and also to identify areas where PAL spectrum was not licensed—and where therefore more spectrum would be available for GAA users. Figure 7 illustrates that all PAL licenses were licensed in most counties in the state. In total, 103 of Georgia's 159 counties (over 64 percent) have PALs issued for all 70 MHz of the spectrum available per county. Factoring in the 19 counties who have 60 MHz of the potential 70 MHz CBRS spectrum licensed, meaning there is only one 10 MHz band of CBRS PAL spectrum licensed, 77 percent of counties in Georgia have most, if not all, CBRS PAL bands already licensed. .

[12] https://www.sec.gov/Archives/edgar/data/101830/000010183015000012/sprintcorp10-kexhibit212014.htm
[13] https://www.t-mobile.com/news/network/new-t-mobile-fixed-broadband-alternative

Figure 7 shows counties where a significant percentage of the PAL spectrum was not licensed. In these counties, demand for the spectrum was light, making more spectrum available for GAA users (and likely less prone to interference), and also likely indicating relatively little demand for wireless spectrum in general.

Figure 7: Tier 2 Priority Access License (PAL) for CBRS Spectrum



There is a larger patch of contiguous counties in eastern Georgia with 30 MHz – 60 MHz of PAL spectrum unassigned as shown in Figure 8.

Figure 8: Contiguous Counties with 30 MHz – 60 MHz PAL Spectrum Unassigned

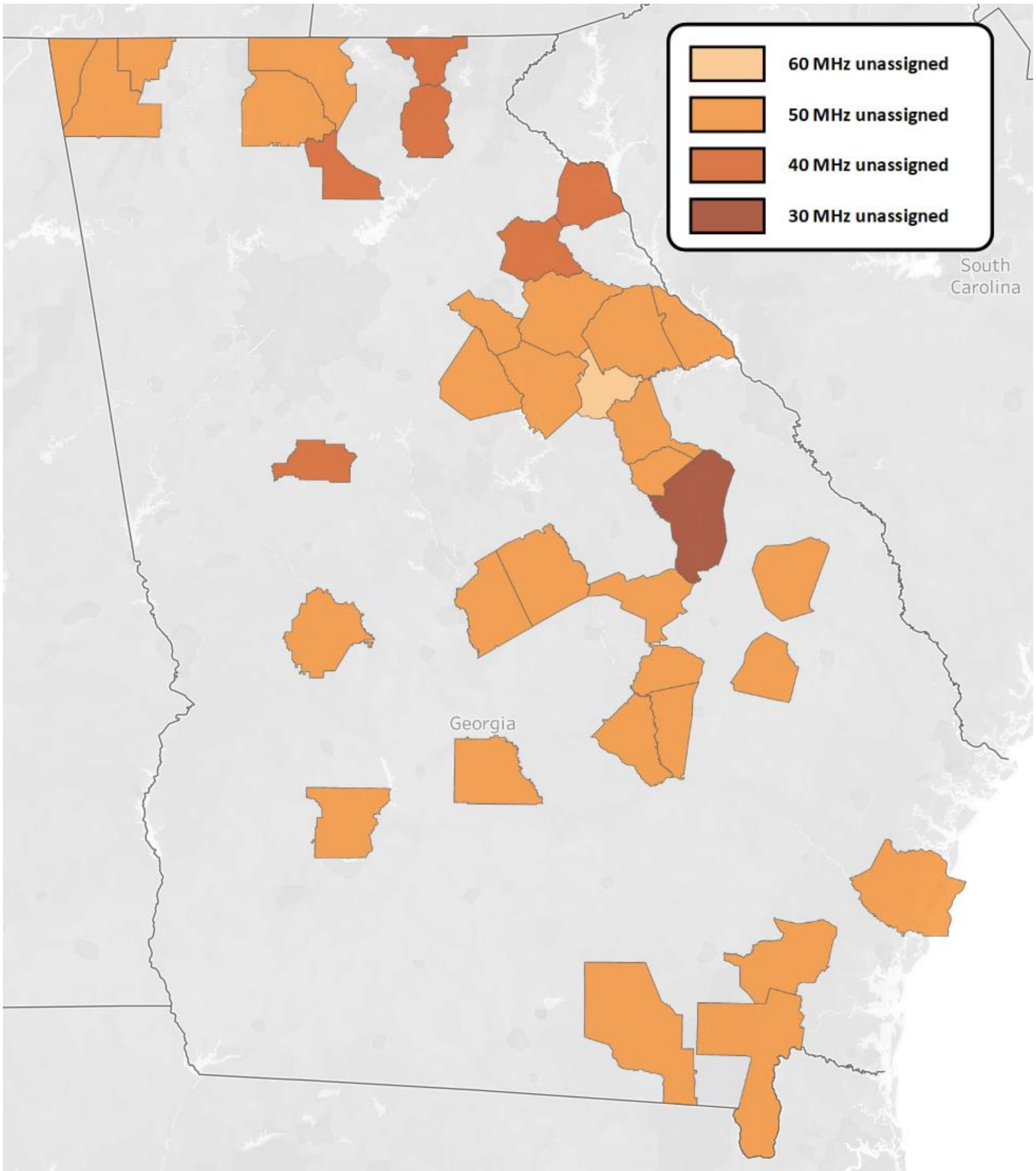


Table 5 below lists the counties by their available CBRS PAL spectrum.

Table 5 Unassigned PAL Spectrum by County

PAL Spectrum Unassigned	Counties
60 MHz	Taliaferro
50 MHz	Lincoln, Wilkes, Oglethorpe, Oconee, Greene, Morgan, Fannin, Gilmer, Catoosa, Walker, Dade, Jenkins, Johnson, Wilkinson, Twiggs, Taylor, Candler, Treutlen, Montgomery, Wheeler, Wilcox, Lee, McIntosh, Brantley, Charlton, Clinch
40 MHz	Hart, Madison, Jefferson, Towns, White, Dawson, Spalding
30 MHz	Jefferson
20 MHz	Upson
10 MHz	Murray, Pickens, Union, Haralson, Elbert, Coweta, Butts, Jasper, Putnam, Monroe, Quitman, Calhoun, Echols, Atkinson, Long, Emanuel, Burke, Screven, Bulloch
0 MHz	Whitfield, Rabun, Chattooga, Floyd, Gordon, Bartow, Polk, Lumpkin, Habersham, Stephens, Cherokee, Forsyth, Hall, Banks, Franklin, Paulding, Cobb, Fulton, Carroll, Douglas, Heard, Gwinnett, Barrow, Jackson, DeKalb, Clarke, Fayette, Clayton, Henry, Rockdale, Newton, Walton, Troupe, Meriwether, Pike, Lamar, Jones, Baldwin, Hancock, McDuffie, Columbia, Richmond, Washington, Harris, Talbot, Muscogee, Crawford, Bibb, Peach, Houston, Chattahoochee, Marion, Schley, Macon, Stewart, Webster, Sumter, Dooly, Pulaski, Bleckley, Laurens, Dodge, Crisp, Randolph, Terrell, Clay, Early, Toombs, Tattnall, Evans, Liberty, Bryan, Effingham, Chatham, Telfair, Jeff Davis, Dougherty, Worth, Turner, Tift, Irwin, Ben Hill, Coffee, Bacon, Appling, Wayne, Pierce, Ware, Glynn, Camden, Miller, Baker, Mitchell, Colquitt, Cook, Berrien, Lanier, Seminole, Decatur, Grady, Thomas, Brooks, Lowndes

3.1.2.3 CBRS License Holders

Fourteen providers have been awarded PALs in Georgia, acquiring a total of 919 licenses (Table 6, below). Although a company may be licensed to use the PAL for a band of spectrum in a specific county, it may be possible to sub-lease spectrum from the license holder if a provider who did not license a PAL believes it would benefit from the capacity guarantee of a PAL license. These providers may also be in a position to address the broadband needs of currently unserved individuals in the counties.

DISH holds 37 percent of PAL licenses in Georgia, having obtained 340 licenses in all 159 counties. Windstream holds 25 percent of the PAL licenses, with ownership in 67 counties. The other 12 PAL holders each obtained licenses for a small patch of counties. Maps of their ownership can be found in Appendix A.

DISH has plans to deploy a 5G network to cover 70 percent of the U.S. population[14] and their CBRS PAL licenses could be used to further that goal. Windstream intends to expand fixed wireless coverage. Comcast, who holds PALs around Atlanta and its surrounding counties, can utilize CBRS spectrum to enhance their mobile hot spot business and/or augment their mobile virtual network operator (wireless resale) operations, where they currently provide mobile service to customers utilizing Verizon's spectrum.[15] Cable operator Mediacom intends to use its CBRS spectrum for fixed wireless.[16]

Table 6: CBRS License Holders

License Holder	Quantity of Licenses Owned
DISH	340
Windstream Services LLC	233
Comcast	87
Mediacom LLC	73
Alabama Power Company	51
AirFi, Inc.	39
Blue Ridge Wireless	31
Cox Communications, Inc	28
Verizon Wireless Network Procurement LP	19
Highland Opportunities, LLC	6
BalsamWest FiberNET, LLC	5
Spectrum Wireless Holdings, LLC	4
City of Donalsonville	2
SAL Spectrum, LLC	1

3.2 5 GHz Unlicensed in Georgia

As noted, the 5 GHz unlicensed band share the spectrum without a frequency coordination system such as an SAS. Therefore, there is no mechanism to protect and evenly allocate spectrum

[14] https://www.lightreading.com/mobile/5g/qanda-with-dishs-charlie-ergen-about-his-new-5g-strategy/a/d-id/753061

[15] https://www.fiercewireless.com/wireless/comcast-ceo-outlines-3-tier-mobile-strategy

[16] https://www.streetinsider.com/Business+Wire/Mediacom+Communications+Reports+Combined+Results+for+Third+Quarter+2020/17558977.html

among potential users. As with CBRS GAA, there is no way to determine specifically where this spectrum is being used and who is using it without directly measuring use in a given area. There is also no way to predict whether and how use will change in the future. However, given the width of the band and the likelihood it is not heavily used in rural areas, we believe it could effectively augment EBS and CBRS spectrum, but in closer proximity to towers than those bands.

3.3 Costs for Fixed Wireless Deployment in the State

It is not a trivial task to extrapolate the capital and operating cost analyses of the three counties to the other counties in the State. There are many cost dependencies including what spectrum is available, how challenging the terrain is, how many locations are unserved[17], how many existing towers there are, and the location of those towers.

For example, a county may have many unserved locations but just a few towers available. Or a county may have just a few unserved locations but the there are no towers close to those locations. A county in a mountainous/hilly region may require more towers to provide service to the unserved areas. Regarding spectrum, if EBS spectrum is available, fewer towers are needed (as long as they are in the vicinity of the unserved locations) since EBS covers a larger area than CBRS or 5 GHz, but there will be additional annual costs to license or lease the spectrum.

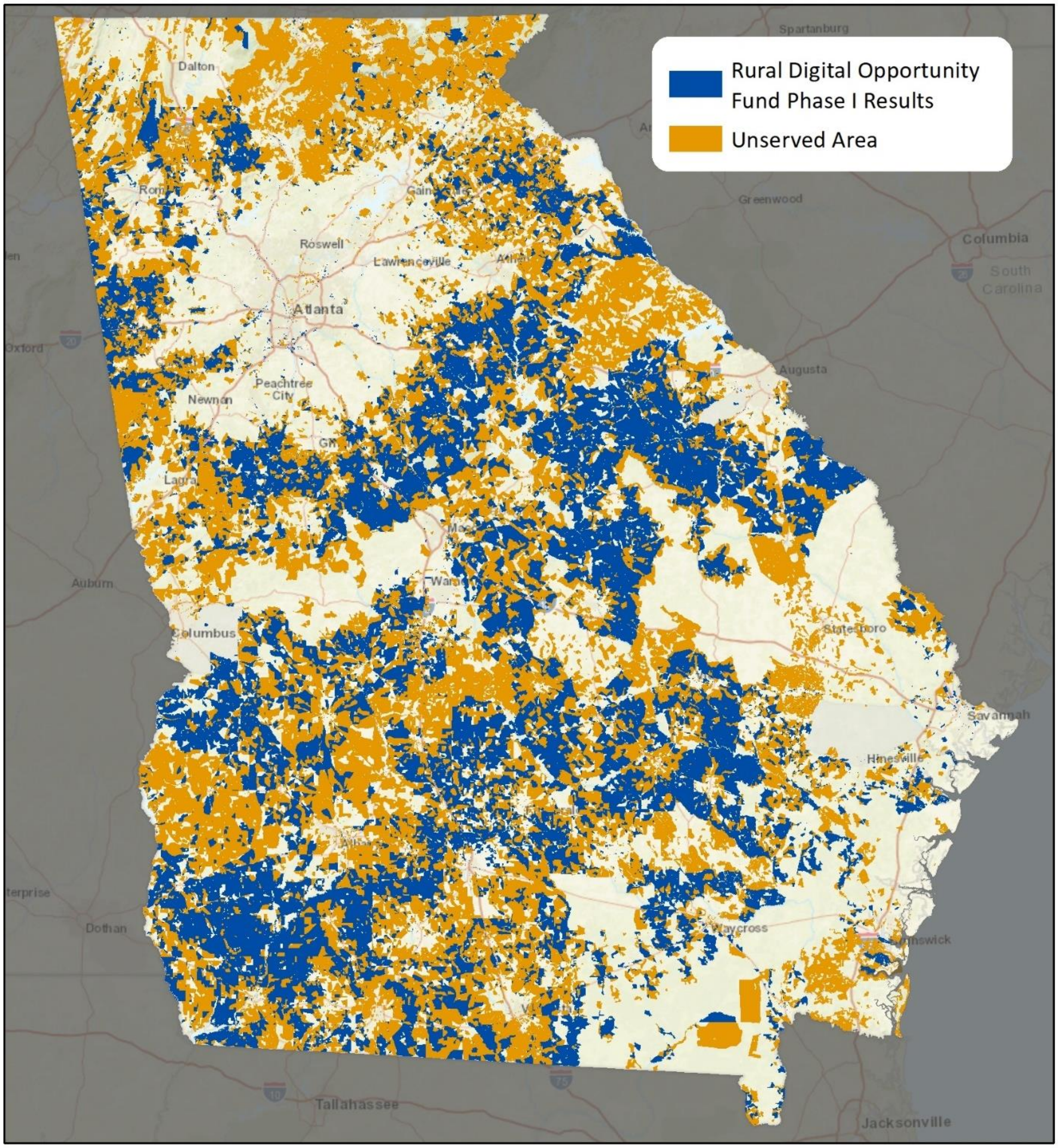
However, based on our analysis of the three case study counties, the capital costs for building a fixed wireless network that provides broadband to a large percentage of the unserved population of a medium-sized county such as Gordon, assuming a take-rate of 60 percent, will be in the $10 million range for all unserved locations and $3 million to 5 million for unserved student locations. In smaller Miller and Glascock Counties, capital costs will be in the $1.5 million to $3 million range to all unserved locations and $600,000 to $1 million for unserved student locations. Note also that operating costs per location are greater for the counties with a lower number of unserved locations because the tower-to-served-location ratio typically is higher.

3.4 Impact of Rural Digital Opportunity Fund (RDOF) Results for Georgia

The Rural Digital Opportunity Fund (RDOF) is a $20.4 billion initiative by the FCC to help promote broadband internet in rural and underserved areas. As we explain below, if RDOF auction winners deploy quickly within the State, many of the State's unserved locations will become served—but much of the State will remain unserved (Figure 9).

[17] There is some correlation between lower population in a county and number of unserved. The population of counties in Georgia ranges from around 1,600 in Taliaferro County to more than 1 million in Fulton County. Two of the counties in our study—Glascock and Miller—are sparsely populated with 3,000 and 5,700 residents, respectively. Gordon County, with approximately 57,000 residents, represents a medium-sized county, but has some challenging terrain.

Figure 9: RDOF Awards and Unserved Areas in Georgia



Respondents were requested to bid in a reverse auction on census block groups (a combination of census blocks) and will have ten years to bring voice and broadband services to the census block groups they won, while meeting milestones and providing a target performance and latency.

The Phase I Auction was held October 29 to November 25, 2020 and targeted census block groups that were completely unserved. Phase II will be held for census blog groups that are partially served, as well as any census block groups that were not funded in Phase I.

The RDOF auction provides a ten-year plan for fiber buildouts in many unserved areas of Georgia, particularly southern Georgia which is largely unserved. 179,455 unserved locations in Georgia received bids with a total of $326,454,112 being dispersed to broadband initiatives over the ten years.[18] The largest bidders won locations across vast portions of the State while smaller bidders focused on specific locations.

Fifteen bidders won RDOF funding in Georgia. The winners with the most locations are Rural Electric Cooperative Consortium (RECC) with 60,184, Windstream with 48,208, Charter (using the subsidiary CCO Holdings) with 23,854, and SpaceX with 22,961. Each of these companies is promising low latency but their deployments use a range of technologies. Figure 10 shows the areas each company won in the RDOF auction.

[18] https://themonticellonews.com/broadband-is-coming-to-rural-georgia-p17153-1.htm

Figure 10: RDOF Awards by Company and Location

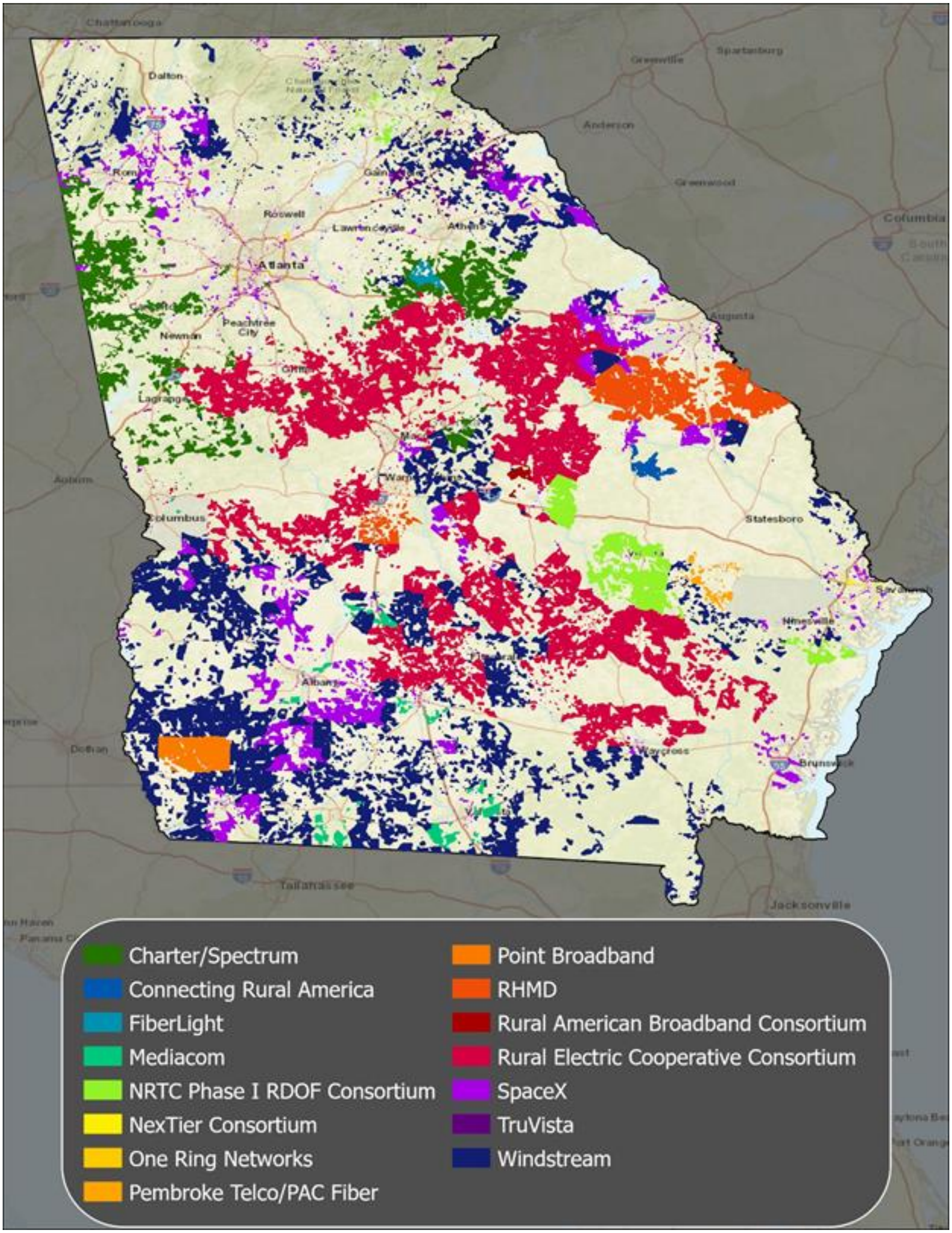


Table 7 lists the providers that won RDOF census group blocks in Georgia, the number of locations they will serve, the technology they will use, and the level of performance they committed to provide. The bidders must commit to a Baseline level at least 50/5 Mbps, an Above Baseline level of at least 100/20 Mbps, or a Gigabit level at least 1 Gbps/500 Mbps. All providers must provide low latency performance.

Table 7: RDOF Winners' Promised Technology and Performance

Provider	Number of Locations	Technology	Performance
Rural Electric Cooperative Consortium	60,184	Fiber	Gigabit
Windstream	48,208	Fiber	Gigabit
Charter/CCO Holdings	23,854	Fiber, Cable	Gigabit
SpaceX	22,961	LEO Satellite	Above Baseline
NRTC Phase I RDOF Consortium	7,420	Fiber	Gigabit
RHMD	6,943	Fiber	Gigabit
TruVista	2,778	Fiber	Gigabit
Point Broadband	2,000	Fiber	Gigabit
Mediacom Communications Corporation	1,824	Cable, Fixed Wireless	Above Baseline
One Ring Networks	810	Fixed Wireless	Baseline
FiberLight	687	Fixed Wireless	Above Baseline
Pembroke Telephone Company.	601	Fiber	Gigabit
Connecting Rural America	555	Fiber	Gigabit
Rural American Broadband Consortium	349	Fiber	Gigabit
NexTier Consortium	281	Fiber	Gigabit

RECC proposes to build gigabit fiber and won much of central Georgia, from Putnam County to Ware County. Windstream also proposes gigabit fiber, predominantly in the southwest, while also winning small blocks throughout the rest of the State. Charter proposes gigabit service using fiber and cable in the northern half of the State, to the east and west of Atlanta—reaching the western border.

SpaceX is promising to deploy low-earth orbit satellite service that provides "above baseline" performance- this means it must reach at least 100/20 Mbps. SpaceX's RDOF awards are mainly in southwest, northwest, and northeast Georgia.

Overall, ten of the winning companies propose to deploy fiber. Only Charter and Mediacom Communications state the possibility of deploying cable, while Mediacom Communications also state the possibility of using fixed wireless. One Ring Networks, and FiberLight deploy only fixed wireless, and SpaceX is the only company offering low Earth orbit satellite.

Although the RDOF winners are promising to deploy broadband in many currently unserved parts of Georgia, much like Glascock County, Gordon County, and Miller County (see case studies in Section 4), many counties or parts of counties may not have received awards.

Furthermore, RDOF awardees have years until they are required to build their networks, so unserved people in RDOF-awarded areas may have a long wait until they receive service. Given that wireless can be built relatively quickly, fixed wireless networks may provide a needed stopgap.

Finally, many RDOF awardees placed extremely low bids for the areas they won—in many cases, too low to build and operate a sustainable network.[19] Therefore, many awardees may default on their obligations, or may need to scale back their commitments in service area or performance. Again, a fixed wireless network may fill a gap.

Augmented EBS spectrum may still be vital to providing broadband to unserved locations throughout the State.

[19] Ziggy Rivkin-Fish, "FCC's Rural Digital Opportunity Fund Auction Was Supposed to Significantly Reduce America's Rural Broadband Gap," Benton Institute for Broadband & Society, Dec. 21, 2020, https://www.benton.org/blog/fccs-rural-digital-opportunity-fund-auction-was-supposed-significantly-reduce-americas-rural.

4 Fixed Wireless Design and Cost Estimate Case Studies for Three Counties

4.1 Case Study Summary

CTC conducted an analysis to determine how the unserved locations in three counties chosen by the State could be served via fixed wireless technology using available spectrum and considering how factors such as density of unserved locations and terrain would affect costs. The three counties chosen to conduct the analysis were Gordon, Glascock, and Miller.

Glascock and Miller counties were chosen due to their need for broadband service to students and their rurality; Gordon County was chosen to analyze a more populous county and one with somewhat challenging terrain. The table below shows a breakdown of population ranges in Georgia counties. Of note, the majority of Georgia's counties have relatively small populations.

Table 8: Population Ranges of Counties in Georgia

Population Type	Range	Number of Counties	Sample Counties
Very High	750,000 to 1,000,000+	4	Fulton, Gwinnett, Cobb, DeKalb
High	100,001 to 288,000[20]	20	Whitfield, Coweta, Hall, Chatham
Mid	25,001 to 100,000	49	Fannin, Gordon, Colquitt, Floyd
Low	1,611 to 25,000	86	Taliaferro (lowest), Glascock, Miller, Putnam, Grady

4.1.1 Spectrum and Percent of Unserved Locations Serviced

We found solutions that provided service to 58.8 percent, 93.5 percent, and 92.2 percent of all unserved locations in the case-study counties of Glascock, Miller, and Gordon, respectively. The lack of unassigned EBS channel blocks in Glascock County forced the use of CBRS and unlicensed 5 GHz only whose propagation areas are much smaller than EBS, thus fewer unserved locations were reached using existing towers.

Solutions provided service to 44 percent, 91 percent, and 85.6 percent of all unserved student locations in the case-study counties of Glascock, Miller, and Gordon, respectively.

[20] Note that the population jumps from approximately 288,000 in Chatham County to 750,000 in DeKalb County. There are no counties that reported population between these two numbers.

4.1.2 Capital Costs

Capital cost trends were consistent with the number of locations served. This is due both the cost of towers and the cost of the CPE for each location. CTC analyzed the costs in each of the counties for all unserved locations and unserved student locations. Our analysis makes the following assumptions:

- All served locations require subscriber equipment—either an indoor or an outdoor CPE.
  - Outdoor CPE cost approximately $1,000, including equipment and installation.
  - Indoor CPE cost approximately $350 (less than outdoor CPE because no outdoor antennas are installed) and are used where possible to reduce costs.
- Service will be used by 60 percent of the served locations.
- Towers will be configured with three sectors for each frequency used.
- EBS spectrum is used where sufficient spectrum is unallocated. CBRS is the primary spectrum where insufficient EBS spectrum is available. Additional frequencies and equipment (CBRS and 5 GHz) are added to provide additional capacity where justified by the number of locations in the coverage area.
- Backhaul is provided by fiber optic cabling where it already exists and 11 GHz microwave links otherwise. We assume that 10 percent of the sites require an second microwave hop.
- Engineering and design costs include propagation studies, RF path analysis for point-to-point connections, structural analysis, construction plans, and permits. This cost is estimated to be 10 percent of the distribution network cost.
- Site acquisition costs include preliminary equipment dimensioning, power needs, shelter requirements, RF suitability, escorts, lease negotiations, and permitting. Actual costs will vary, but the average is approximately $25,000.
- Estimates includes core network equipment for each solution to manage functions such as authentication, billing, security, and connection to the internet. We estimate $200,000 for equipment and setup of the core network equipment.

Table 9 summarizes the cost for the counties with student and all served location scenarios.

Table 9: Estimated Fixed Wireless Capital Costs

County – Locations	Number of Towers	Locations Served	Percent of Locations Served	Capital Cost	Average Distribution Network Cost per Served	Installation and CPE Cost per Location Served
Glascock – All	8	973	59%	$1,410,000	$875	$950
Glascock – Students	3	228	44%	$581,000	$1,950	$1,000
Gordon – All	12	3,451	94%	$2,850,000	$350	$785
Gordon – Students	5	706	91%	$952,000	$880	$785
Miller – All	39	15,031	92%	$10,600,000	$235	$785
Miller – Students	20	3,364	86%	$3,500,000	$555	$785
Total – All Locations	59	19,455	89%	$7,760,000	$486	$840
Total – Student Locations	28	4,298	91%	5,033,000	$1,128	$856

Note: The capital cost model assumes a penetration rate of 60%, which is feasible for an area with no other broadband internet option.

The following table lists the amount of capital required if 0 percent, 50 percent, or 75 percent of the total costs were subsidized.

Table 10: Estimated Capital Costs With Some Percentage Subsidized

County -Locations	0% Capital Subsidy	50% Capital Subsidy	75% Capital Subsidy
Glascock – All	$1,410,000	$705,000	$352,500
Glascock – Students	$581,000	$290,500	$145,250
Gordon – All	$2,850,000	$1,425,000	$712,500
Gordon –Students	$952,000	$476,000	$238,000
Miller – All	$10,600,000	$5,300,000	$2,650,000
Miller – Students	$3,500,000	$1,750,000	$875,000
Total – All Locations	$7,760,000	$3,880,000	$1,940,000
Total – Student Locations	5,033,000	$2,516,500	$1,258,250

4.1.3 Operating Costs

Operating costs vary across the three counties based on the number of towers required and the number of locations or student locations predicted to be served by the analysis model, primarily the number of locations served. As shown in the table and figure below, the more locations served, the lower the annual operating cost per location—the estimated cost per location served by our model for a student-only network is just over $1,100 in Glascock County to serve 228 students while in Gordon County it is just under $400. These are the estimated operating costs for 100 percent adoption.

Table 11: Estimated Fixed Wireless Operating Costs (Assuming 100 Percent Adoption)

County – Locations	Number of Towers	Locations Served	Annual Cost	Annual Cost per Location Served
Glascock – All	8	973	$588,185	$605
Glascock– Students	3	228	$256,550	$1,125
Gordon – All	39	15,031	$3,130,800	$210
Gordon – Students	20	3,364	$1,343,100	$400
Miller – All	12	3,451	$1,000,022	$290
Miller – Students	5	706	$430,412	$610

Figure 11: Annual Fixed Wireless Operating Cost

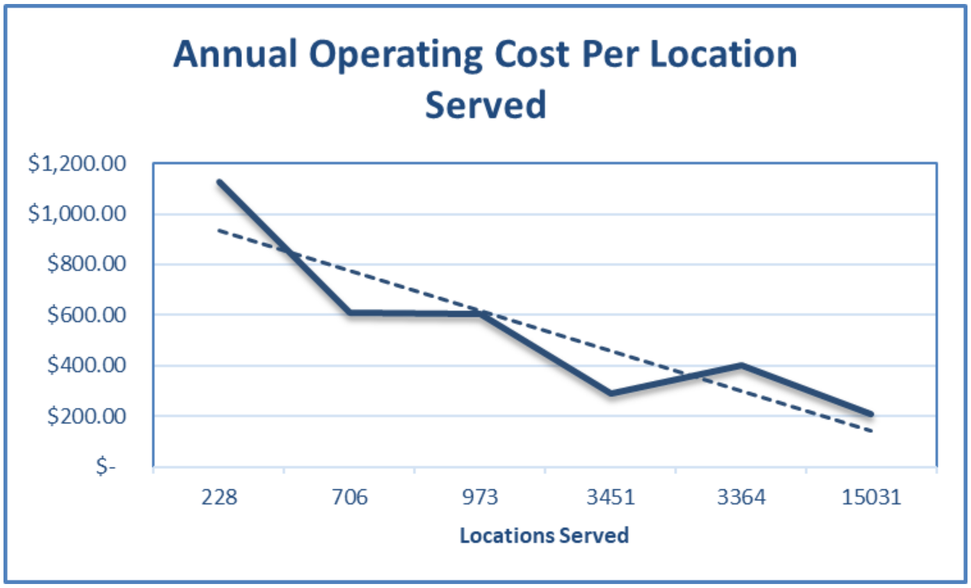


Table 12 shows the estimated monthly cost per location served at different adoption rates. It is apparent how quickly the cost per location increases as the adoption rate decreases, especially when the overall number of potential locations served is low (for example, see Glascock County – Students) and where EBS is not available.

These are the monthly costs per location that would need to be charged (if they are not subsidized) to sustain network operations. These fees would not recoup capital costs.

Table 12: Estimated Monthly Operation Cost per Location Served

Description	Monthly Operating Cost per Location Served			
	100% Adoption Rate	60% Adoption Rate	45% Adoption Rate	30% Adoption Rate
Glascock County – Students	$93.77	$152.55	$200.63	$296.77
Miller County – Students	$50.80	$94.77	$124.18	$182.99
Glascock County - All	$50.38	$78.67	$102.24	$149.40
Miller County – All	$24.15	$36.87	$46.98	$67.19
Gordon County – Students	$33.27	$52.10	$67.28	$97.65
Gordon County – All	$17.36	$24.57	$30.57	$42.58

Our operating cost estimates consider maintenance and equipment replacement for the distribution equipment at the tower sites and core. Regular maintenance includes any adds, moves, and changes required. Electronics may need to be replaced at five- to 10-year intervals due both to technological obsolescence and wear and tear—and unlike a fiber network, the electronics comprise almost all of the capital cost of the network, thus significantly increasing the operational cost as a fraction of the total cost of operations.

Our model also considers customer premise equipment (CPE) replacement at 10 years, amortizing the cost annually. In each county's unserved and unserved student areas, the cost of the distribution network (the antenna sites and the supporting network) ranges from $235 to $1,950 per location (assuming a 60 percent adoption rate; see Table 9). The installation cost of CPE per subscriber, including labor, materials, and electronics is approximately, on average, $840 per location.

There may also be costs or fees associated with spectrum licensing or auction bids. The EBS auction is slated to occur sometime in 2021, therefore no actual auction bids are available. For the sake of our analysis, we estimated the EBS auction pricing at the average bid for a comparable 20 MHz of CBRS PAL spectrum within each of the counties, except for Glascock County. As with our coverage analysis, our operating cost estimates assume that Glascock County will only use CBRS GAA or unlicensed spectrum and therefore no costs were associated with CBRS spectrum usage.

We also considered staffing to operate the network including program and network management, network technician and technician training, help desk/customer service, portal/application/access management, general counsel, and some business administration roles for billing and other duties. Staffing requirements were scaled for each of the counties based on the number of estimated towers and users. The model also includes insurance and minimal office expenses.

Most of the operating costs are due to tower space leasing. Leasing space for three sectors of antennas (as needed on each tower site) costs approximately $36,000 per year. This is a critical consideration (especially in Gordon County which requires 39 towers to cover all unserved locations and 20 towers to cover unserved students) because the fixed wireless model uses existing towers with an average 33 unserved locations per tower, so ***the cost for tower leases alone exceeds $1,000 per year per location***.

Of note, if a new tower is installed to provide service to more users, permitting for new tower locations may require a public hearing process and may require months, and may be difficult to achieve if there is local opposition to the tower.

4.2 Case Study Analysis Methodology and Assumptions

For each county we determined the:

- Percent of unserved locations that can be covered for a selected buildout scale
- Capital costs of deploying the network
- Total cost of ownership (TCO) of the network

We considered towers from multiple databases to determine their potential coverage, as well as the number of locations that could be served.

We created RF models to depict the areas that would receive a minimum throughout of 25 Mbps download and 3 Mbps upload speeds at the cell edge. We examined the coverage footprints for all three sets of frequencies that may be available for the State's use: 2.5 GHz EBS, 3.5 GHz CBRS, and 5 GHz unlicensed.

For each county, we estimated the percentage of homes that can be served with the selected towers, the cost to deploy, and the total cost of ownership.

At the State's request, we performed two analyses performed for each county. First, we performed an analysis using all unserved locations in the county. Second, we performed an analysis using locations of unserved students: [21]

1. Glascock County – all unserved locations
2. Glascock County – unserved student locations
3. Miller County – all unserved locations
4. Miller County – unserved student locations
5. Gordon County – all unserved locations
6. Gordon County – unserved student locations

4.2.1 Frequency Planning

Our models use EBS spectrum where that spectrum is unallocated. EBS can be augmented by CBRS at specific towers if needed for capacity, and further augmented with 5 GHz unlicensed if even more capacity is needed.

[21] Based on unserved locations provided by the State of Georgia and reflected in the publicly available map https://broadband.georgia.gov/maps/gbdi-unserved-county (accessed December 2020).

Based on our review of the spectrum databases, Gordon and Miller Counties had EBS channels unassigned, and therefore available at the upcoming auction. For these two counties, EBS was used as the base spectrum, then augmented with the other frequencies as needed.

For Glascock County, there are no unassigned EBS channels so CBRS is used as the base layer and augmented with unlicensed 5 GHz where needed for capacity.

We generated coverage propagation maps and capacity estimates, such that the signal levels would achieve a minimum throughput of 25 Mbps download and 3 Mbps upload for each of the frequencies used. For all the three bands, CBRS, EBS and 5 GHz, the coverage maps indicate the coverage area where throughputs of 25 Mbps download and 3 Mbps upload could be achieved at the cell edge.

Figure 12 (below) estimates the relative coverage areas for 25/3 Mbps service for each of the three frequency bands. EBS covers the most area, followed by CBRS and 5 GHz.

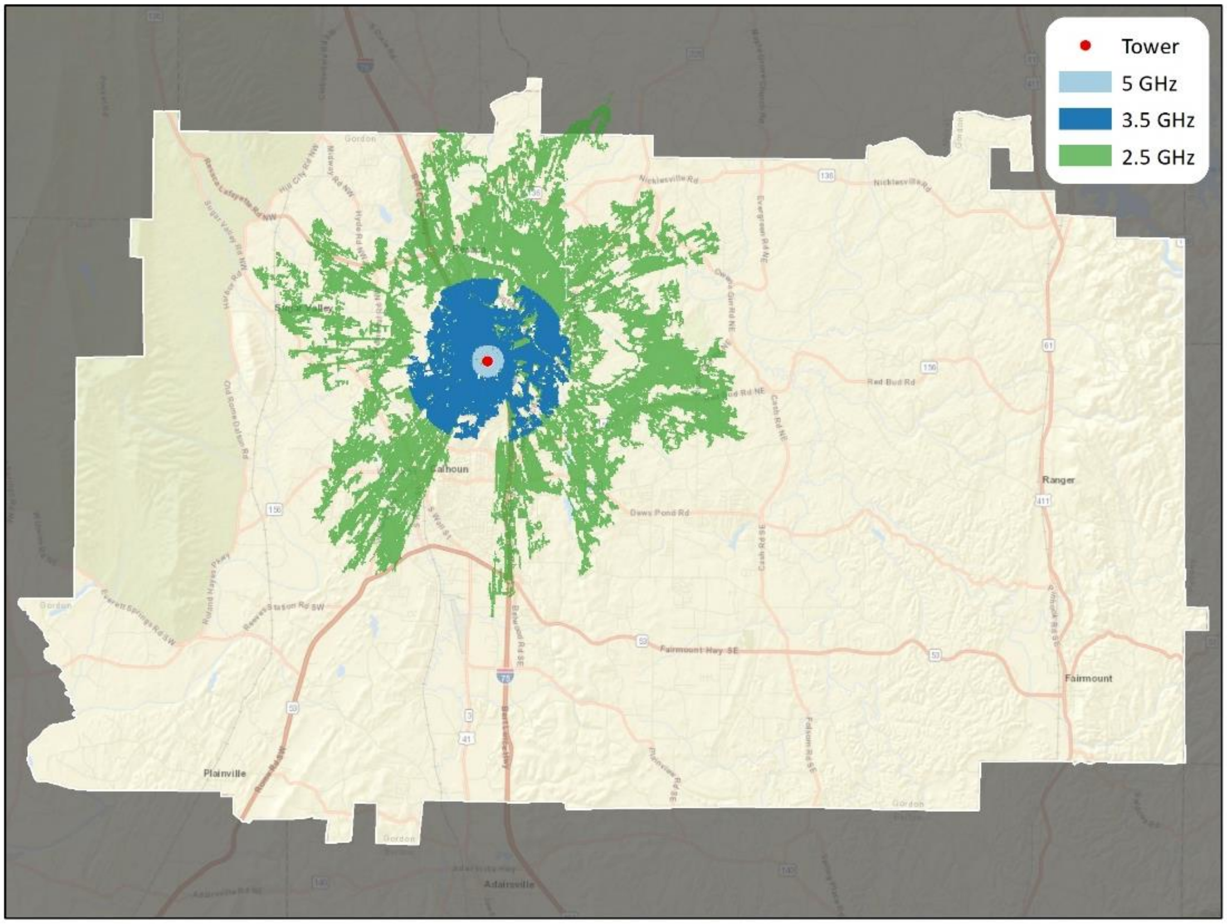
For EBS, we used a capacity-limited design. This means that the potential coverage area for EBS frequencies is actually much greater than depicted in this study due to its allowable high broadcast power and frequency characteristics. EBS can propagate over relatively long distances—up to 30 miles if using an outdoor receiving antenna.

However, given the number of locations that must be served with 25/3 Mbps service, a site configured to cover a very large area would become heavily loaded and provide only a fraction of the required speed to each of the locations within its coverage area. Additional sites would be needed to reuse the frequency to provide sufficient capacity.

Because EBS licenses will be issued on a county-by-county basis, it also makes sense to reduce the coverage area of a single tower such that multiple towers can be used in a single county and not interfere with each other. Various radius configurations were mapped, and our models determined that a 6-mile radius was a good balance for covering as many locations as possible without overloading the towers. Our capacity-limited model requires a power reduction and limits the coverage to 6 miles, thereby limiting the service area for each tower to a manageable number of locations.

The CBRS and 5 GHz unlicensed models assume that equipment runs at the full power allowed by the FCC limits.

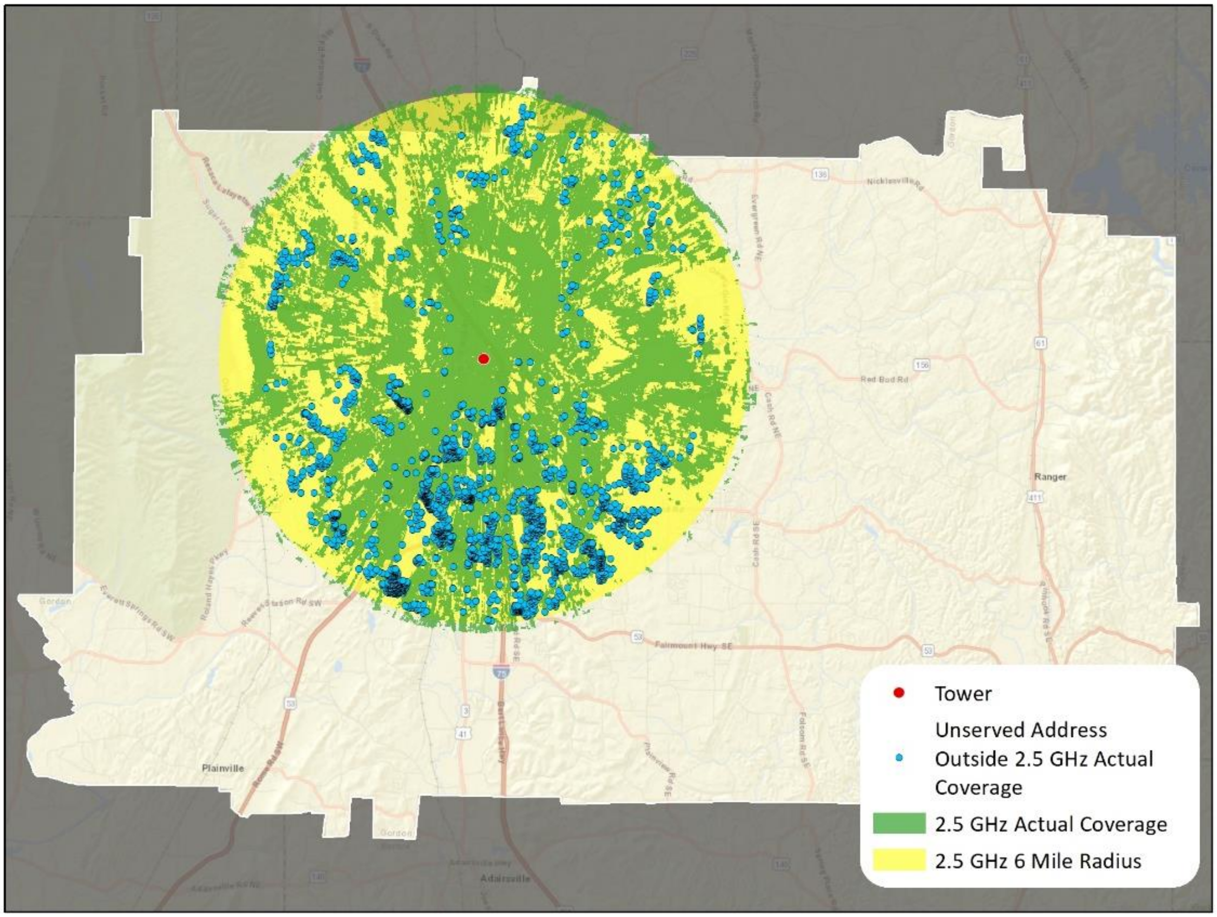
Figure 12: Coverage Comparison for EBS, CBRS and 5 GHz



4.2.2 Coverage Modeling

The radio frequency (RF) coverage analysis was modeled using the CloudRF propagation software. The software was chosen because of its ability to output accurate coverage maps in a GIS layer than can be overlaid on the unserved locations, and therefore identify which of the locations would be covered by the wireless model. CloudRF uses a sophisticated model that considers terrain and ground clutter such as trees, vegetation, and buildings. The fine structure of the propagation model can be seen in Figure 13, indicating that terrain and other features has a significant effect on coverage and capacity, and that a simple radius model is not sufficient.

Figure 13: Theoretical Coverage vs Actual Coverage Using ITM



The industry uses a wide range of propagation models used RF analysis. Widely used models include the line of sight (LOS) model, cost 231 model, Okumura Hata model, and Longley-Rice model (also called the Irregular Terrain Model, or ITM).

For our analysis we used ITM, which is the most conservative and takes into consideration the atmospheric conditions, the ground elevation, the deployment environment, the obstacles between the base and mobile stations, and the ground clutter.

4.2.3 Indoor vs. Outdoor Customer Premises Equipment (CPE)

There are two main ways to provision fixed wireless service at an location:

- Install an outdoor antenna and CPE on the roof or elsewhere on the property
- Provide a signal using an indoor CPE

Using an indoor CPE is cheaper and reduces the time and complexity of installation. Where possible service should be provided using an indoor CPE utilizing a wireless gateway device that distributes the signal within the location using Wi-Fi.

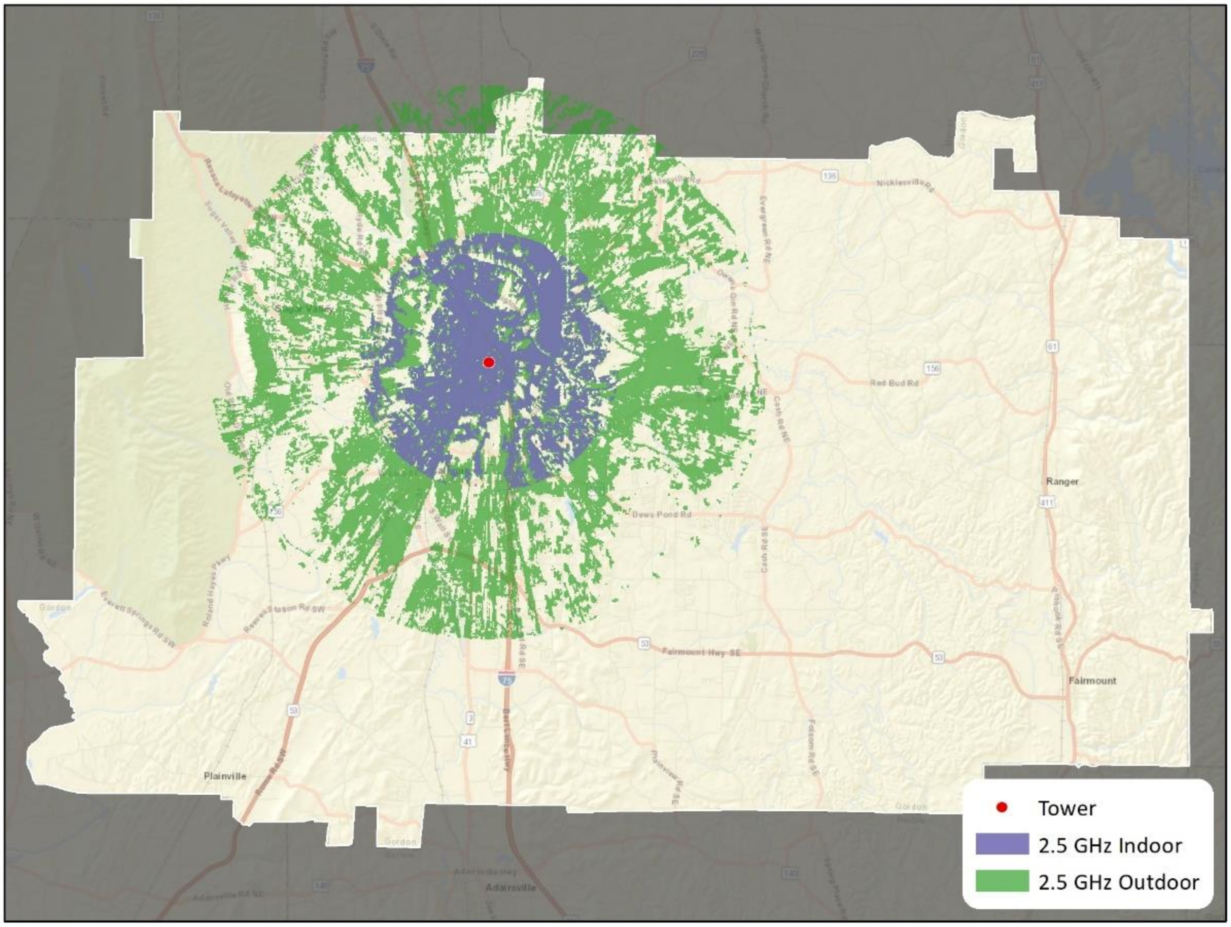
Our model estimated which locations could be served with an indoor CPE and which ones would need to have an outdoor antenna installed on the roof of the home. We created coverage maps of indoor versus outdoor coverage analysis for each of the three counties. To serve users indoors, stronger signal levels are needed. Therefore, many locations could not be served indoors, especially those further away from the base station.

Indoor CPEs are more feasible for EBS than for the other frequencies, due to the allowance for higher output power and the ability of the lower frequency to penetrate walls. While 25 percent of EBS-served locations can be served with indoor CPE, only 10 percent of CBRS- and 5 GHz-served locations can be served with indoor CPE.

The need for outdoor CPEs has the net effect of increasing the network costs for the non-EBS networks (Glascock County), because a higher percentage of the homes will need the costlier outdoor installation.

Figure 14 shows the difference between the indoor and outdoor service areas for a EBS network. Locations within the purple area are predicted to have indoor coverage and should use indoor devices.

Figure 14: Indoor vs Outdoor Coverage Comparison



Additional modeling assumptions include the following:

- Channel bandwidths used are 40 MHz for the CBRS band, 20 MHz for the 2.5 GHz band, and 80 MHz for unlicensed 5 GHz band.
- The CBRS and the 5 GHz band equipment operate at the maximum allowed power.
- Power for EBS antennas was limited to 6 kW for capacity reasons.
- 15 dB of fade margin was included. Fade margin is defined as difference between receiver signal strength and receiver sensitivity. Fade margin accommodates additional miscellaneous losses which might occur.
- 20 dB of loss was assumed due to building material absorption for indoor coverage.
- Antennas were placed at 80 percent of the tower height.

- Subscriber equipment antennas were placed at 4.57 meters (15 feet) above the ground for outdoor CPE and 1 meter (3.3 feet) for indoor CPE.
- Ground elevation and clutter resolution were 30 meters—therefore this model takes into consideration any obstacles or clutter of up to 30 meters in size.

4.2.4 Locations

The case study analyzes two categories of locations: unserved locations and unserved student locations. The State provided a database that had all resident and business locations in the State. The student locations were also provided by the State.

To find the unserved locations from each of these datasets, a map of unserved areas was provided by the State. Overlaying the locations onto the map allowed us to select only the unserved locations. These unserved locations were used in our case studies.

4.2.5 Tower Selection

We analyzed multiple commercial and government databases and identified 8,598 existing tower locations in the State. We examined their height and ownership relative to their potential use as part of a solution for the target counties. CTC assessed the coverage provided by each of the tower sites using the three fixed wireless frequency band options (CBRS, 5 GHz, and 2.5 GHz) to determine how many of the county's locations and student locations would be within each spectrum band's predicted coverage area.

We found that some towers outside of the three counties could serve a substantial number of locations inside the counties. This is particularly true for towers that are outside the counties, but very near their borders. For this reason, our computer algorithm checked all towers in the State to see if they would provide any service to locations inside the counties. Any towers that did not provide enough service were dropped from consideration. The towers that provided significant service were kept.

A down selection algorithm was used to optimize the tower selection for the three counties. Because of the cost to lease and maintain towers over time, we only included towers that have the capability to provide service to serve at least 33 or more locations in one of the three counties. This resulted the following count of towers utilized in each of the scenarios:

- 8 towers for Scenario 1 (All unserved locations in Glascock County)
- 3 towers for Scenario 2 (Unserved student locations in Glascock County)
- 12 towers for Scenario 3 (All unserved locations in Miller County)
- 5 towers for Scenario 4 (Unserved student locations in Miller County)

- 39 towers for Scenario 5 (All unserved locations in Gordon County)
- 20 towers for Scenario 6 (Unserved student locations in Gordon County)

We based our analysis on the following assumptions:

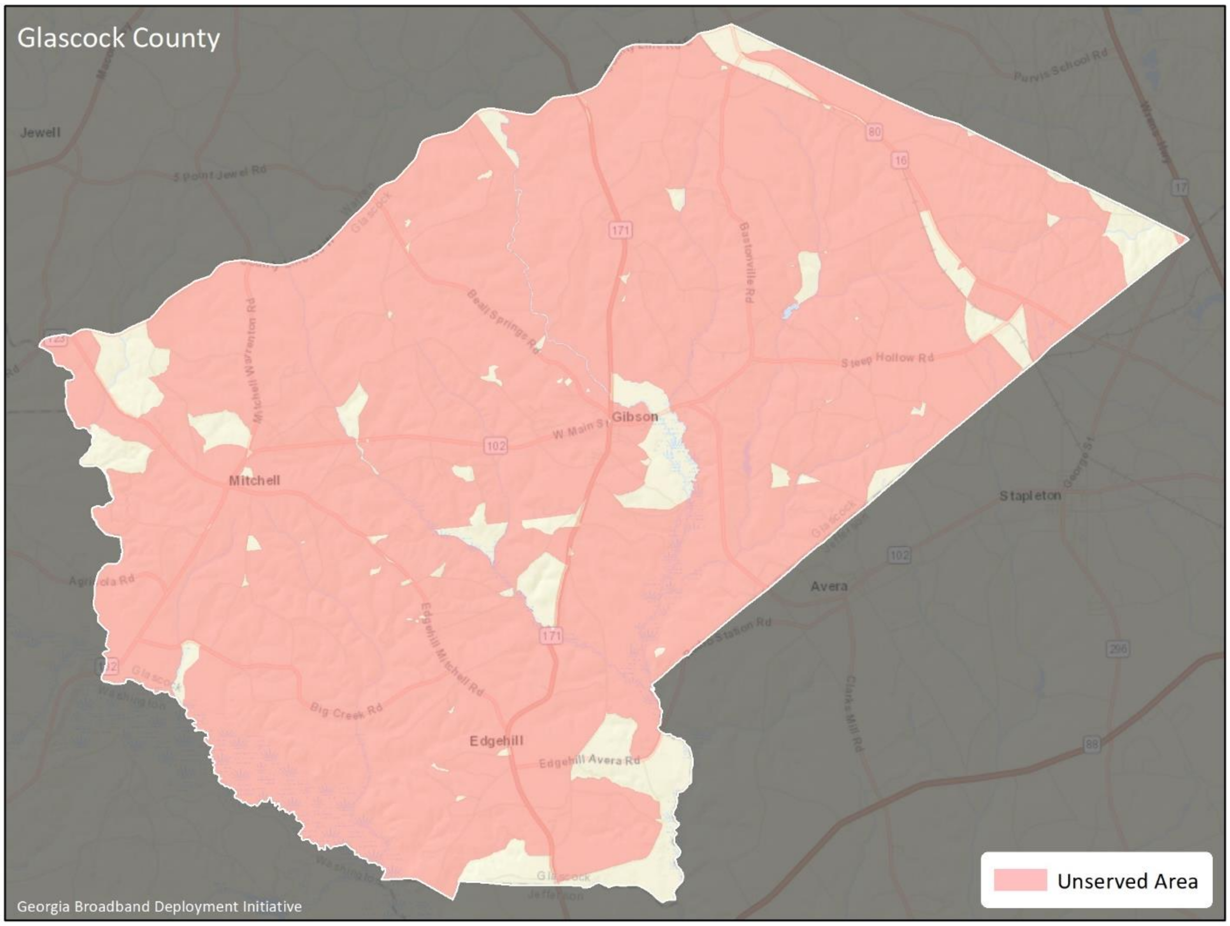
- We considered towers and water tank structures in our analysis. Other types of structures like buildings, chimneys, and billboards were removed, because we were seeking to optimize the model with large, substantial structures that could cover a large area.
- For the same reason, we only considered structures with height greater than 50 feet.
- For structures with height greater than 250 feet, we assumed maximum tower height of 250 feet, as we assumed that larger structures were radio or television broadcast towers that would not allow placement of WISP antennas at the higher heights.
- We assumed the height for government owned towers to be 100 feet. The government tower database did not have tower height listed for most towers. However, the heights that were provided averaged approximately 100 feet.
- Assuming a 3-sector site, a 20 MHz EBS channel has the capability to serve 192 locations with 25/3 Mbps capacity. With 60 percent market penetration, the maximum number of locations in the service area is 320 locations.
- For towers with RF contours serving more than 320 locations we added additional capacity using CBRS and 5 GHz antennas.
    - Channel size for CBRS was assumed to be 40 MHz, or double that of EBS channel. The spectral efficiency (capacity per unit frequency bandwidth) was assumed to be the same. Therefore, number of additional locations served by a 3-sector site with CBRS channel is twice as high—640, or a total of 960 locations when operating alongside of EBS equipment.
    - If the number of locations that needs to be served by a single tower exceeds 960 locations, capacity can be further augmented using the 5 GHz band.
- The speeds in our analysis are held constant at 25 Mbps download and 3 Mbps upload. As a result, adding bandwidth at a particular (distribution/tower) location will increase the number of users that can be supported by that location. We found that for every 10 MHz of bandwidth, the fixed wireless network, can deliver a minimum of 25/3 service to up to 64 homes.

4.3 Glascock County

4.3.1 Determining Unserved Locations in Glascock County – Scenario 1

Figure 15 shows the unserved areas in Glascock County. Glascock County is considered entirely unserved[22] meaning that no location in the county has access to broadband service as defined in this report.

Figure 15: Unserved Areas in Glascock County



4.3.2 High-Level Coverage and Cost Estimate – All Unserved Locations

Eight towers were identified to serve at least 33 unserved locations within the county.

Base stations and antennas deployed to those eight towers could deliver service to 973 locations, an estimated 58.8 percent of the county's unserved locations. The blue shading in Figure 16 below depicts the predicted CBRS coverage. The red dots illustrate the tower locations. As

[22] https://broadband.georgia.gov/maps/gbdi-unserved-county

mentioned earlier, we use CBRS as the prime technology because all the EBS spectrum in the county is already allocated.

Figure 16: Scenario 1 Coverage and Tower Locations in Glascock County

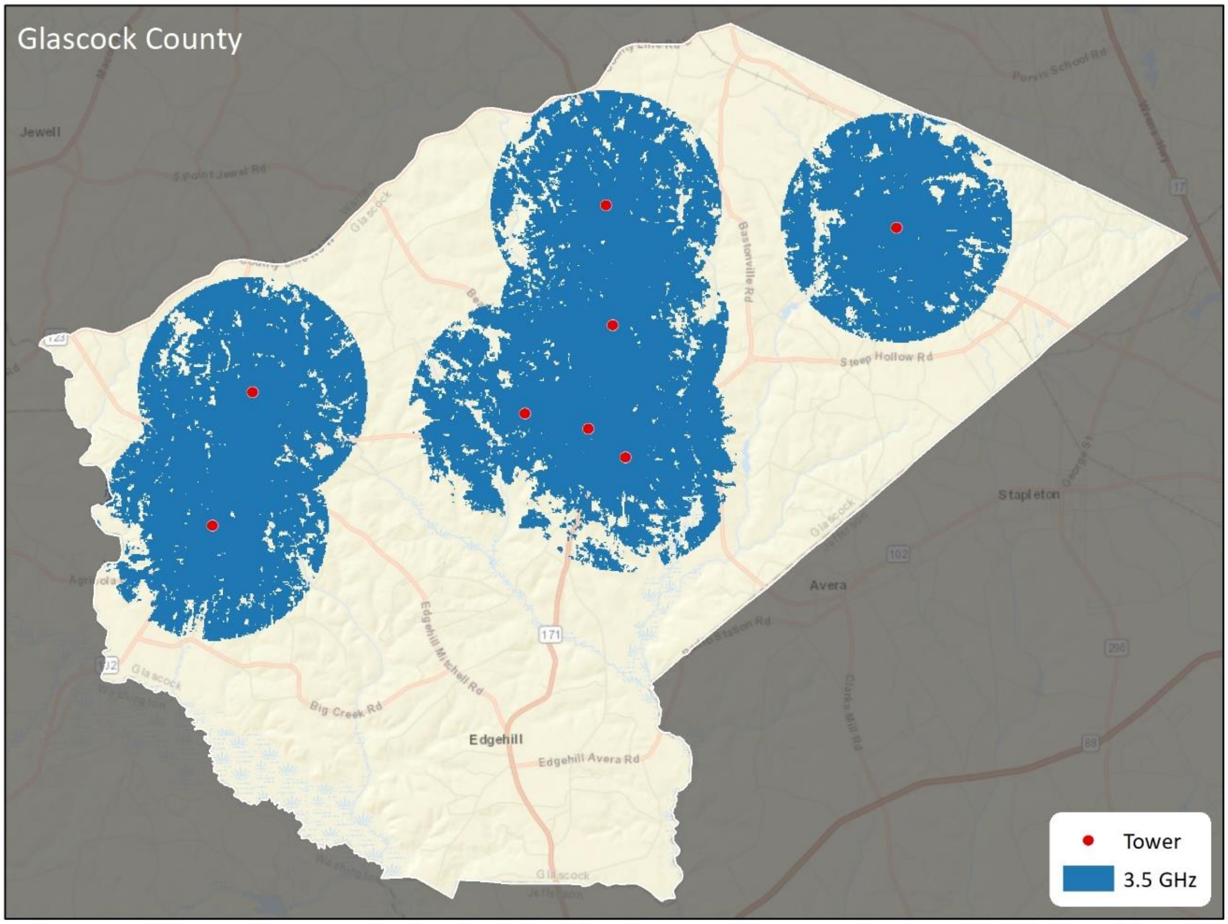


Table 13 indicates the coverage of county locations.

Table 13: Predicted Coverage in Glascock County (All Locations)

Locations	Number
Total locations in unserved area	1,655
Locations with indoor CPE	71
Locations with outdoor CPE	902
Total locations served	973
Locations not served	682
Percent of locations served	58.8%

The cost breakdown for Scenario 1 is provided in Tables 11 and 12.

Table 14: Capital Cost Estimate for Scenario 1 (Glascock County)

	Cost
Network Core	$200,000
Access Point Equipment	$90,000
Microwave Backhaul and Installation	$320,000
Engineering and Design	$41,000
Site Acquisition	$200,000
Total Distribution Network Costs	$851,000
Total Locations	973
Cost per Location (Distribution Network Only)	$875

Table 15: Total Cost Estimate for Scenario 1 at 60 Percent Penetration Rate (Glascock County)

Item	**Cost**
Incremental Premises Cost (60% Penetration)	$556,110
Total Cost per Unserved Location (60% Penetration)	$1,827

4.3.3 Determining Unserved Student Locations in Glascock County – Scenario 2

CTC identified the unserved student locations within the county based on the State's data. Since the entire county is unserved, the unserved student locations under study include all of the student locations within the county.

4.3.4 High-Level Coverage and Cost Estimate – Unserved Student Locations

Three existing telecommunications towers were identified as being able to serve at least 33 unserved student locations within the county.

Base stations and antennas deployed to those three towers could deliver service to an estimated 44 percent of the county's unserved student locations. The blue shading in Figure 17 below depicts the predicted CBRS coverage. The red dots show the tower locations.

Figure 17: Scenario 2 Coverage and Tower Locations (Glascock County)

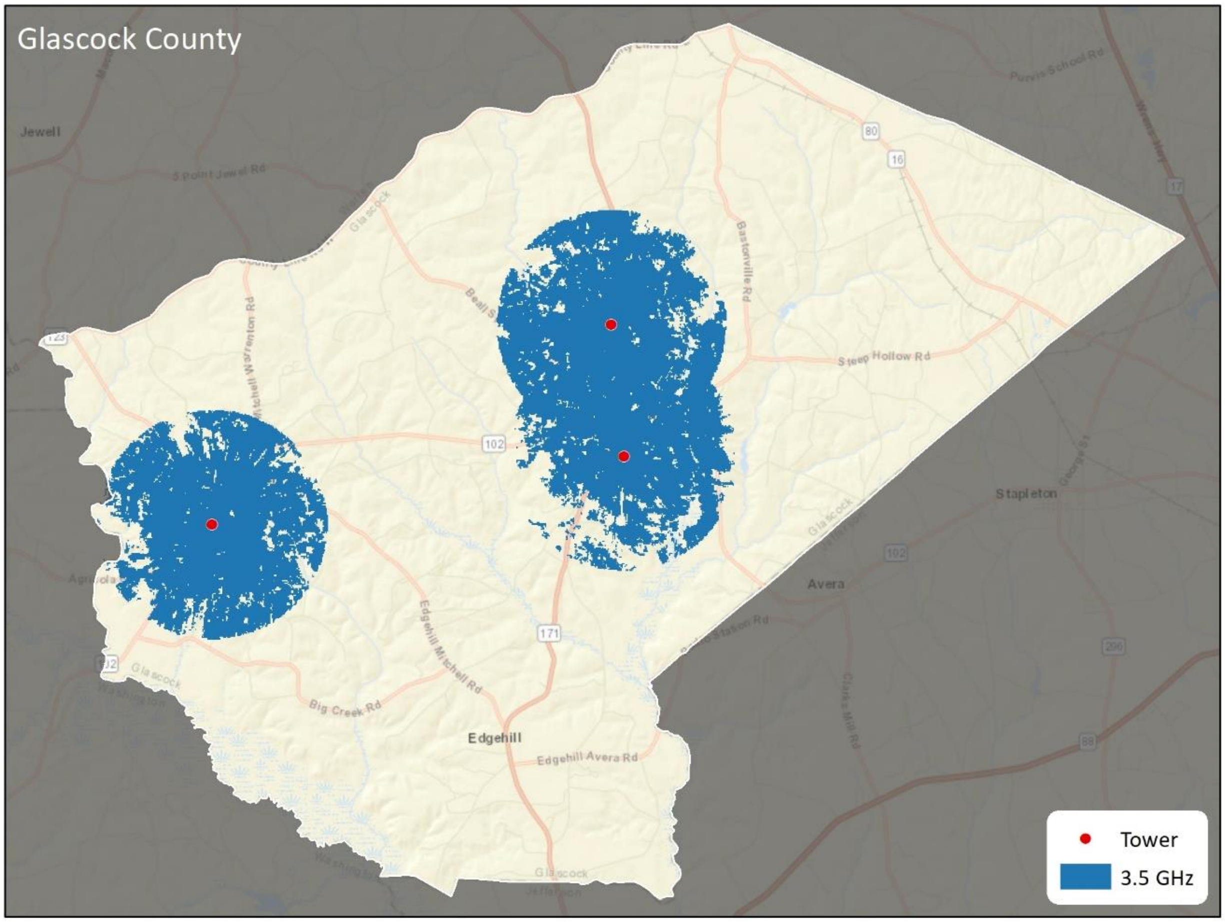


Table 16 below indicates the penetration into the county's unserved student locations.

Table 16: Predicted Coverage of Unserved Students (Glascock County)

Locations	Number
Total unserved student locations	520
Served by indoor CPE	0
Served by outdoor CPE	228
Total student locations served	228
Student locations not served	292
Percent of locations served	44%

The cost breakdown for Scenario 2 is shown in the tables below.

Table 17: Capital Cost Estimate for Scenario 2 (Glascock County)

	Cost
Network Core	$200,000
Access Point Equipment	$33,750
Microwave Backhaul and Installation	$120,000
Engineering and Design	$15,375
Site Acquisition	$75,000
Total Distribution Network Costs	$444,125
Total Locations	228
Cost per Location (Distribution Network Only)	$1,950

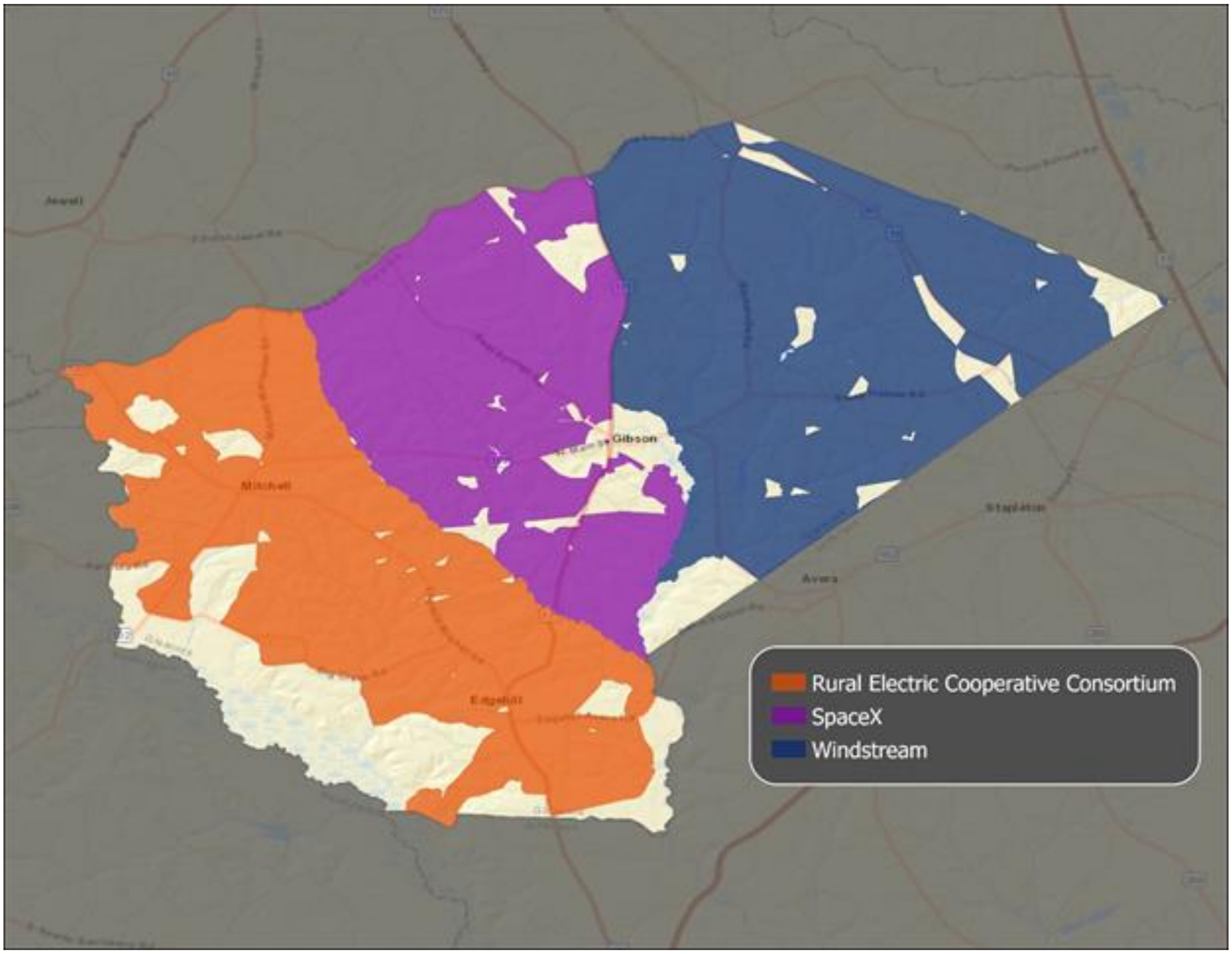
Table 18: Total Cost Estimate for Scenario 2 at 60 Percent Penetration Rate (Glascock County)

Item	**Cost**
Incremental Premises Cost (60% Penetration)	$137,000
Total Cost per Unserved Location (60% Penetration)	$2,950

4.3.5 Rural Digital Opportunity Fund Results for Glascock County

The FCC-awarded RDOF funding covers most of the county and will subsidize service to 1,376 locations. Figure 18 shows RDOF auction results for Glascock County.

Figure 18: RDOF Auction Results for Glascock County



Rural Electric Cooperative Consortium (RECC) was awarded the western part of the county, serving 496 locations. It is connecting with RECC's wide expanse of RDOF-funded areas that spread north, west, and south of Glascock County. Windstream won the eastern part of the county, serving 532 locations, while SpaceX won the center of the county, sandwiched between RECC and Windstream. SpaceX proposed to serve 348 locations and will provide their coverage area with satellite internet, providing service of at least 100/20 Mbps. RECC and Windstream are offering to provide gigabit fiber in their locations. 1,028 locations will be served by fiber while 348 will be served by satellite.

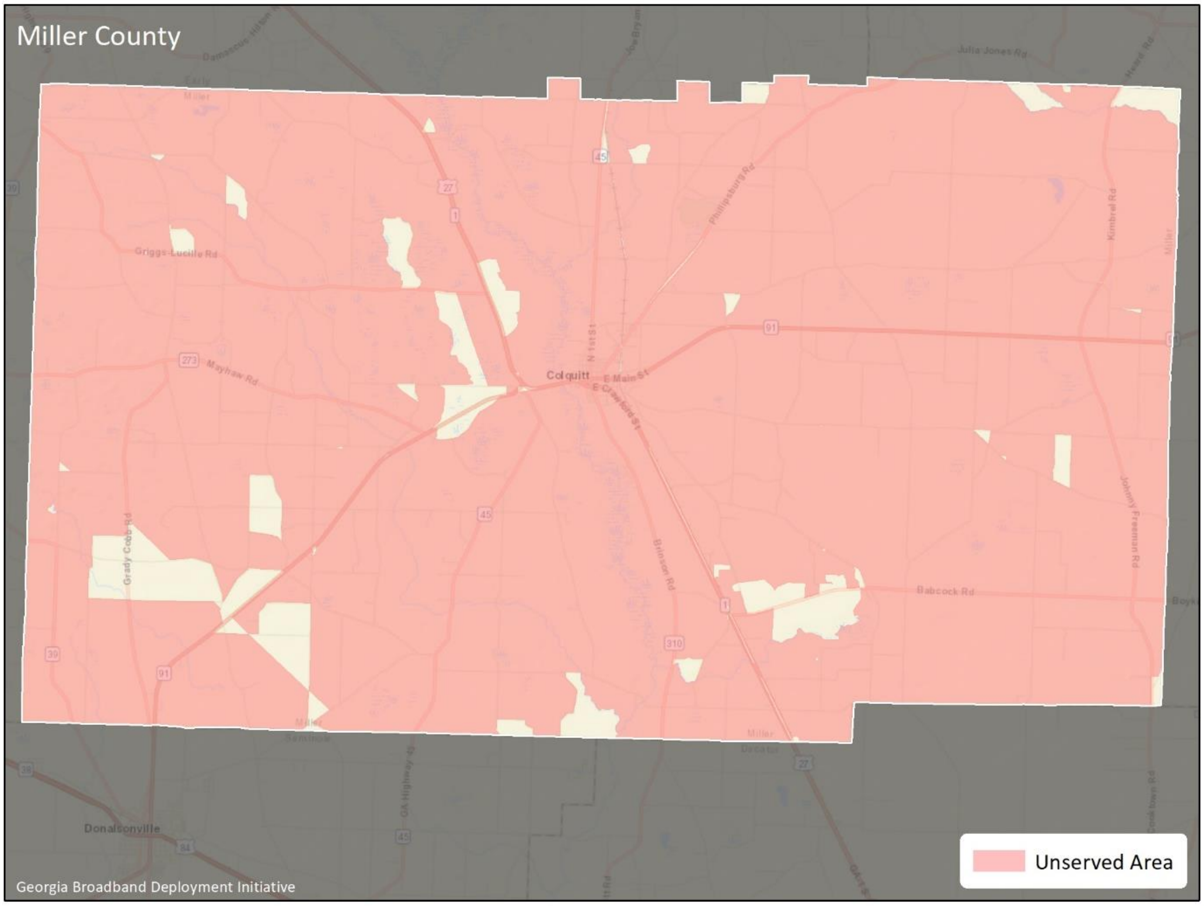
In Glascock, the unserved areas in the proposed fixed wireless model are between the tower propagation areas in the north as well as the southern tip of the county. Therefore, one scenario is that the wireless network provides near-term relief, and the RDOF awardees overbuild with fiber in the eastern and western parts of the State and satellite service in the center, with most parts of the county having two broadband options.

4.4 Miller County

4.4.1 Determining Unserved Locations in Miller County – Scenario 3

CTC identified the unserved locations within the county and determined Miller County is 96 percent unserved.[23] Figure 19 below shows the county's unserved areas.

Figure 19: Unserved Areas in Miller County



4.4.2 High-Level Coverage and Cost Estimate – Scenario 3

Of the 8,598 existing telecommunications towers presently in the State, 12 were identified which could each serve at least 33 unserved locations within the county.

Base stations and antennas installed at those 12 towers could deliver service to an estimated 93.5 percent of the county's all unserved locations. The light blue, dark blue, and green shading in Figure 20 below depicts the predicted 5 GHz, CBRS, and EBS coverage, respectively. The red dots illustrate the tower locations.

[23] https://broadband.georgia.gov/maps/gbdi-unserved-county

Figure 20: Scenario 3 Coverage and Tower Locations (Miller County)

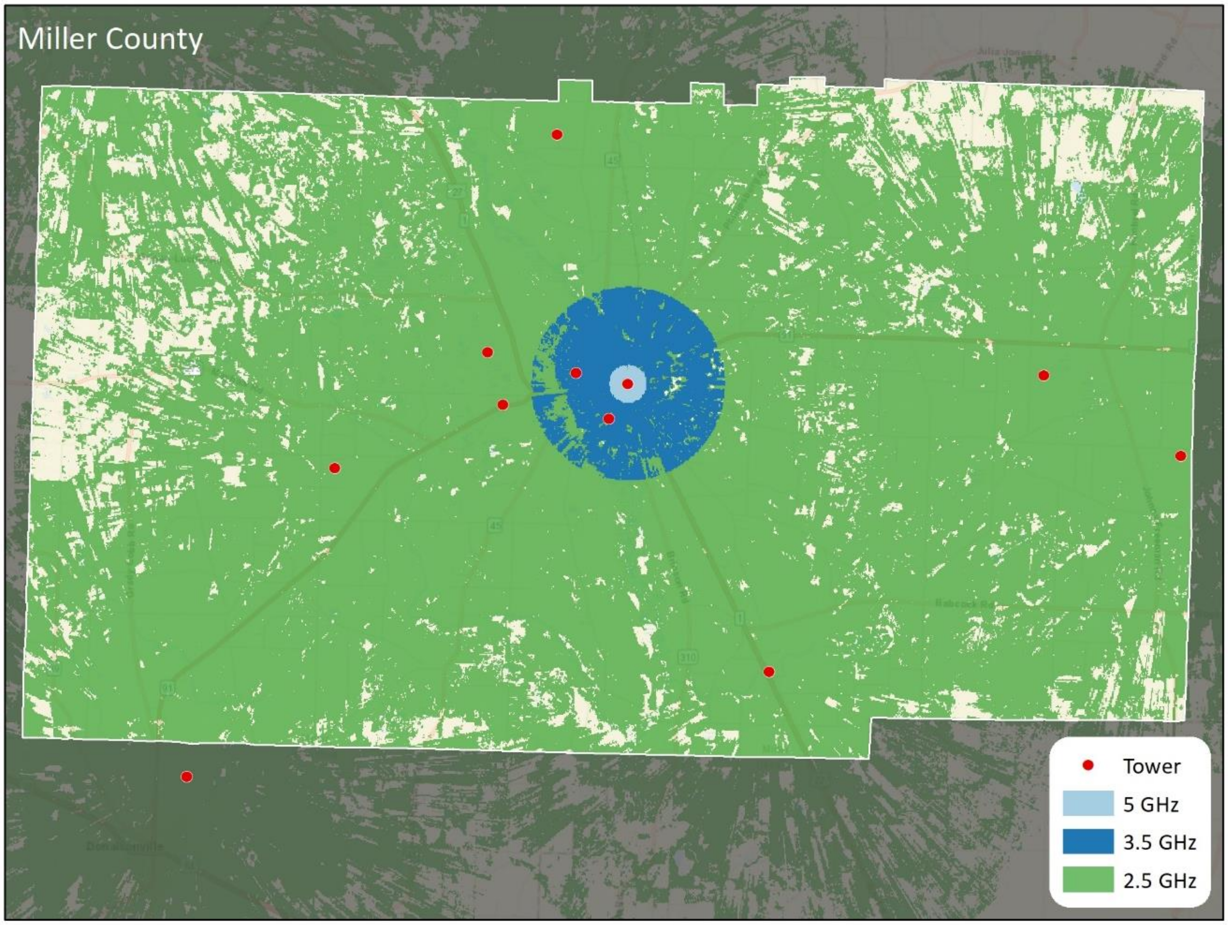


Table 19 below indicates the service to the county's unserved locations.

Table 19: Predicted Coverage with Existing Towers (Scenario 3) (Miller County)

Locations	Number
Total unserved locations	3,690
Served with indoor CPE	1,139
Served with outdoor CPE	2,312
Total locations served	3,451
Locations not served	239
Percent of locations served	93.5%

The cost breakdown for Scenario 3 is shown in the tables below.

Table 20: Capital Cost Estimate for Scenario 3 (Miller County)

	Cost
Network Core	$200,000
Access Point Equipment	$157,500
Microwave Backhaul and Installation	$480,000
Engineering and Design	$63,750
Site Acquisition	$300,000
Total Distribution Network Costs	$1,201,250
Total Locations	3,451
Cost per Location (Distribution Network Only)	$348

Table 21: Total Cost Estimate for Scenario 3 at 60 Percent Penetration Rate (Miller County)

Item	**Cost**
Incremental Premises Cost (60% Penetration)	$1,630,000
Total Cost per Unserved Location (60% Penetration)	$1,140

4.4.3 Determining Unserved Student Locations in Miller County – Scenario 4

CTC identified the unserved student locations within the unserved areas of the county based on the State's data.

4.4.4 High-Level Coverage and Cost Estimate – Scenario 4

Five existing telecommunications towers were identified as being able to serve at least 33 unserved student locations within the county.

Base stations and antennas deployed to those five towers could deliver service to an estimated 91 percent of the county's unserved student locations. The dark blue, and green shading in Figure 21 below depicts the predicted CBRS and EBS coverage, respectively. The red dots show the tower locations.

Figure 21: Scenario 4 Coverage and Tower Locations (Miller County)

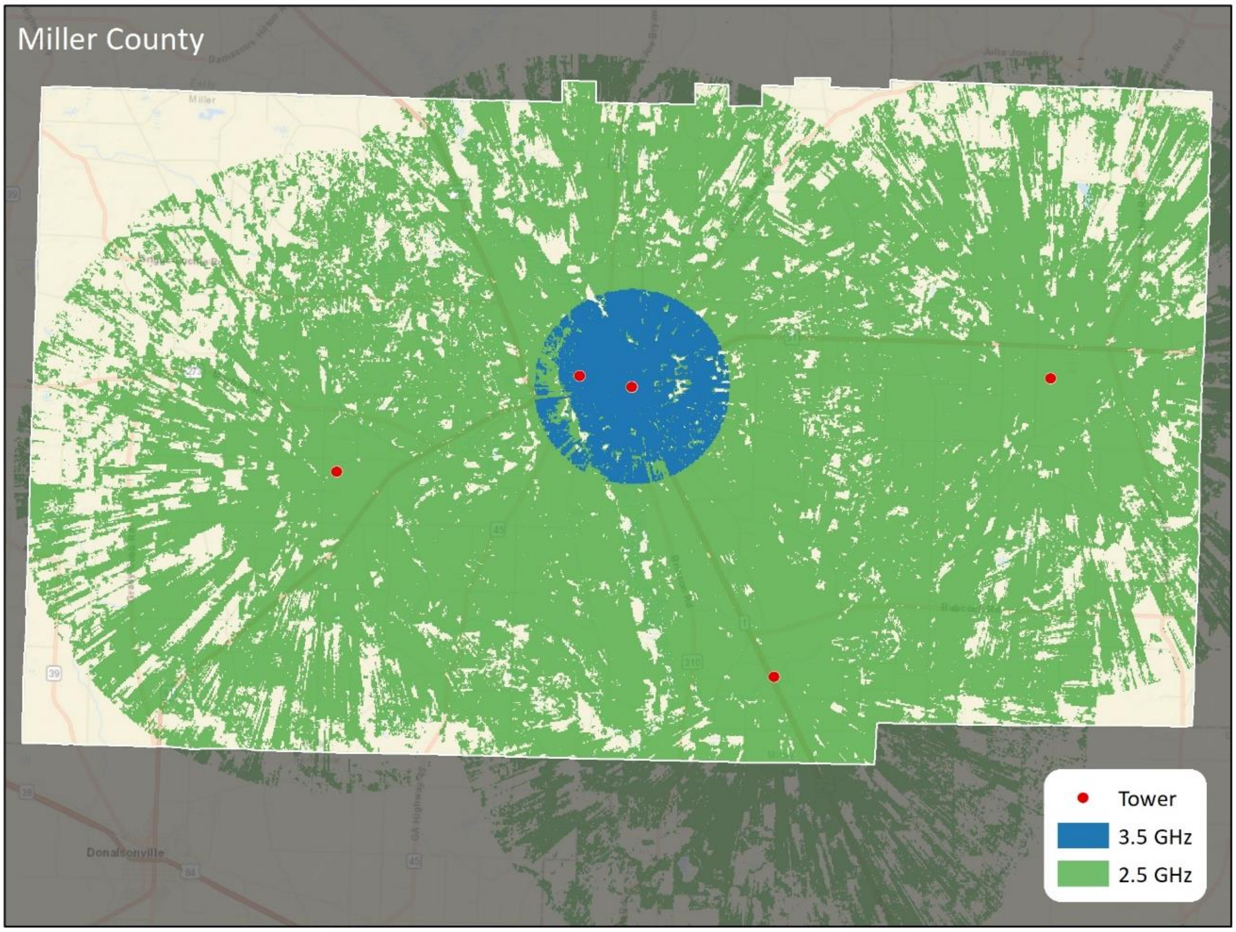


Table 22 indicates the service to the county's unserved student locations.

Table 22: Predicted Coverage With Existing Towers (Scenario 4) (Miller County)

Locations	Number
Total unserved student locations	775
Served by indoor CPE	233
Served by outdoor CPE	473
Total students served	706
Students not served	69
Percent of students served	91%

The cost breakdown for Scenario 4 is shown in Tables 20 and 21.

Table 23: Capital Cost Estimate for Scenario 4 (Miller County)

	Cost
Network Core	$200,000
Access Point Equipment	$67,500
Microwave Backhaul and Installation	$200,000
Engineering and Design	$26,750
Site Acquisition	$125,000
Total Distribution Network Costs	$620,000
Total Locations	706
Cost per Location (Distribution Network Only)	$877

Table 24: Total Cost Estimate for Scenario 4 at 60 Percent Penetration Rate (Miller County)

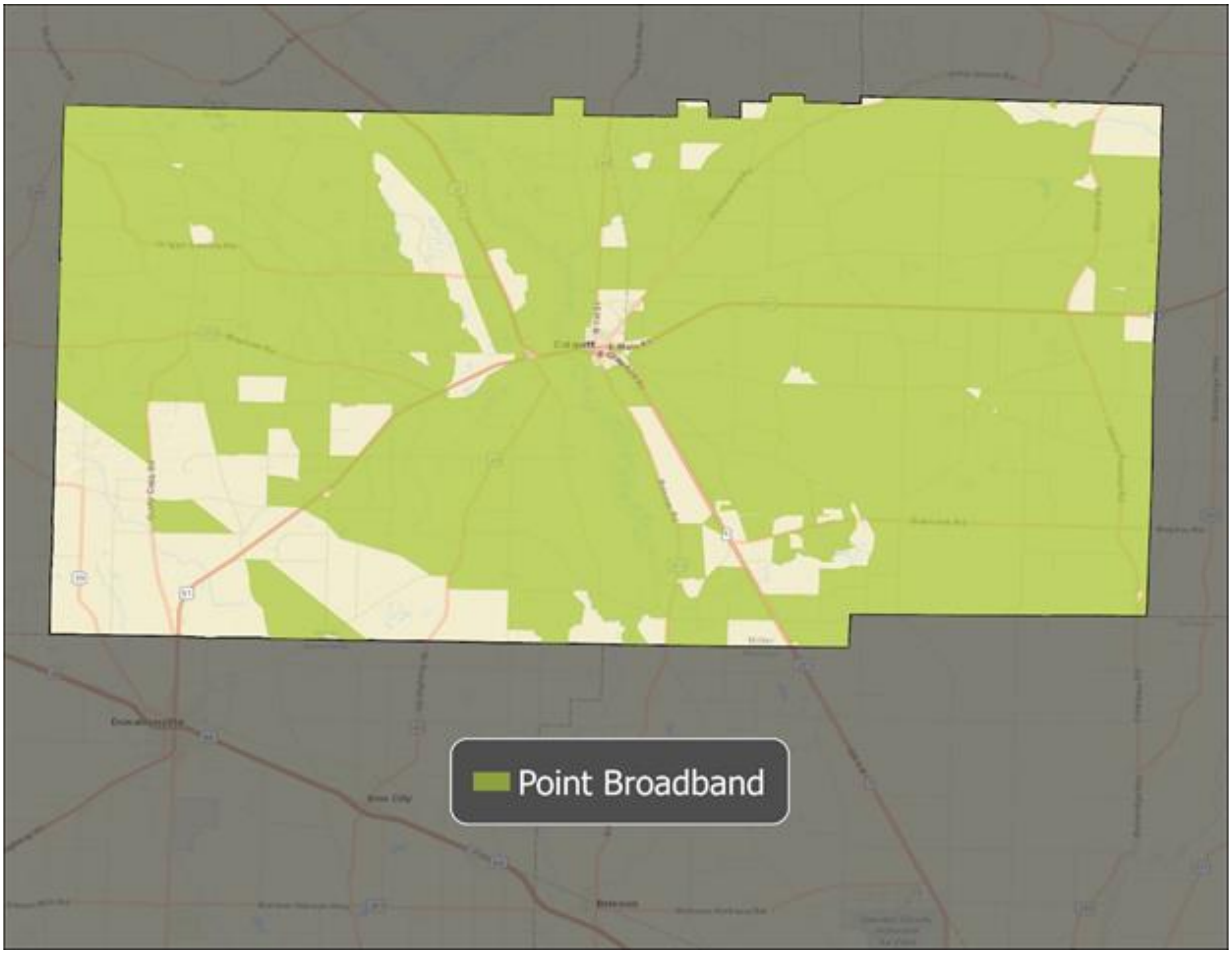
Item	Cost
Incremental Premises Cost (60% Penetration)	$333,000
Total Cost per Unserved Location (60% Penetration)	$1,700

4.4.5 Rural Digital Opportunity Fund Results for Miller County

As noted, Miller County is 96 percent unserved, and all five RDOF census areas were awarded to one company, Point Broadband (Figure 22), with surrounding counties won by Windstream and SpaceX. Point Broadband proposes to bring gigabit fiber to 2,000 locations in Miller County.

Point Broadband is a local company, headquartered in West Point, Georgia; it provides service in both Georgia and Alabama. Outside of Miller County, the rest of Point Broadband's RDOF locations are on the eastern border of Alabama.

Figure 22: RDOF Auction Results for Miller County



The wireless network in our fixed wireless model will provide service to 3,451 locations using EBS, CBRS, and 5 GHz spectrum. It would provide service to 1,451 more locations than Point Broadband's proposal. One scenario is that the wireless network provides short-term relief, then Point builds gigabit fiber as proposed in its proposed areas, and the wireless network provides coverage to areas that will remain unserved by Point and provides a second option in the Point areas.

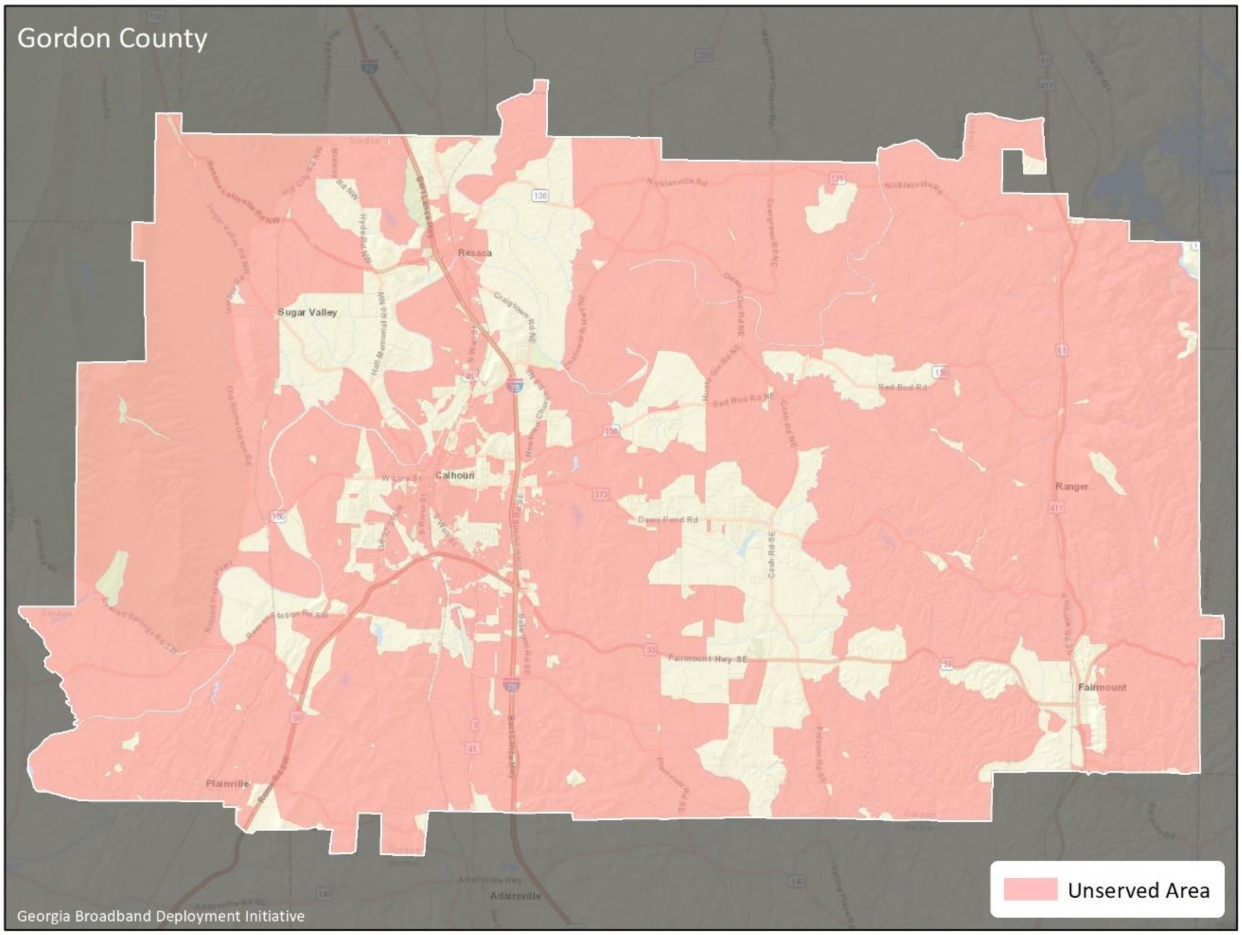
We note the majority of the locations remaining unserved under RDOF are in a relatively dense area in the city of Colquitt in the center of Miller County, which, although designated as unserved by the State (with more inclusive and accurate criteria than the federal criteria used by the FCC in RDOF), is considered served by the FCC. Point Broadband cannot use RDOF funds to serve those areas, though we believe it is likely that Point will eventually build in Colquitt using other funds, and therefore there is a likelihood that most of the county will eventually be served by Point.

4.5 Gordon County

4.5.1 Determining Unserved Locations in Gordon County – Scenario 5

Using the State's data, CTC identified the unserved locations within the unserved areas in Gordon County. Figure 23 shows the county's unserved areas.

Figure 23: Unserved Areas in Gordon County



4.5.2 High-Level Coverage and Cost Estimate – Scenario 5

Thirty-nine existing telecommunications towers were identified as being able to serve at least 33 unserved student locations within the county.

Base stations and antennas installed at those 39 towers could deliver service to an estimated 92.2 percent of the county's unserved locations. The light blue, dark blue, and green shading in Figure 24 below depicts the predicted 5 GHz, CBRS, and EBS coverage, respectively. The red dots illustrate the tower locations.

Figure 24: Scenario 5 Coverage and Tower Locations (Gordon County)

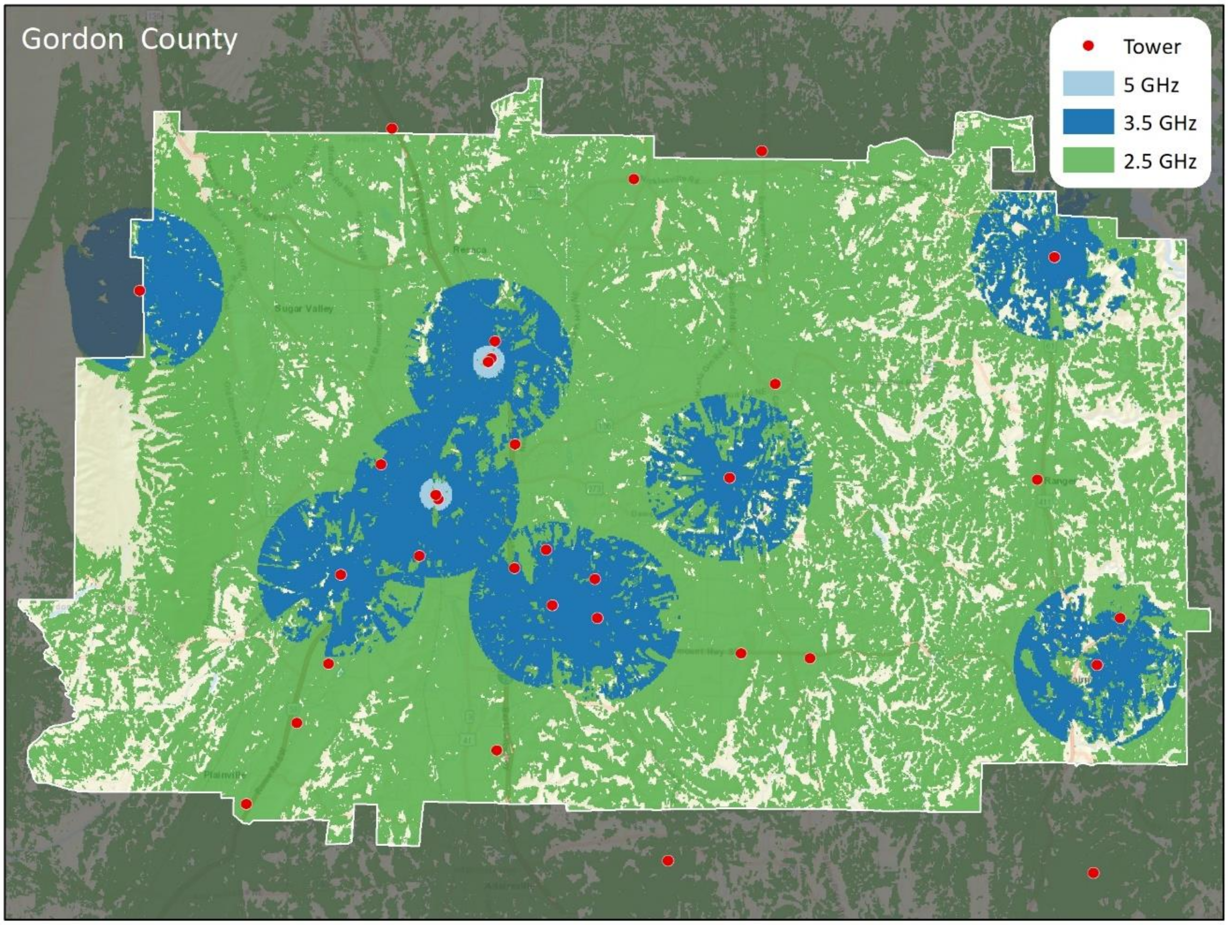


Table 25 below indicates the penetration into all the county's unserved locations.

Table 25: Predicted Coverage With Existing Towers (Scenario 5) (Gordon County)

Locations	Number
Total unserved locations	16,298
Served by indoor CPE	4,960
Served by outdoor CPE	10,071
Total locations served	15,031
Locations not served	1,267
Percent of unserved locations served	92.2%

The cost breakdowns are shown in the tables below.

Table 26: Capital Cost Estimate (Gordon County)

	Cost
Network Core	$200,000
Access Point Equipment	$562,500
Microwave Backhaul and Installation	$1,560,00
Engineering and Design	$212,250
Site Acquisition	$975,000
Total Distribution Network Costs	$3,510,000
Total Locations	15,031
Cost per Location (Distribution Network Only)	$234

Table 27: Total Cost Estimate for Scenario 5 at 60 Percent Penetration Rate (Gordon County)

Item	Cost
Incremental Premises Cost (60% Penetration)	$7,100,000
Total Cost per Unserved Location (60% Penetration)	$1,020

4.5.3 Determining Unserved Student Locations in Gordon County – Scenario 6

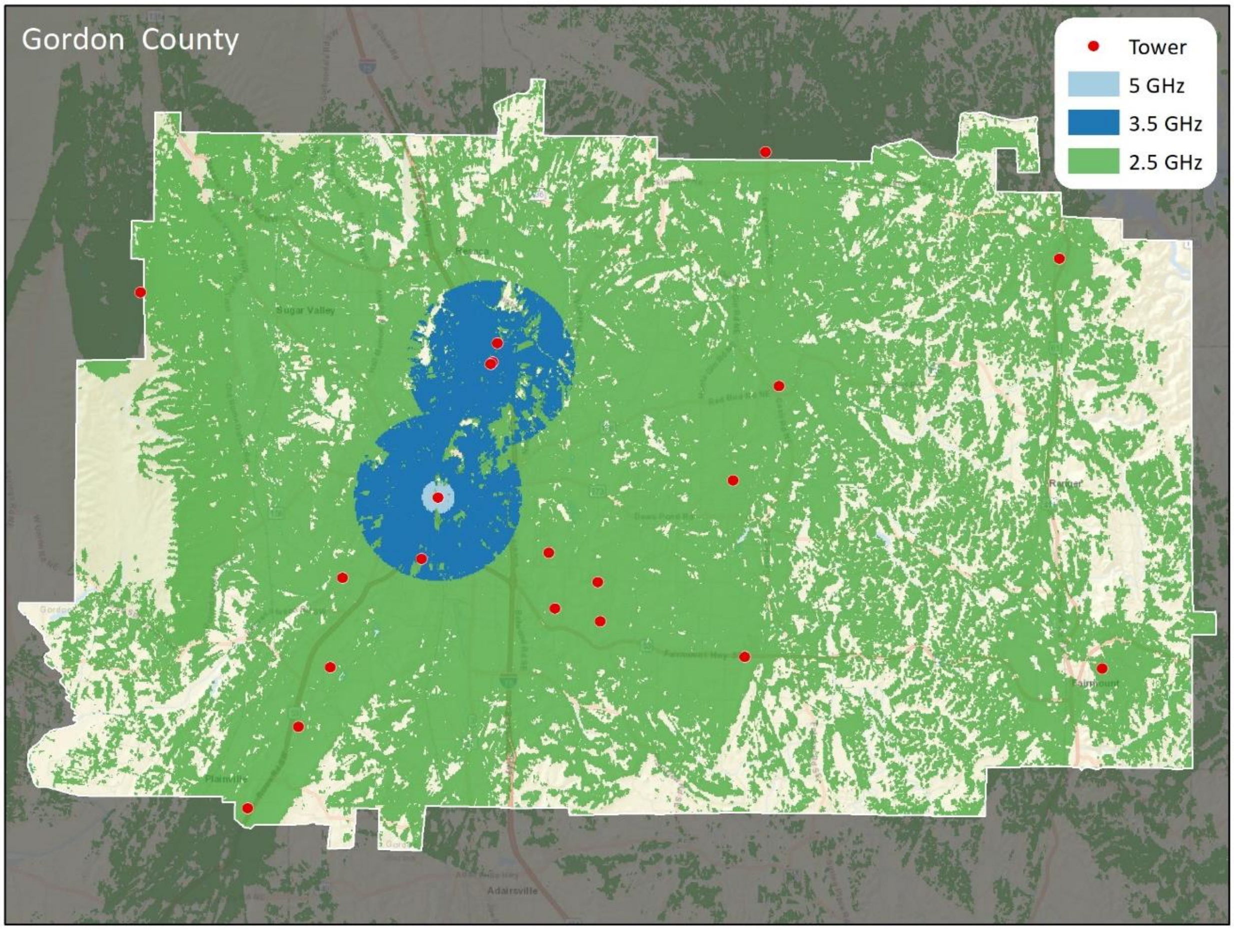
Using the State's data, CTC identified the unserved student locations within the unserved areas of the county.

4.5.4 High-Level Coverage and Cost Estimate – Scenario 6

Of the 8,598 existing telecommunications towers presently in the State, 20 were identified which could serve at least 33 unserved student locations within the county.

Base stations and antennas deployed to those 20 towers could deliver service to an estimated 85.6 percent of the county's unserved student locations. The light blue, dark blue, and green shading in Figure 25 below depicts the predicted 5GHz, CBRS, and EBS coverage, respectively. The red dots show the tower locations.

Figure 25: Scenario 6 Coverage and Tower Locations (Gordon County)



The table below indicates the service to the county's unserved student locations.

Table 28: Predicted Service to Unserved Students (Gordon County)

Locations	Number
Total unserved student locations	3,930
Served by indoor CPE	1,110
Served by outdoor CPE	2,254
Total locations served	3,364
Locations not served	566
Percent of locations served	85.6%

The cost breakdowns for Scenario 6 are shown in the tables below.

Table 29: Capital Cost Estimate for Scenario 6 (Gordon County)

	Cost
Network Core	$200,000
Access Point Equipment	$258,750
Microwave Backhaul and Installation	$800,000
Engineering and Design	$108,875
Site Acquisition	$500,000
Total Distribution Network Costs	$1,900,000
Total Locations	3,364
Cost per Location (Distribution Network Only)	$555

Table 30: Total Cost Estimate for Scenario 6 at 60 Percent Penetration Rate (Gordon County)

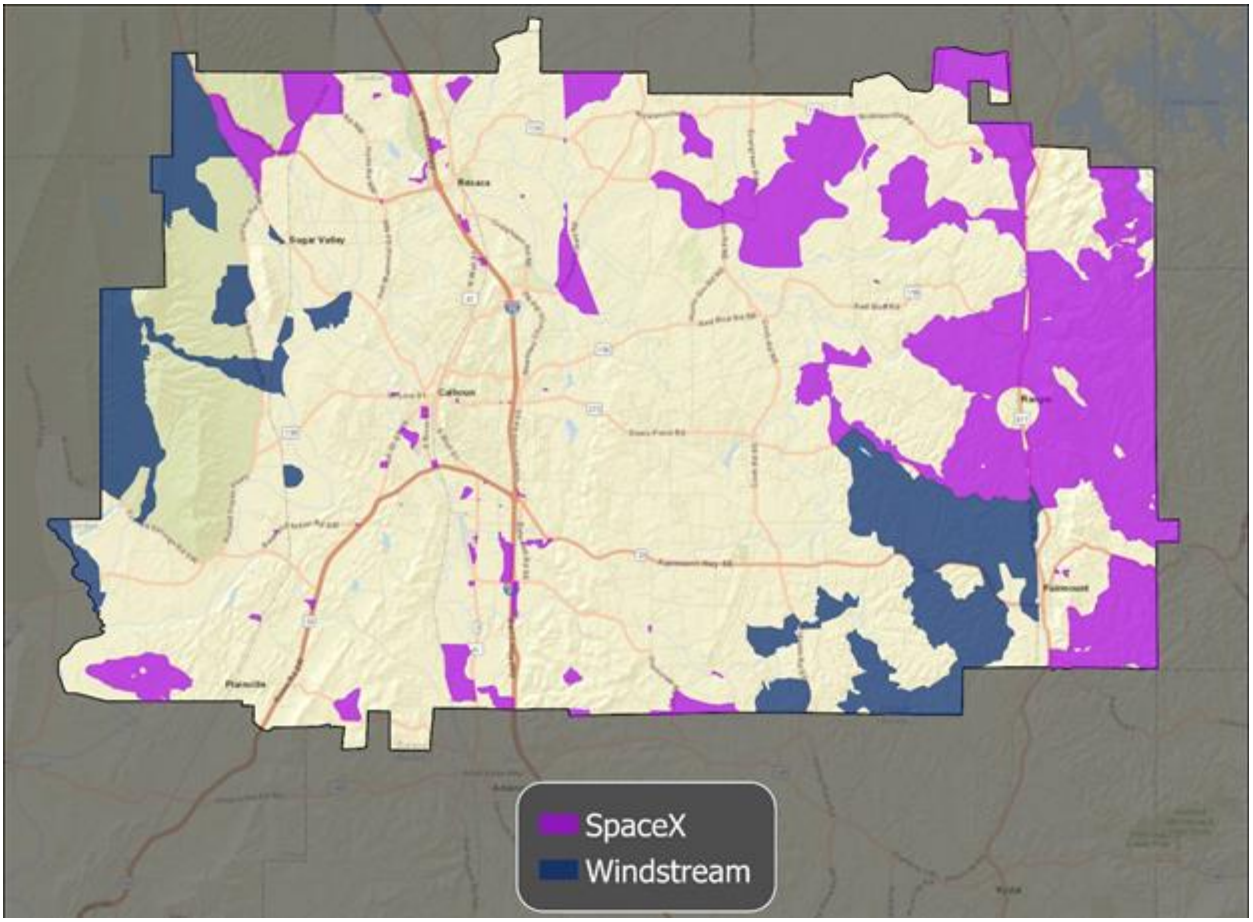
Item	**Cost**
Incremental Premises Cost (60% Penetration)	$1,600,000
Total Cost per Unserved Location (60% Penetration)	$1,350

4.5.5 Rural Digital Opportunity Fund Results for Gordon County

According to the State, approximately half of Gordon County is unserved, and unserved locations are distributed throughout most of the county's geography. However, RDOF funding has been awarded predominantly in the eastern third of the county, extending from Audubon to Oakman, and south to Ranger and Yarboroughs Mill. Funding in other parts of the county is located closer to the edges of the county's borders.

Figure 26 shows RDOF auction results for Gordon County.

Figure 26: RDOF Auction Results for Gordon County



RDOF funding was awarded for 1,816 locations between two bidders, SpaceX, and Windstream—slightly more than ten percent of the unserved locations in the county, leaving the majority of the county, especially the central portion, unserved.

SpaceX proposes to provide satellite connectivity to 1,463 locations, while Windstream will provide fiber to 353 locations. Windstream won locations only in the southeast and western border. The interest in the western part of Gordon County is probably because of proximity to the northern tip of Floyd County and some additional bleed into neighboring counties, where Windstream won RDOF bids. Windstream's southeastern area connects with their RDOF awards in the corners of Bartow County, Cherokee County, and Pickens County.

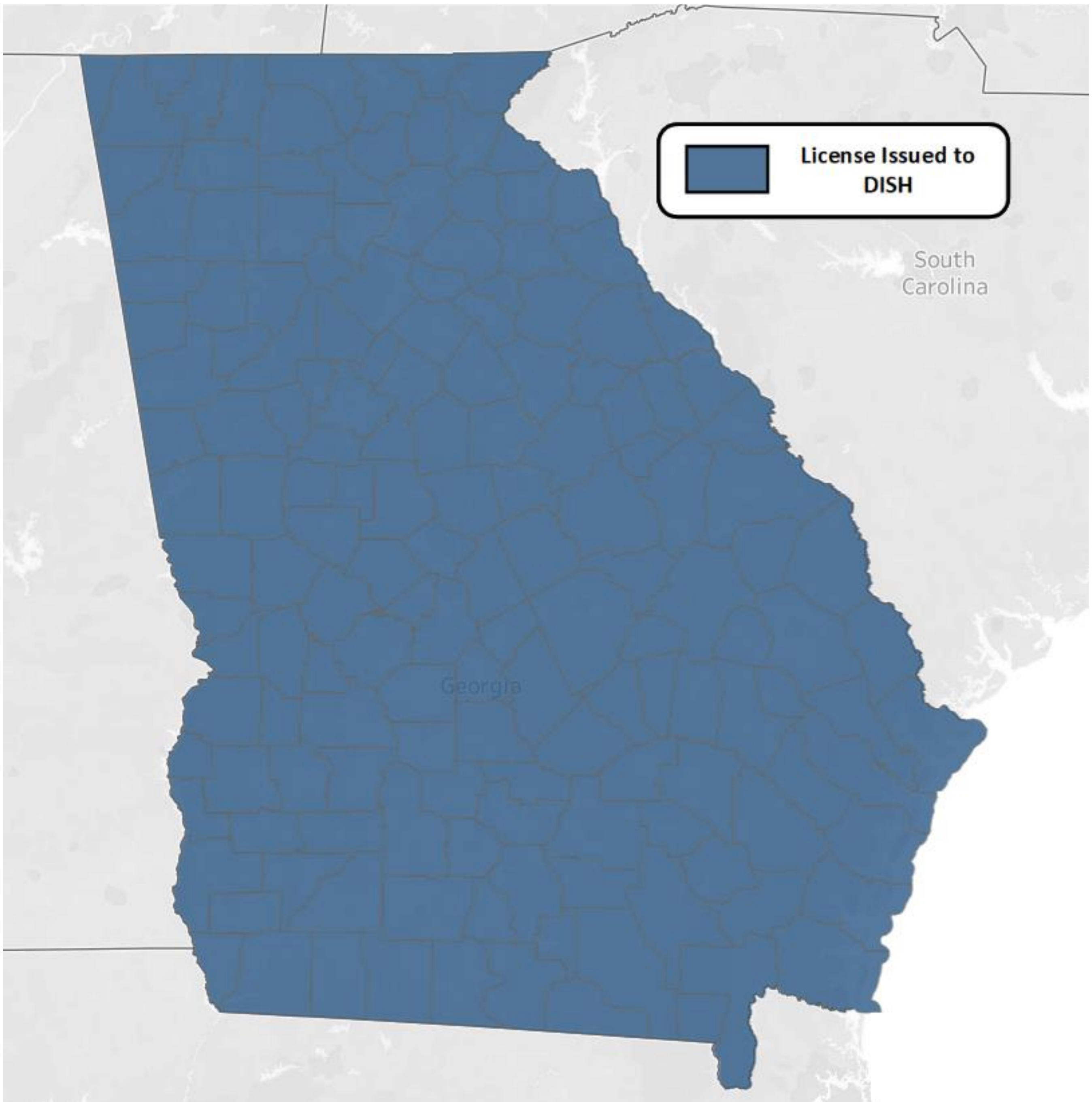
SpaceX's coverage in eastern and northern Gordon County does not continue onwards to the neighboring counties. Instead, SpaceX's RDOF awards extend south of Gordon County rather than north or east of it. Windstream's area on the western border could provide service to an area that could not be reached by the proposed wireless network. SpaceX's coverage can also provide service to the eastern side of the county where tower coverage would be weaker.

Appendix A – CBRS Priority Access License (PAL) Holders

The following maps show where each licensee holds licenses.

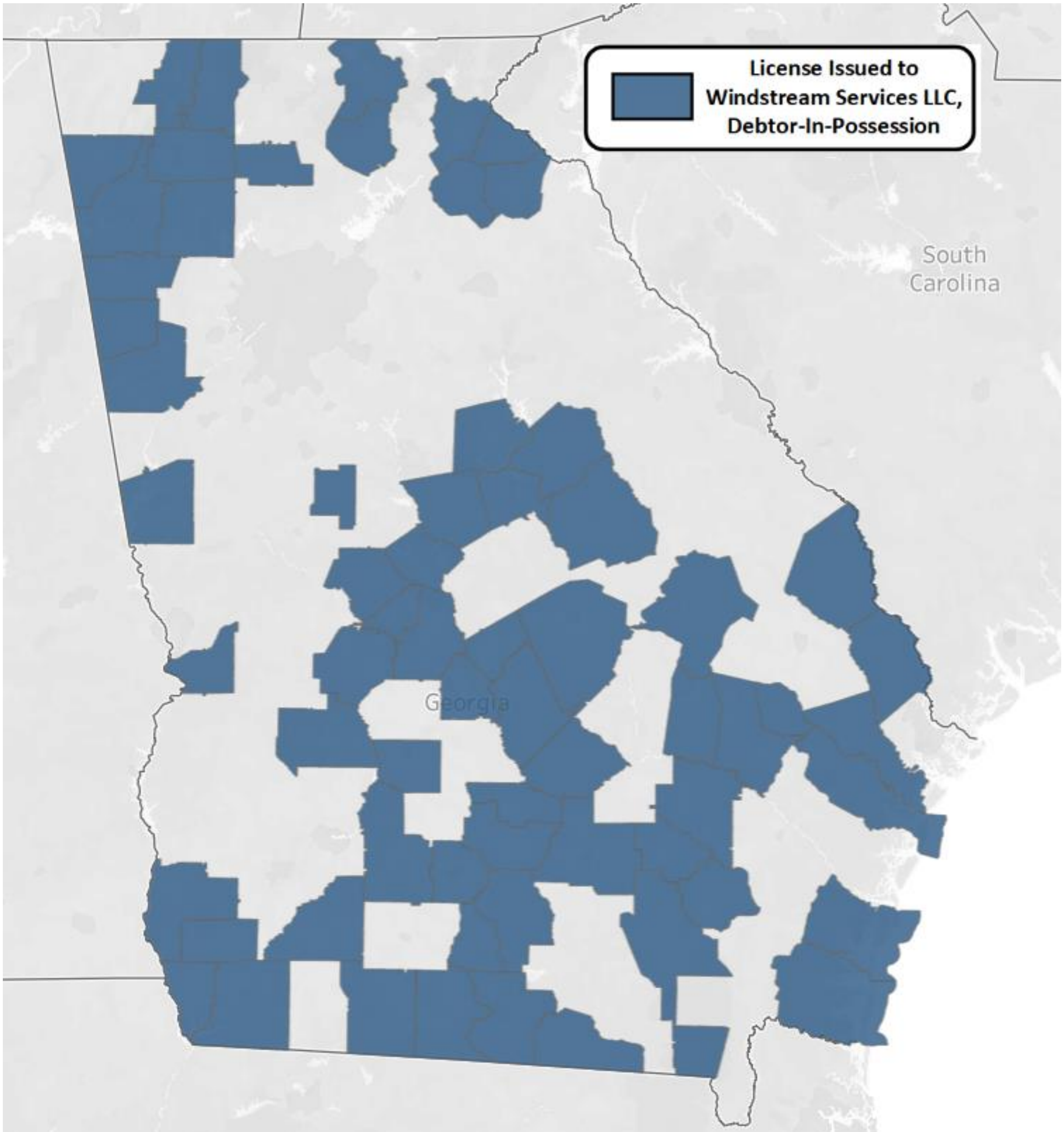
DISH holds 340 licenses in all 159 counties in Georgia.

Figure 27: DISH PAL Licenses



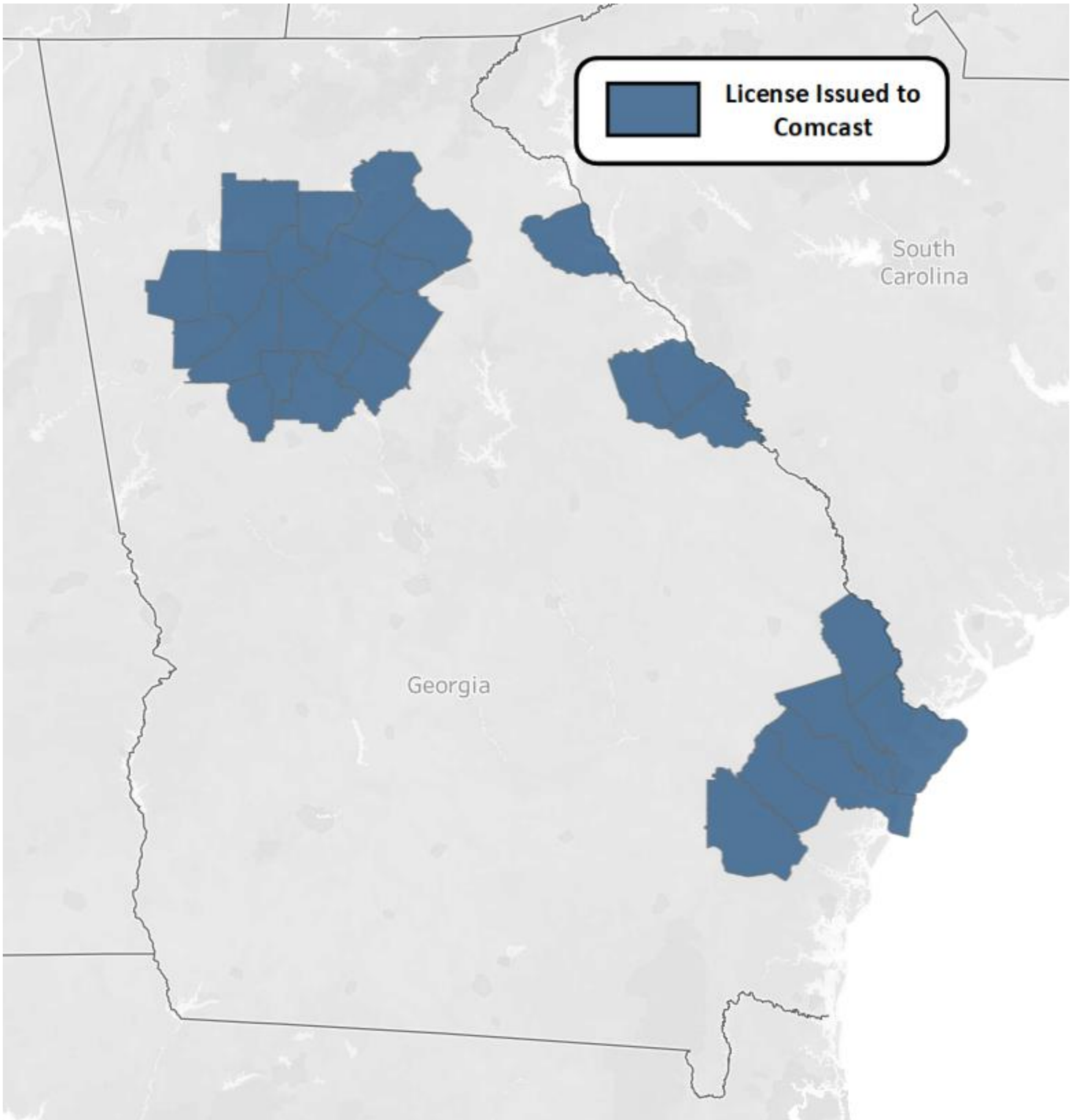
Windstream Services LLC, Debtor-In-Possession holds 233 licenses in 67 counties.

Figure 28: Windstream PAL Licenses



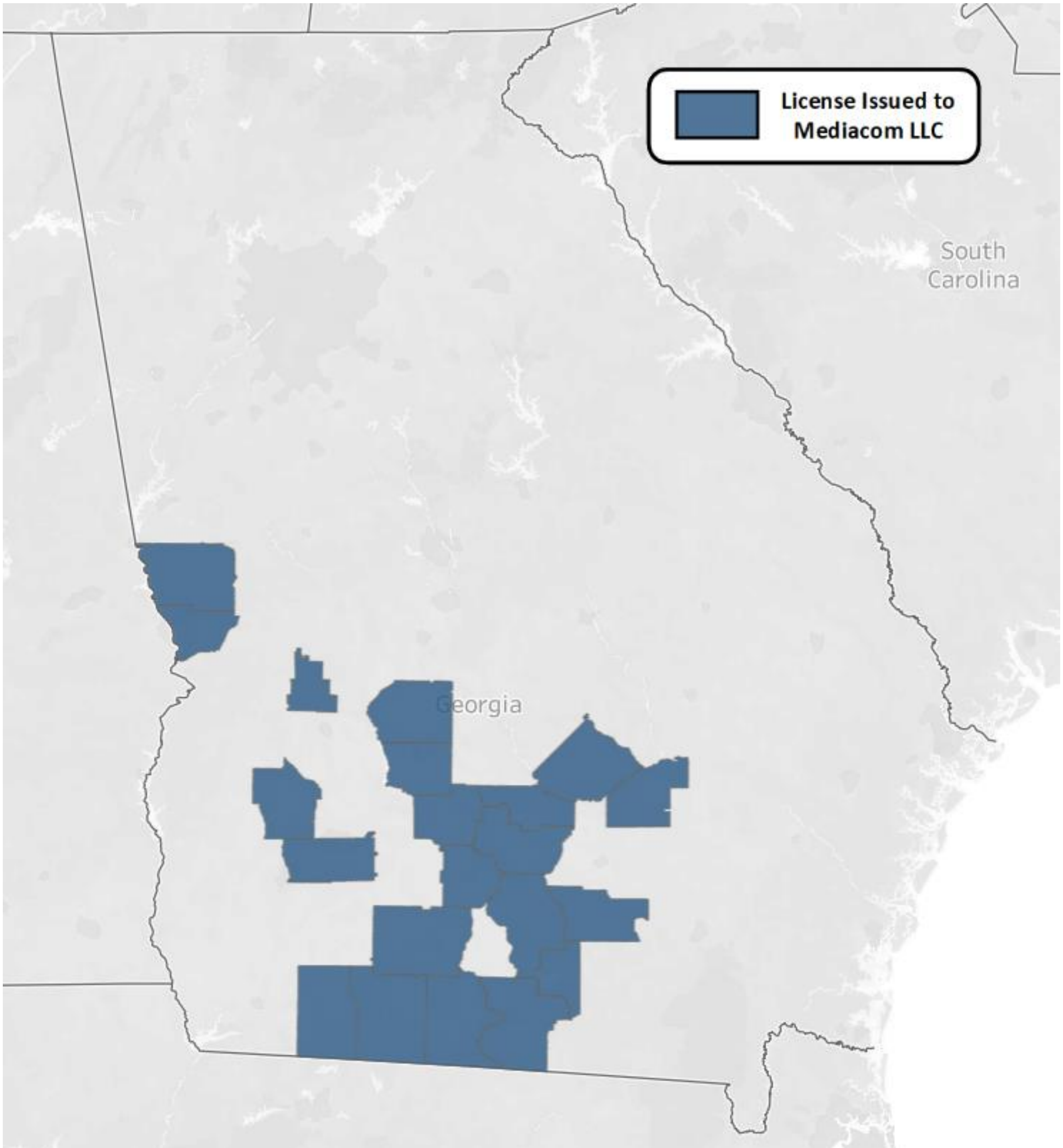
Comcast holds 87 licenses in 27 counties, in four contiguous patches of counties in the north and along the eastern border with South Carolina.

Figure 29: Comcast PAL Licenses



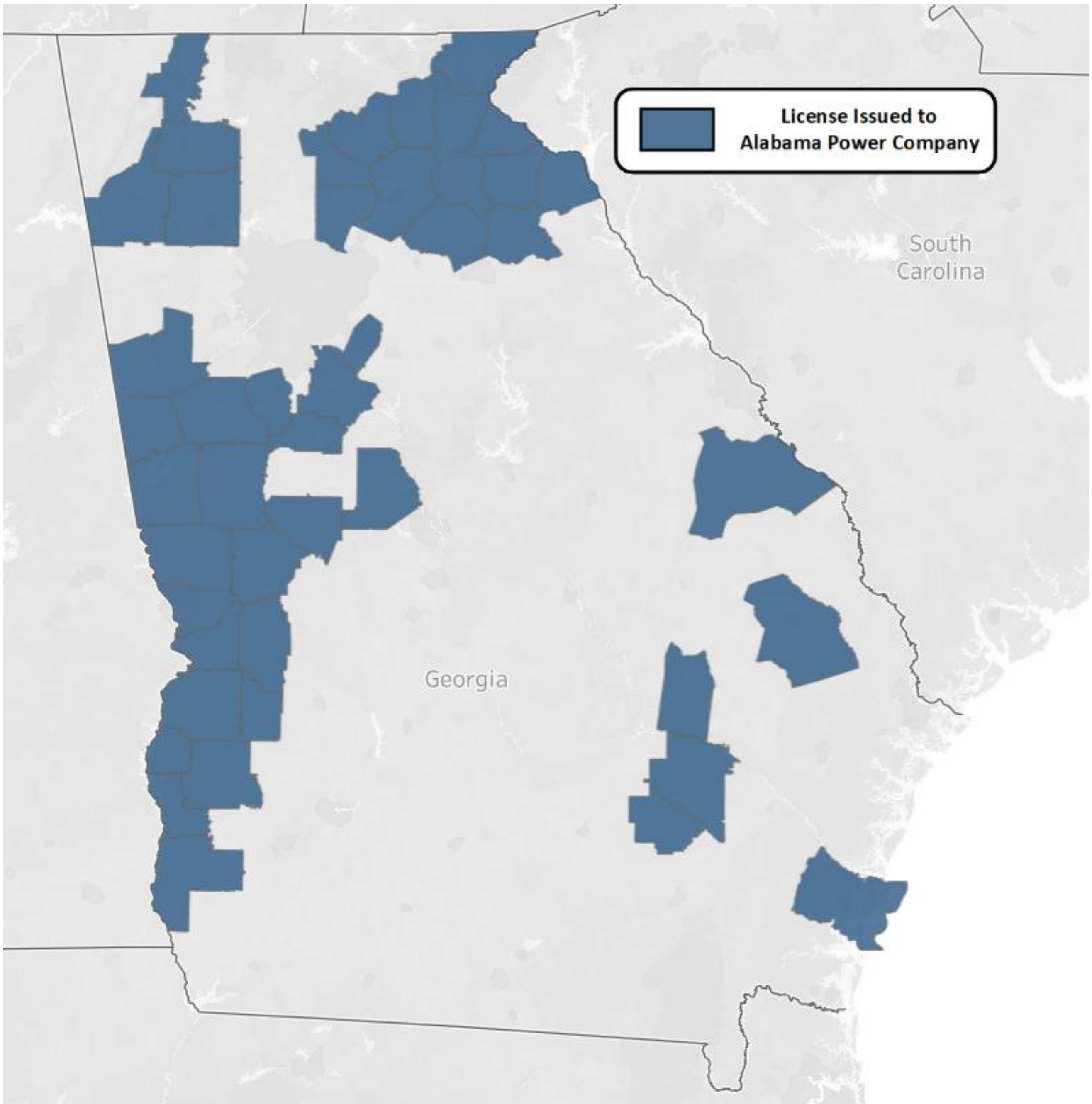
Mediacom LLC holds 73 licenses in 21 counties the southern half of Georgia.

Figure 30: Mediacom PAL Licenses



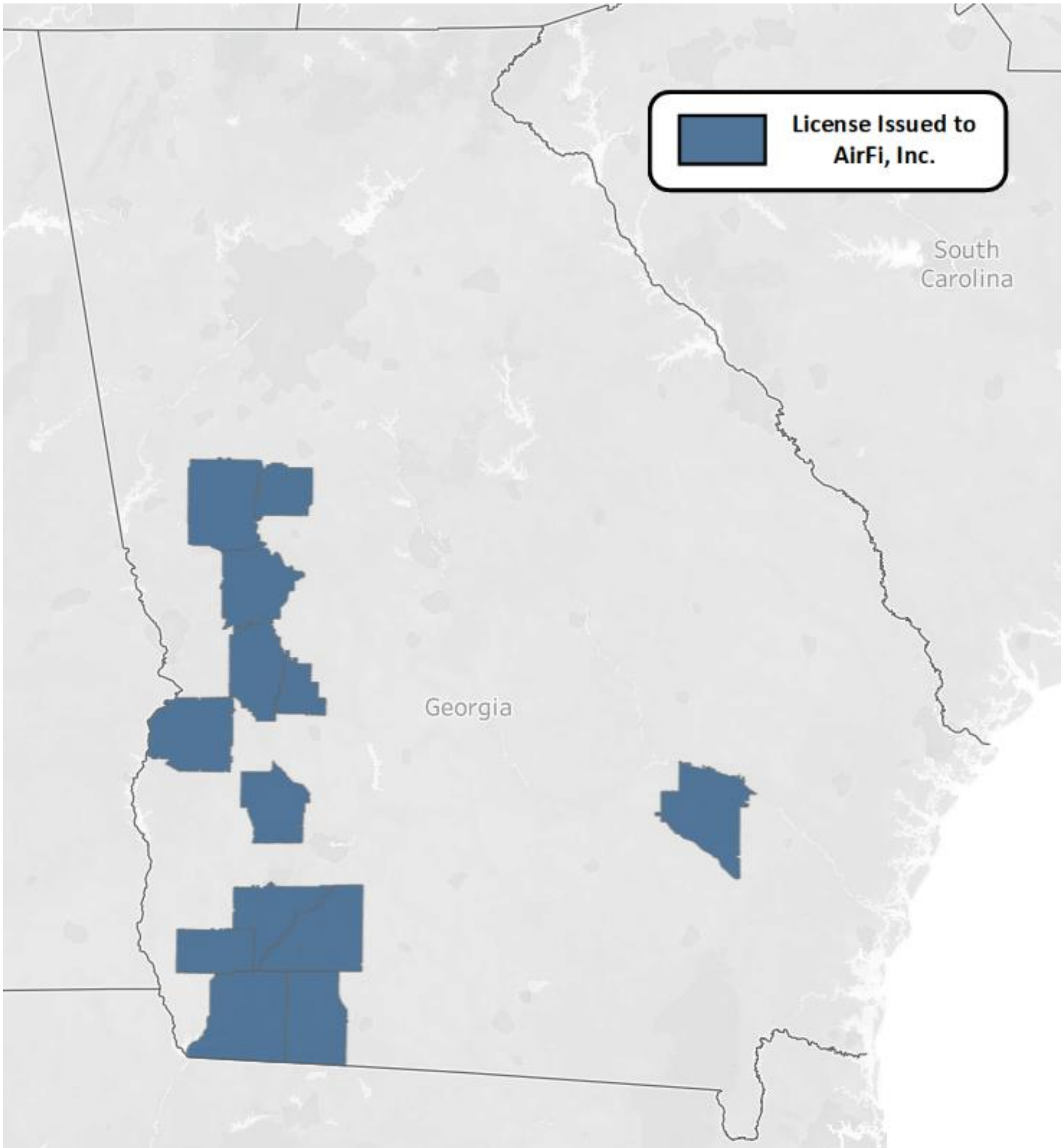
Alabama Power Company holds 51 licenses in 45 counties, in several large patches throughout all of Georgia.

Figure 31: Alabama Power PAL Licenses



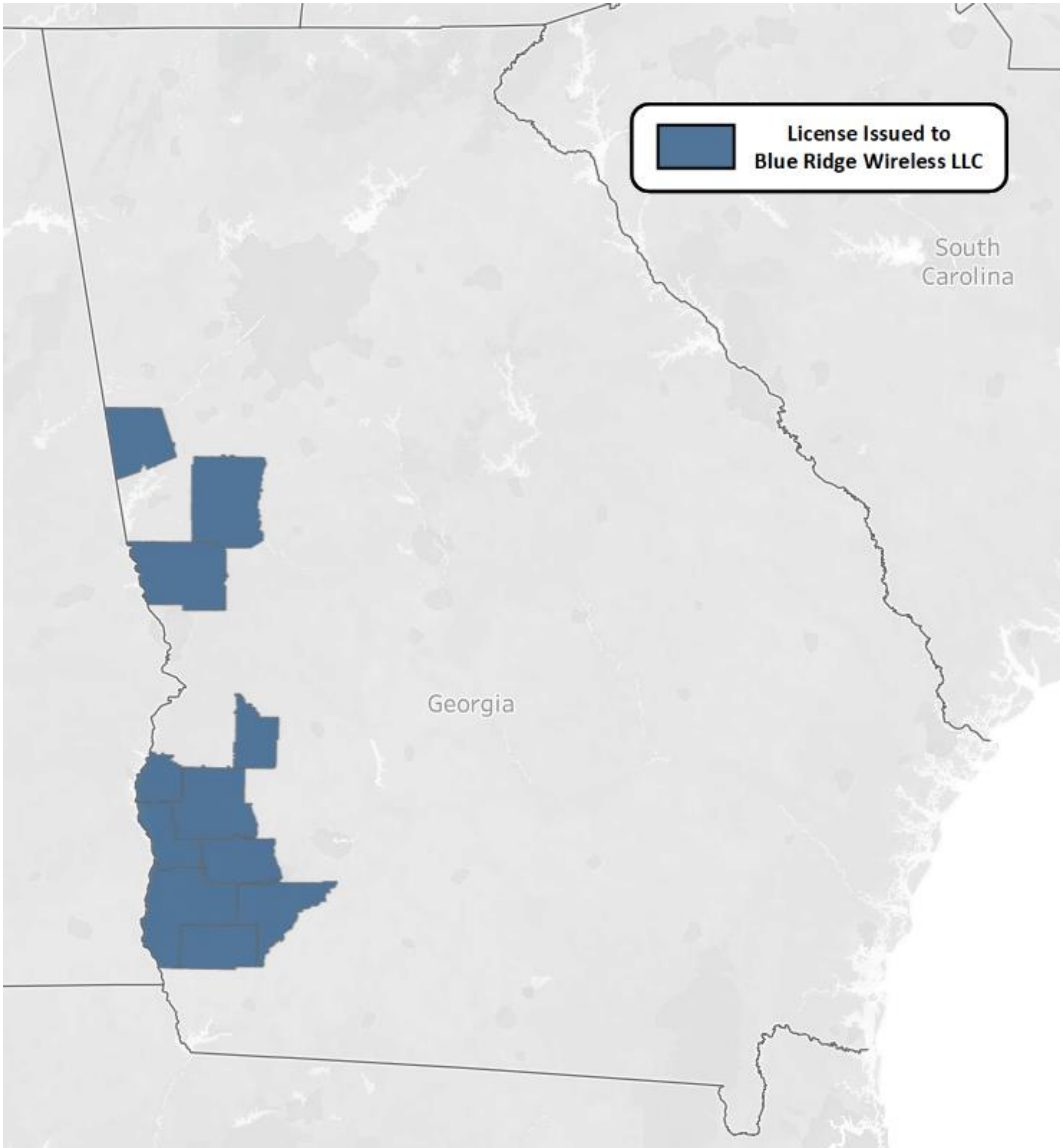
AirFi, Inc. holds 39 licenses in 13 counties in western Georgia.

Figure 32: AirFi, PAL Licenses



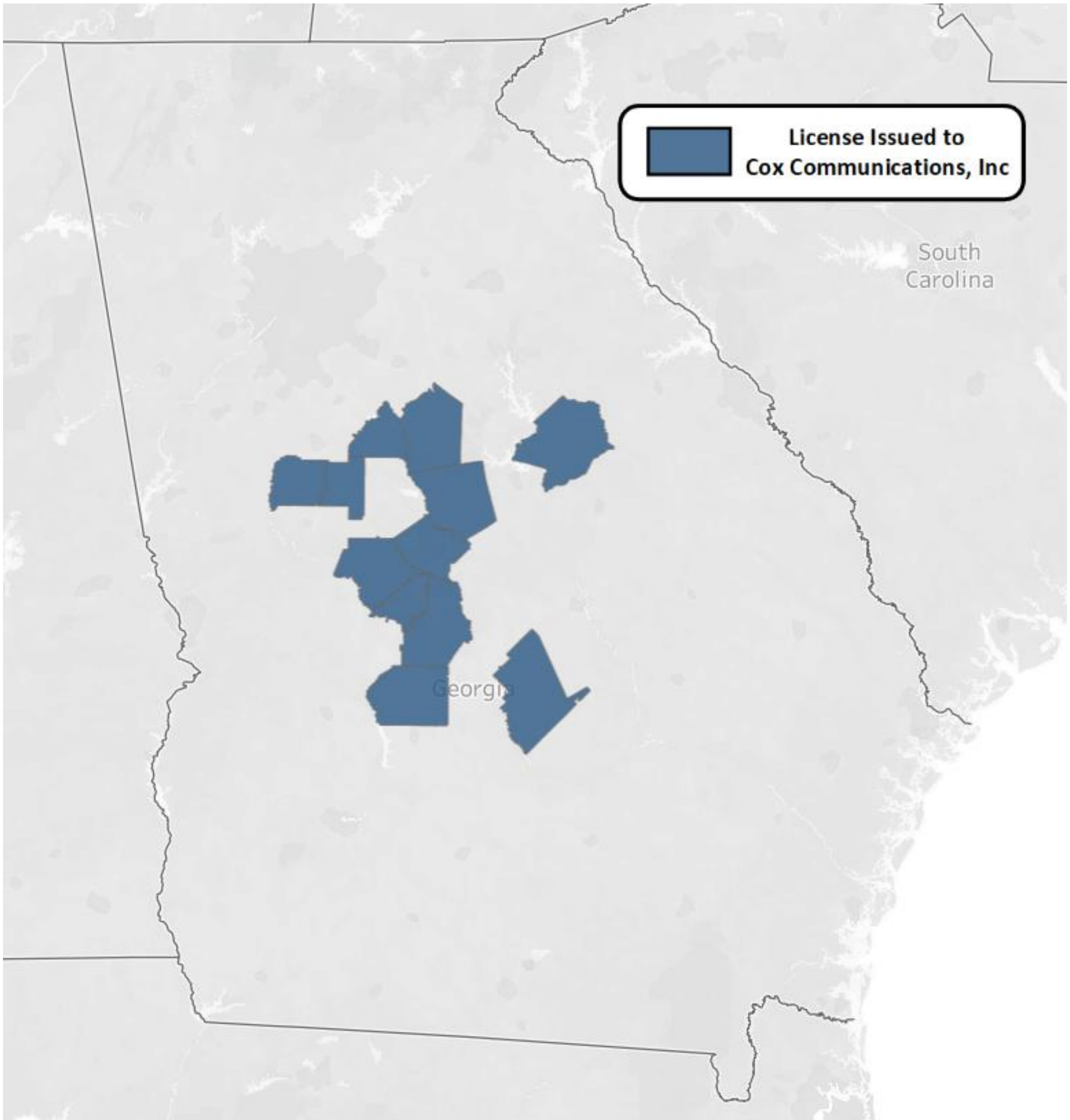
Blue Ridge Wireless LLC hold 31 licenses in 11 counties in western Georgia.

Figure 33: Blue Ridge Wireless PAL Licenses



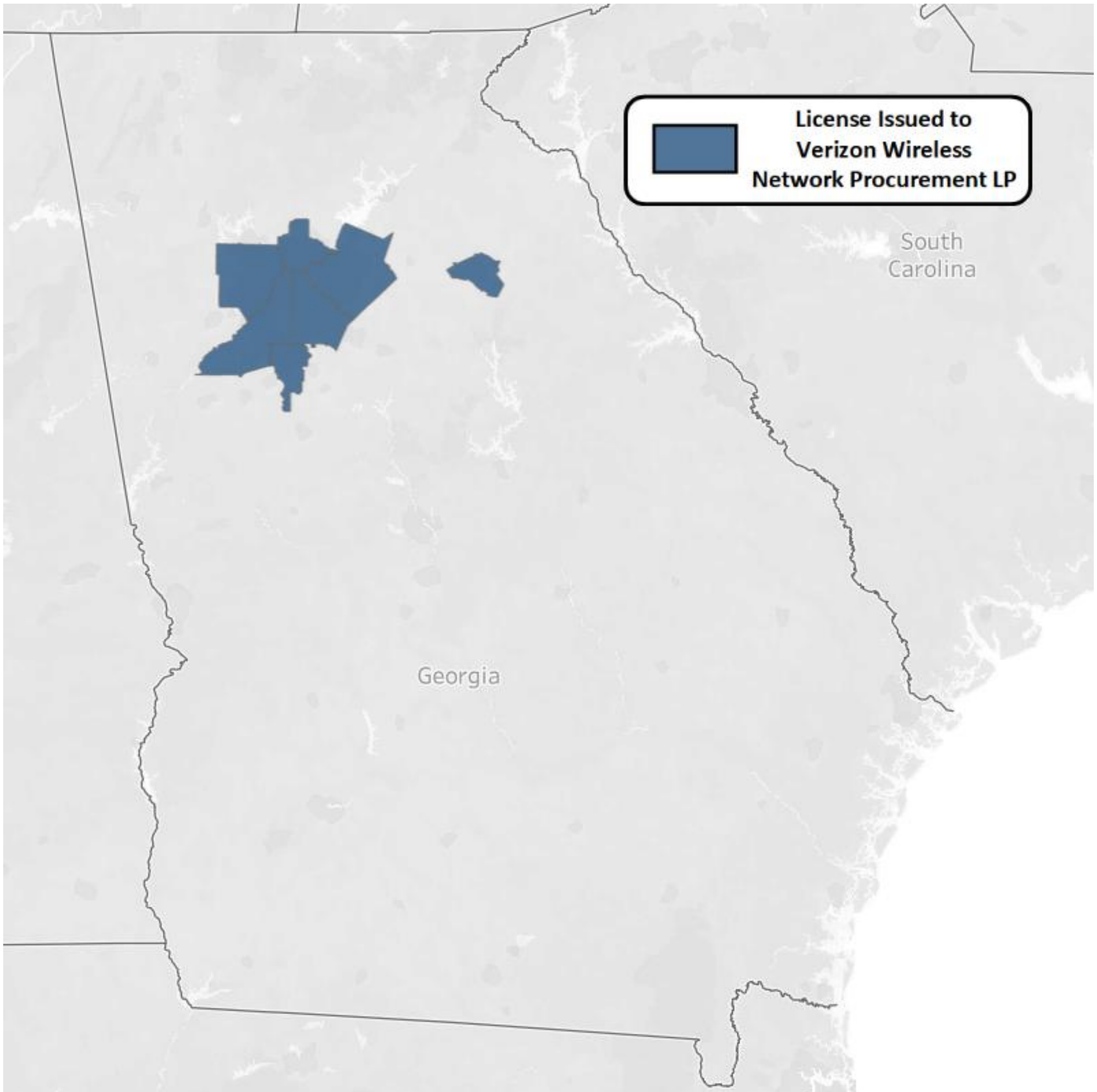
Cox Communications, Inc holds 28 licenses in 12 counties in central Georgia.

Figure 34: Cox Communications PAL Licenses



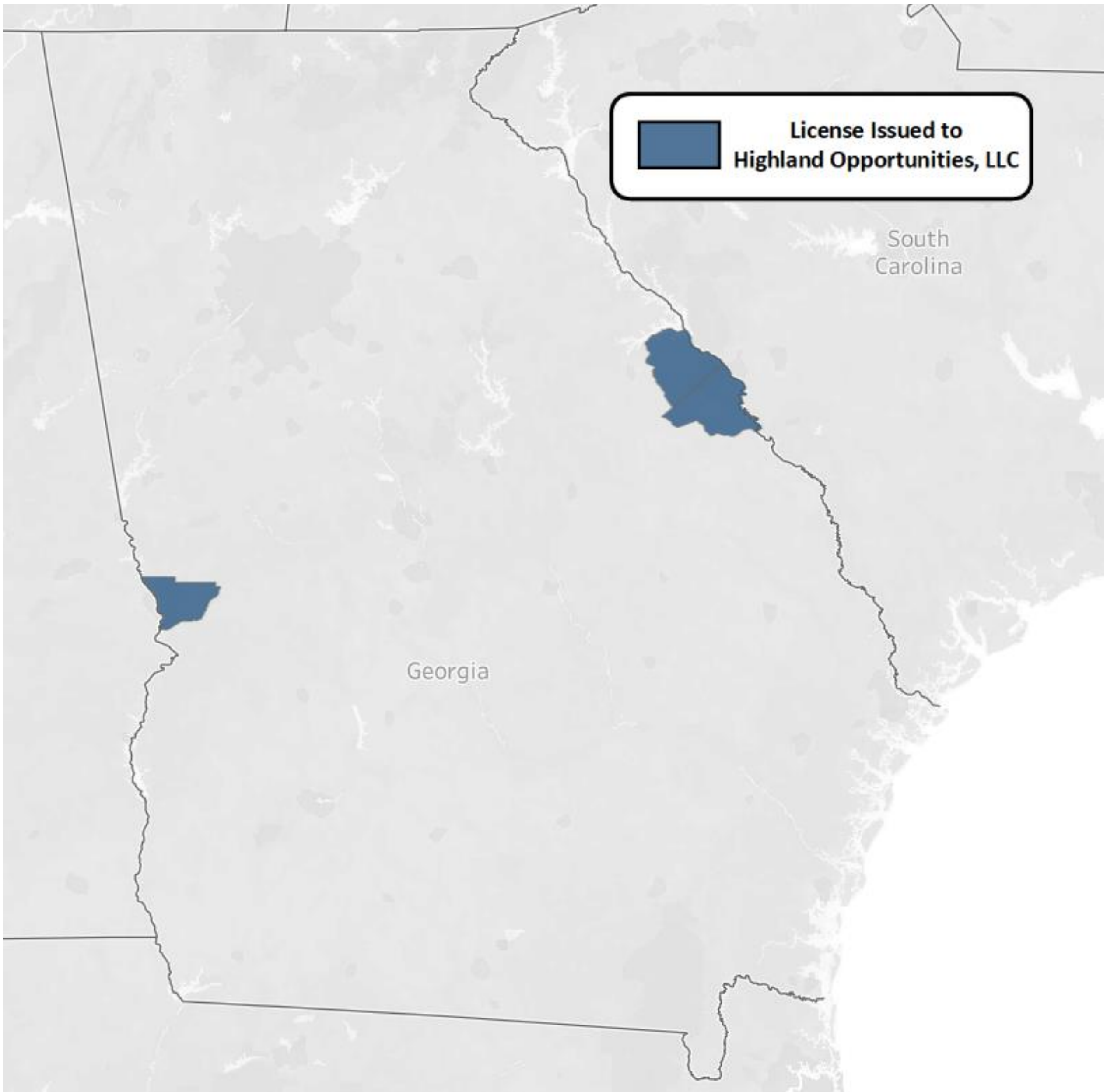
Verizon Wireless Network Procurement LP holds 19 licenses in six counties in Northern Georgia.

Figure 35: Counties in Which Verizon Wireless PAL Licenses



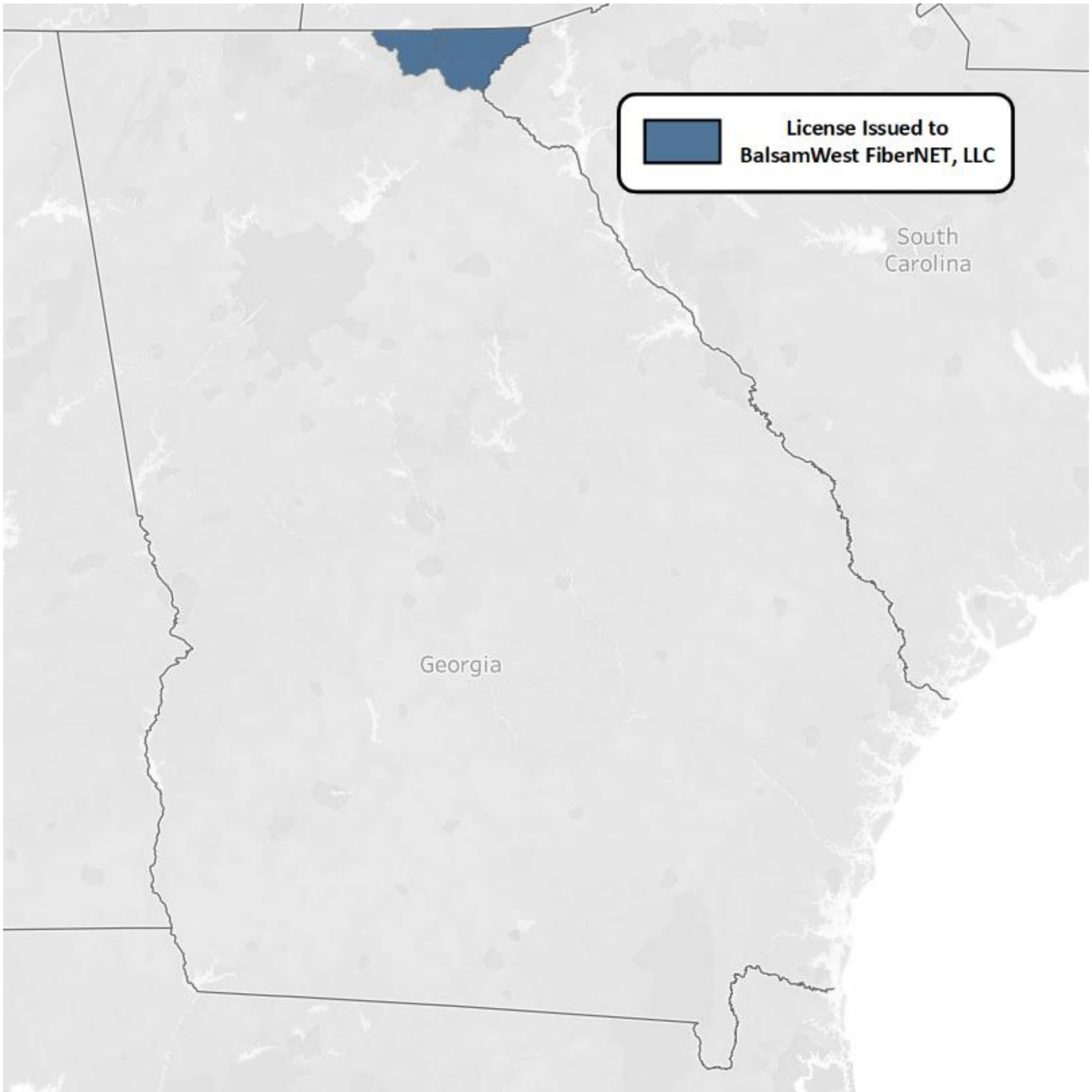
Highland Opportunities LLC holds six licenses in three counties.

Figure 36: Counties in Which Highland Opportunities PAL Licenses



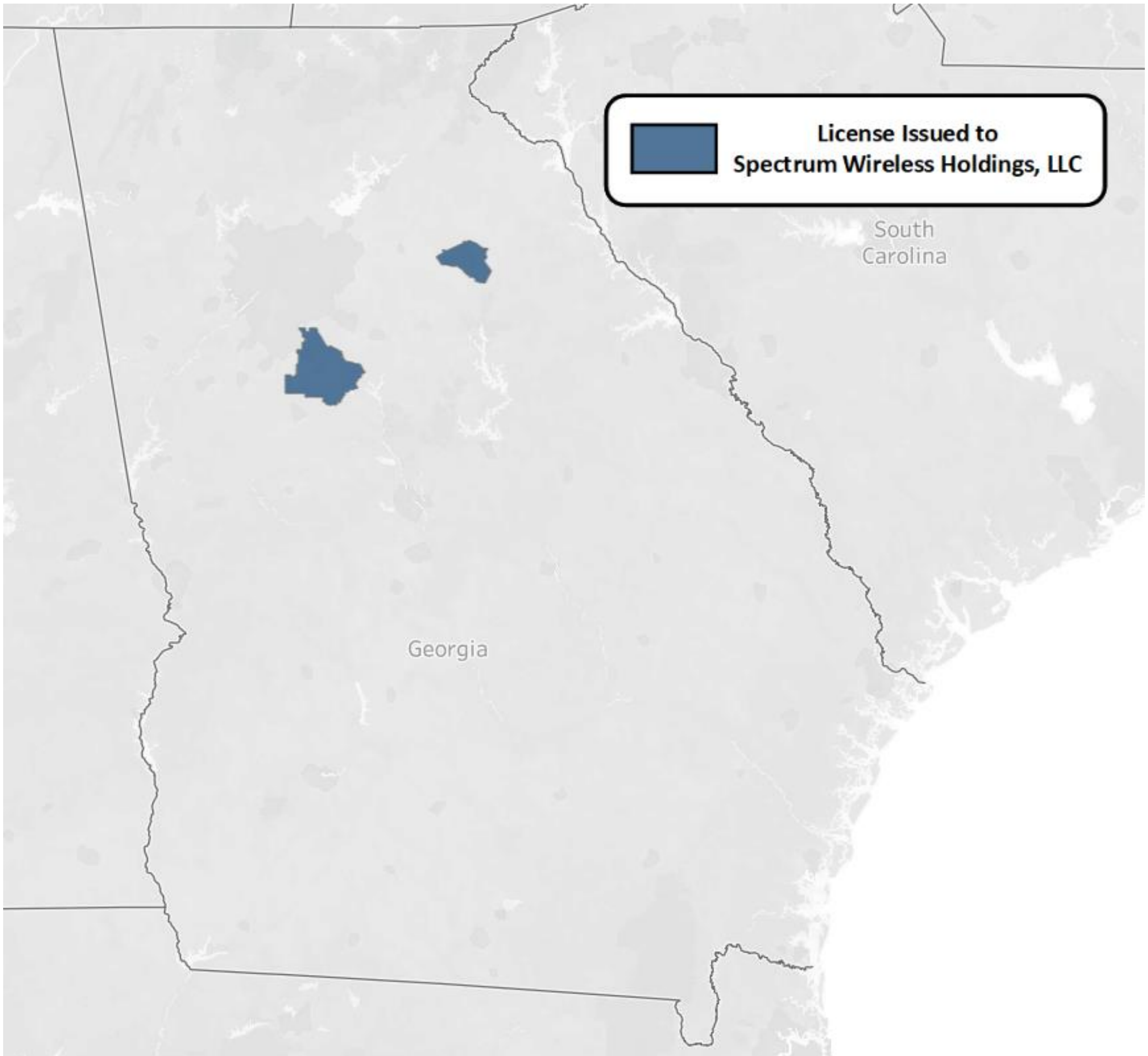
BalsamWest FiberNet, LLC holds five licenses in two counties.

Figure 37: BalsamWest FiberNet PAL Licenses



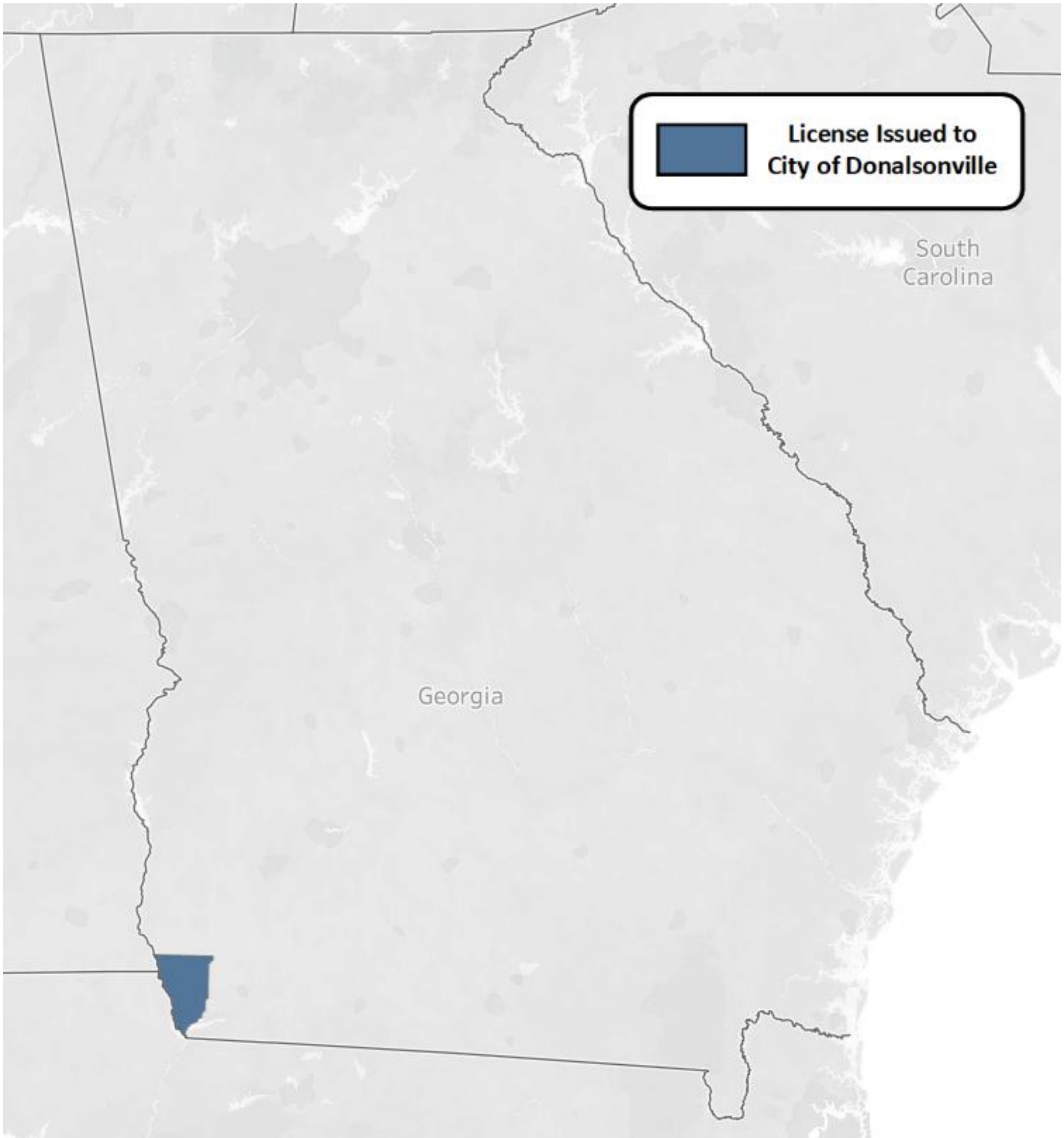
Spectrum Wireless Holdings, LLC holds four licenses in two counties.

Figure 38: Spectrum Wireless Holdings PAL Licenses



The City of Donalsonville holds two licenses in one county.

Figure 39: City of Donalsonville PAL Licenses



SAL Spectrum, LLC holds one license in one county.

Figure 40: SAL Spectrum PAL License Area