CITY OF FAIRFIELD, CA

Broadband Action Plan

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Magellan ADVISORS

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Executive Summary

This Broadband Action Plan is an addendum to the previous Broadband Development Plan. After review of the Broadband Development Plan, City of Fairfield leadership is exploring options to invest in broadband because it is critical to the community and well-aligned with government innovation and economic vitality. The City seeks to capitalize on network investment to attract industry, specifically internet service providers and similar companies, to Fairfield.

This Broadband Action Plan considers and provides options for the City to develop broadband infrastructure. While the focus is a wholesale network business model with publicly-owned infrastructure that can be leased to and used by third parties for community benefits including economic development, enhanced quality of life, and greater resilience to manmade and natural disasters, there are a number of other options the City can take to enhance broadband.

Options available to Fairfield for considering the development of broadband include:

- Status Quo: Fairfield could choose to take no action and rely on market forces to meet the needs of the community. The City should be advised that because most telecommunications companies are market takers, not market makers, they invest based on demand, not to generate it. This means that few investments are made in new infrastructure that serves communities where demand hasn't reached an obvious tipping point, allowing internet service providers to achieve a rapid return on any investments they make by capturing a large market share.
- **Working with Current Providers**: The City could open and maintain dialogue with incumbent internet service providers in Fairfield about their plans and needs for continued investment in the community. While this approach is

unlikely to disrupt the existing broadband environment in Fairfield, it could lead to constructive improvements in services for residents and businesses. This option has no risk for the City.

- **Programmatic Options:** The City could provide incentives for private investment in network infrastructure by assisting providers with pursuing funding opportunities to build new assets in Fairfield. Although most grant programs are targeted at more rural, underserved communities, it is possible that Fairfield could be eligible for some future funding opportunities that could attract the interest of providers. Having a public partner in these situations is often beneficial, and Fairfield could leverage that position to ensure investment is targeted in a way that aligns with the City's goals. The City could consider collaboration with Non Profits for digital literacy programs, and other options such as donation programs, low cost internet options, etc. for addressing digital equity. This option has no risk for the City.
- **Public Private Partnership:** Fairfield could establish relationships with internet service providers (either incumbent or new entrants) in which a variety of business model options are possible, including for the City and the partner to co-invest in new infrastructure. This option has many varieties and could be explored through a competitive Request for Information (RFI) or Request for Proposals (RFP) process to engage interested parties. Resultant agreements might include sharing of revenue for City-owned assets in exchange for a private partner to oversee network operations and management This option has little risk for the City.
- **City-Owned Utility:** The most aggressive option the City has is to invest in its own broadband infrastructure and offer dark fiber or lit services via a City of Fairfield Broadband Utility. This option will require the most investment and risk, but will give the City the most control over how infrastructure is deployed, ensuring equitable access and targeting areas that are most in line with

Fairfield's needs. This option is modeled in this report to demonstrate the financial feasibility of a Fairfield Broadband Utility.

Whether or not the City decides to move forward with the Broadband Utility option, Fairfield should partner with key stakeholders to target network investment where it will have the most value and identify prospective private sector broadband, cellular, and similar companies to lease network infrastructure and services. These tactics will enable the City of Fairfield to ensure robust citywide broadband is available, connecting more community members who require high-speed internet for daily functions and future growth.

This Plan analyzes the feasibility of a city-wide future-proof network capable of delivering high-speed broadband and other services to the community for decades[1]. This concept is used for a design that allows for general cost and coverage estimates based on available data and multiple assumptions. Various options for services and business scenarios are compared to ascertain the feasibility of the conceptual network and show interaction between various cost components and revenue streams.

Actionable steps and options for the City to build abundant, robust broadband are at the heart of the Plan, leveraging current infrastructure, planned projects, and partnerships with other public and private organizations. Potential pilot projects along the Texas Street corridor in the Heart of Fairfield, shown below, would allow the City to proof the concept and validate business assumptions. This area contains many businesses and City facilities, providing immediate benefits to the community.

[1] See the City of Fairfield Broadband Development Plan (Aug 2020) for additional details about broadband technologies including fiber-optics.

Network development through key industrial areas may be priorities depending on stakeholder needs and opportunities.

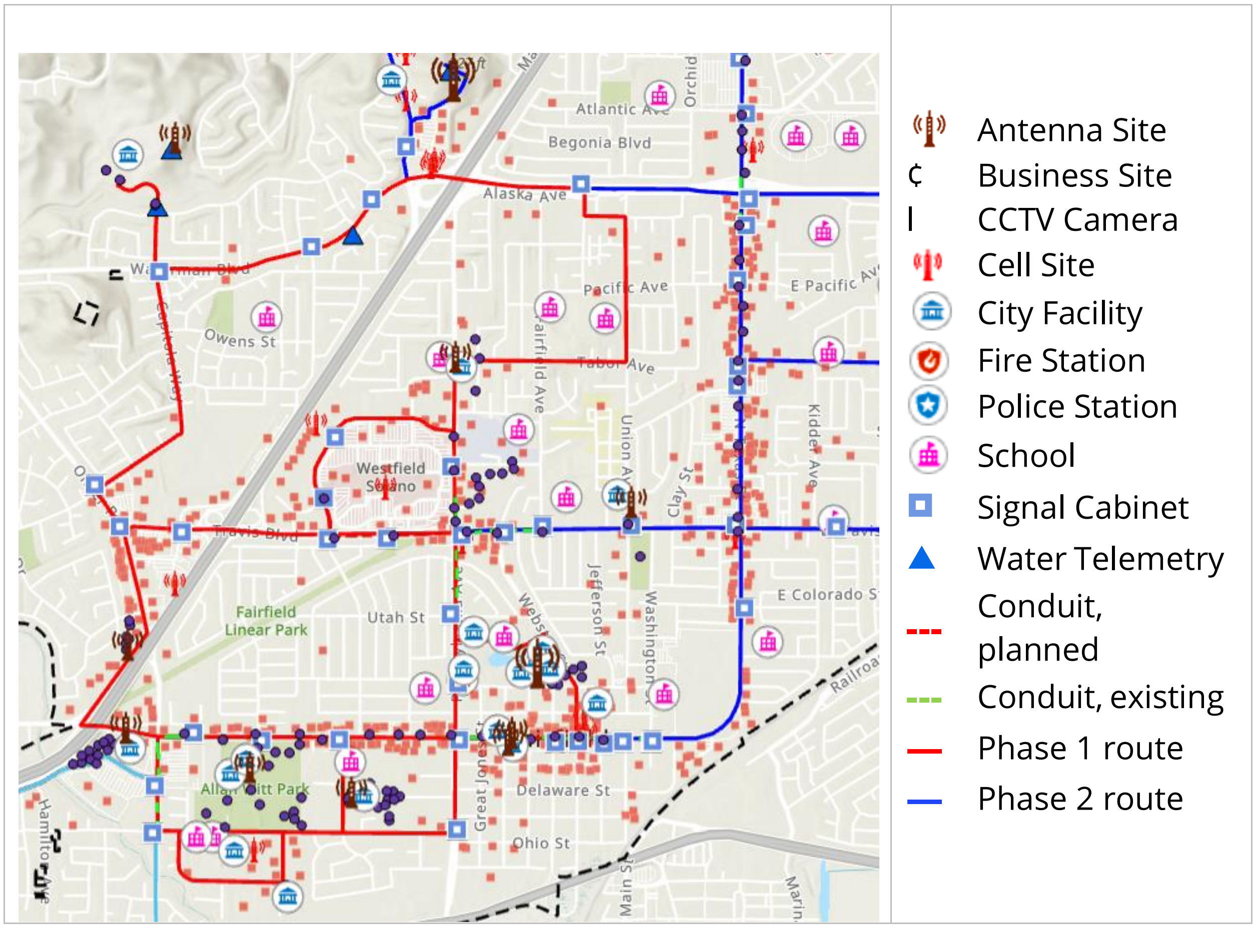


Figure 1. Heart of Fairfield Pilot Area

The City of Fairfield could choose to establish a Broadband Utility division with an enterprise and initial staff and build a citywide fiber optic backbone similar to the conceptual design in alignment with capital projects, City requirements, and community demand. The financial analysis shows that a combination of services can provide acceptable results with the conceptual network.

1. Introduction

During 2019-2020, Magellan Advisors produced a Broadband Development Plan[2] for the City of Fairfield that focused on internal municipal requirements and private providers as potential partners. The Plan included an in-depth consideration of broadband business models and technologies, an employee inventory of municipal and other local network assets, and a vision for a network to incorporate those assets to meet the City's connectivity needs.

Since that time, new City leadership became interested in taking a more active role in exploring the feasibility of establishing a "broadband utility." Recognizing that the City could not practically take on such an enterprise, as broadband operations can be quite complex and labor-intensive, it was determined that a feasibility and business model exploration focusing on an "open access" or wholesale business model should be undertaken. The City asked Magellan Advisors for an addendum to the original plan to include input from the community, as well as:

- Gap analysis to determine areas of the City that are unserved or underserved
- Conceptual network design adjustments to meet the needs of a more diverse range of stakeholders, better align with Fairfield's broadband goals, and identify cost saving and revenue generating opportunities
- Financial analysis of various business scenarios to ensure that the City has a full understanding of the business and financial suitability of the various options

[2] Final reported delivered August 4, 2020.

The goal is for Fairfield to make informed decisions on ensure connectivity for the City and community, including strategies that require no General Fund funding.

2. Community Input

Community input was acquired via a community survey and interviews with representatives of some major stakeholder organizations and key community sectors. An analysis of survey results is below, followed by a summary of findings from stakeholder interviews. Although results from the survey and interviews is not statistically reliable due to distribution methods, the data does provide key insights into the current broadband environment in Fairfield and the need for a City-sponsored broadband program.

COMMUNITY INTERNET SURVEY

Magellan Advisors provided online and print survey instruments, the latter with only two pages specifically for those without internet service. All responses were received via the online instrument; no print surveys were submitted. The City promoted the survey via various means, including email, partners' email, and multiple social media, in several waves between early August and the end of November (2021). There was a total of 300 responses, which yielded a total of 247 unique, usable responses, 64% of which (158) were complete. Eighty five percent (211) were from households, 15% (36) were from organizations. Half of responses came from each of Fairfield's two zip codes, 94533 and 94534.

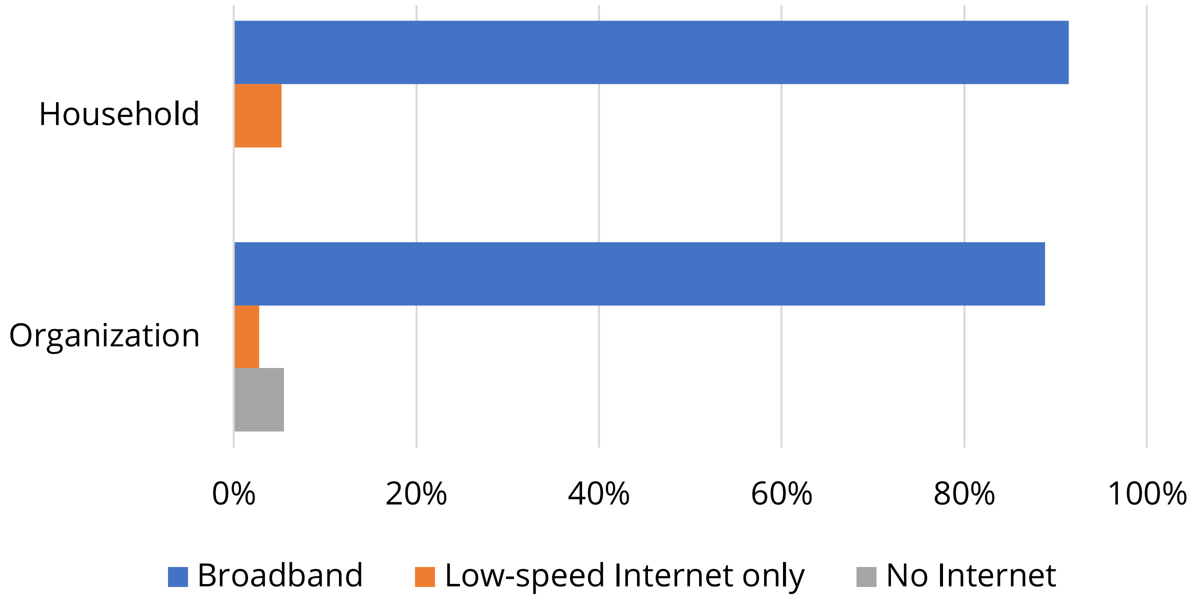


Figure 2. Percentage of 239 Survey Responses by Type and Internet Service

As shown in Figure 2, all respondent households had internet, and 91.5% had broadband. Two organizations indicated having no internet, and 90% had broadband.

Of the 132 households that provided demographic data, the average household size was 3.0 persons with a median age of 46.5 years. The US Census Bureau[3] estimated the population mean household size was 3.1 and the median age was 35.3.

[3] Unless otherwise indicated all estimated population statistics were sourced from the U.S. Census Bureau, 2019 American Community Survey, 1-year estimates, accessed via https://data.census.gov/cedsci/

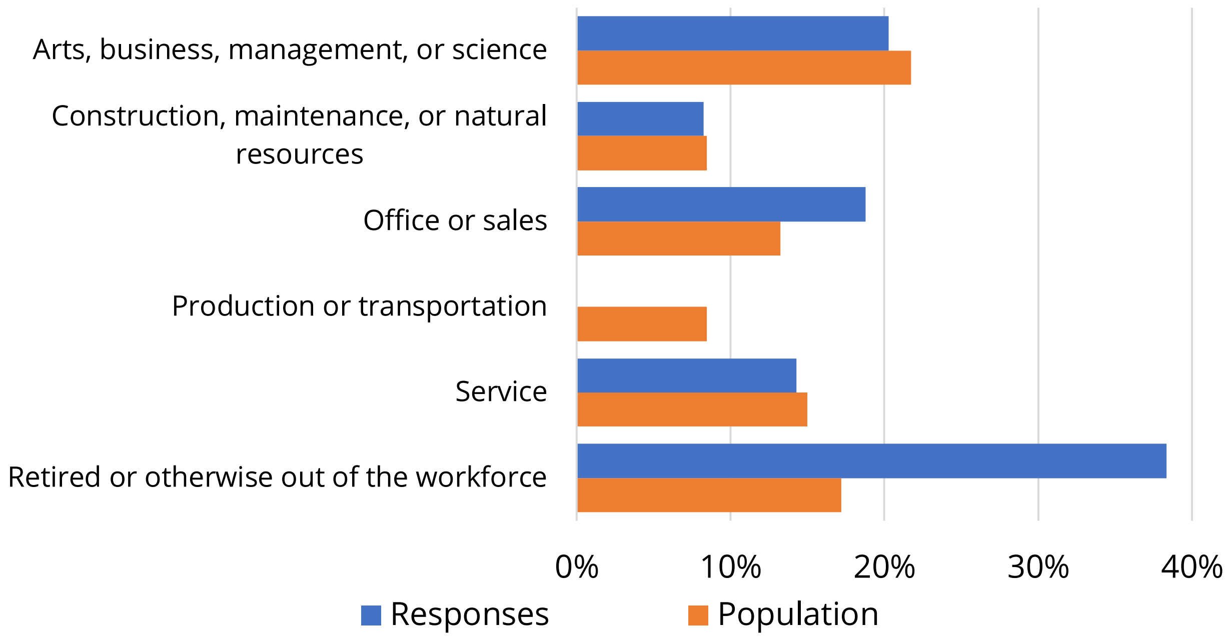


Figure 3. Occupation by Percentage of 132 Survey Responses and in the Population Compared

The occupations of survey respondents, illustrated in Figure 3, were similar to those in the population as indicated by US Census data. There were two notable exceptions. No persons employed in production or transportation occupations, which represented 8% of the local workforce, responded to the survey. Census data indicate that about 17% of the working age population was retired or out of the workforce, but over a third of survey respondents were retired or out of the workforce. Survey respondents were generally more educated than the population overall, as shown in Figure 4. Seventy percent of respondents were college-educated, and nearly 40% had graduate degree. The percentage of responses from those with some college was half of the population estimate (13.3% verses 26.3%), and percentage of respondents with high school only was one tenth the percentage in the population (2.2% verses 23.8%).

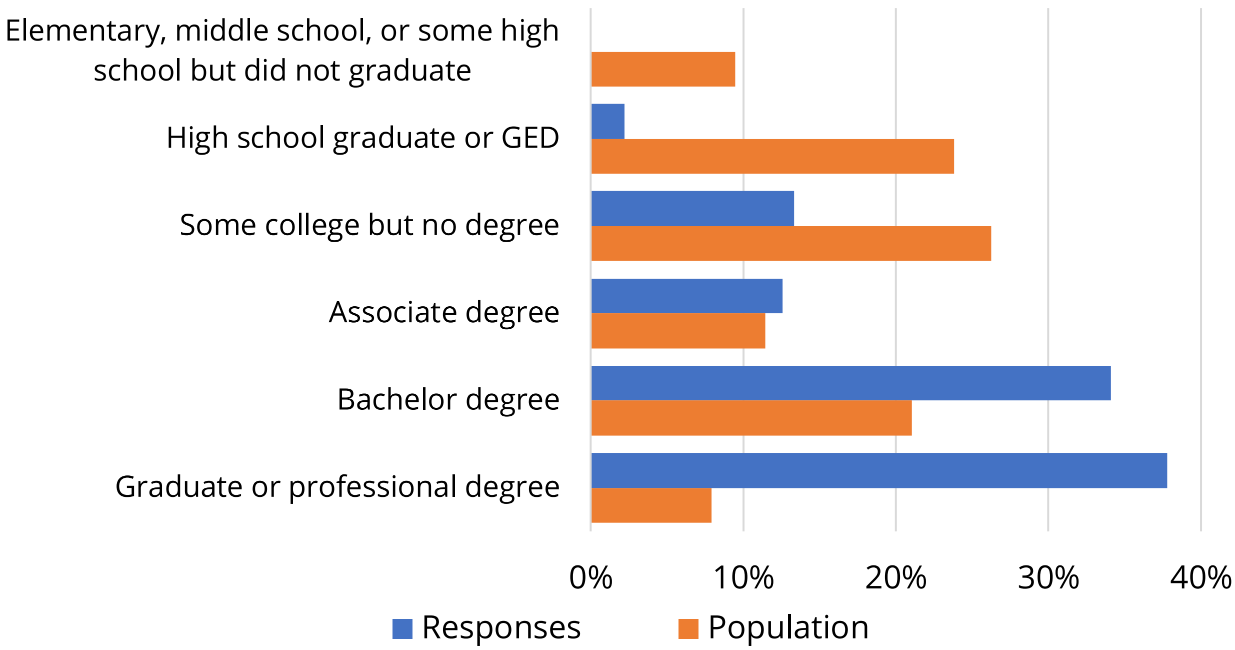


Figure 4. Level of Educational Achievement by Percentage of 135 Responses and in the Population

About 15% of responses were from organizations. Of the 22 that provided firm information, about a quarter (5) were in retail. Two responses came Fairfield's accommodation and food services sector, two from health care and social assistance, and two from manufacturing. A total of six were from companies providing professional and other services. Construction, educational services, finance and insurance, real estate and rental and leasing, and transportation and warehousing sectors each had one response.

Relative to the local economic base,[4] the survey had most responses from retail, manufacturing, transportation and warehousing, finance and insurance, and real

4 Local industry data is for Solano County from the California Employment Development Department, online at https://www.labormarketinfo.edd.ca.gov/LMID/Size_of_Business_Data.html. This data does not include disaggregated service sectors.

estate sectors. See Figure 5. Each responding company had one location in Fairfield and only one was not headquartered in the city. In total, respondents employed 99 people in Fairfield and 468 at all locations. The largest respondent had 20 local employees. The median size of responding companies was 2.5 employees.

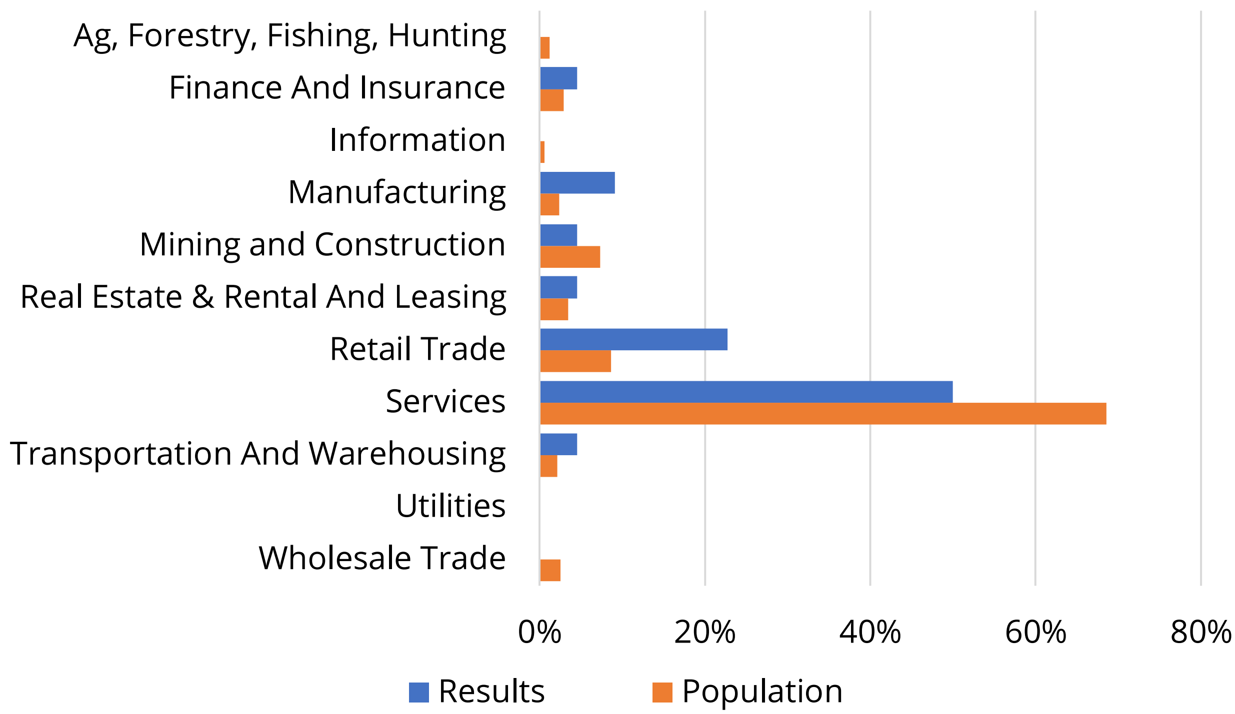


Figure 5. Percentage of 22 Survey Results by Sector Compared to the Local Economic Base Population of Firms

Professionally, respondents roughly mirrored the City's economy. Respondents tended to be more educated and older than Fairfield's general population**. Given the distribution methods, number of responses and respondent demographics, we cannot say that the survey results are statistically reliable**. *We can say that the survey results document the experience and perspective of 211 households (approximately 0.57% of Fairfield's 37,310 households) and 36 organizations (approximately 2.5% of Fairfield's approximately 4,750 organizations) in Fairfield.*

The survey yielded useful empirical indicators of broadband in the city. Recognizing results of survey analysis as indicators, we report statistics but use approximate language in discussing the findings. Generally, these results should be considered the “best case” for the more affluent and informed residents of the community. Additional effort would be required to determine the situation for younger, less educated residents. The same applies to large, multi-location service and wholesale companies.

Broadband Providers

While 225 respondents indicated having broadband, only 180 provided the name of the internet service provider. As shown in Figure 6, Comcast appears to dominate the Fairfield market with three quarters of subscribers, while AT&T has less than a quarter. Respondents had broadband Direct TV, T-Mobile, and Valley Internet. We know all these companies offer broadband although our market assessment found only Valley Internet with active service offering in Fairfield. Each had about 1% of responses.

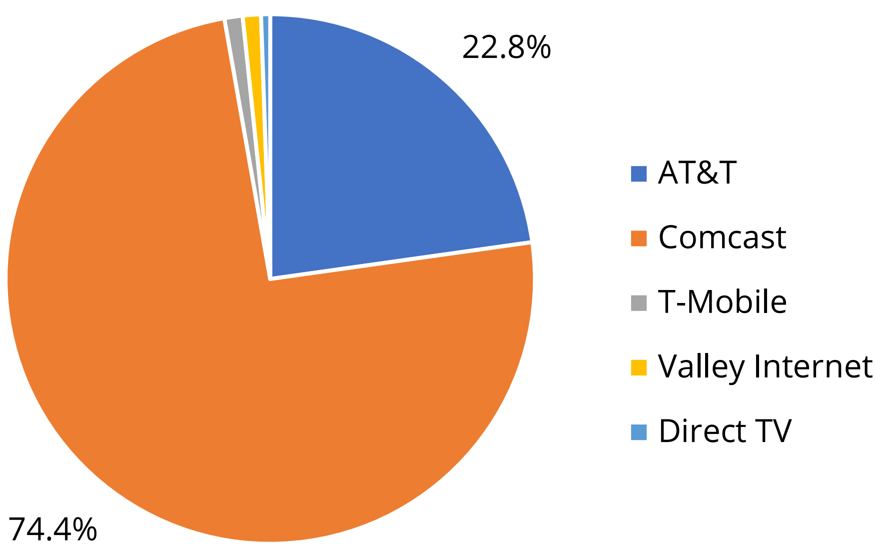
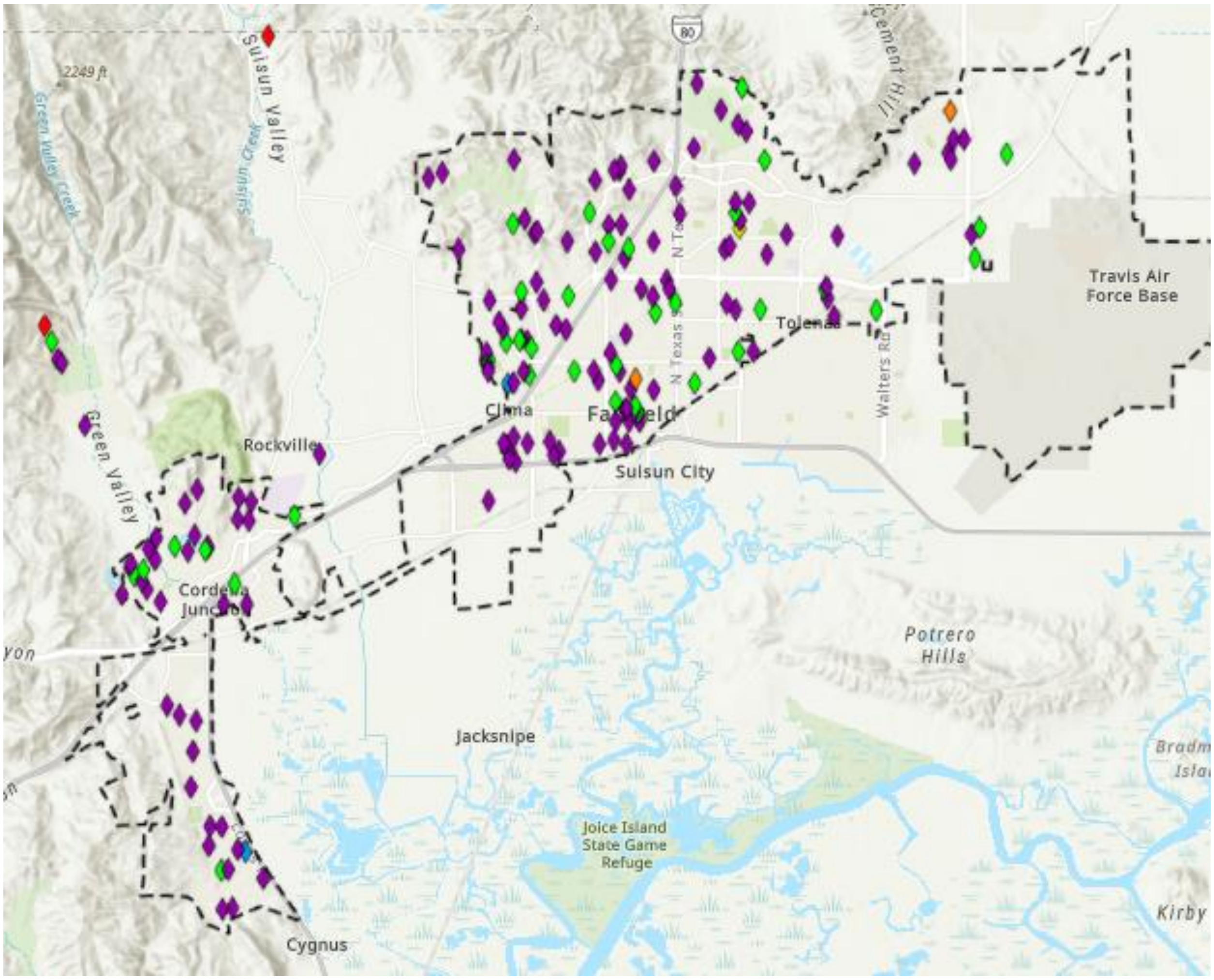


Figure 6. Internet Service Providers by Percentage of 180 Responses

The average reported monthly recurring costs for broadband was just over $100, and about $60 more for all services. See Table 1 of this document for a breakdown by provider. About a third of respondents got only broadband internet service from their providers. Over half got three or more services, including broadband, and over a third of respondents got four or more. Telephone and HDTV were the most common other services, each of which were used by about 60% of respondents.

Reponses appear to be geographically diverse, as illustrated in Figure 7. Areas of low response were between Dover Ave and North Texas St. and the Rancho Solano neighborhood. AT&T and Comcast appeared throughout the city. Comcast dominated responses in the Heart of Fairfield and Cordelia areas and across the northern portions of the city. AT&T was more common in central neighborhoods, which is also where alternate providers, DirectTV and T-Mobile had nominal presence. The outliers to the northwest are included to show the geographic limits of coverage. AT&T and Comcast appear to cover Green Valley but do not reach the county line on Suisun Valley.



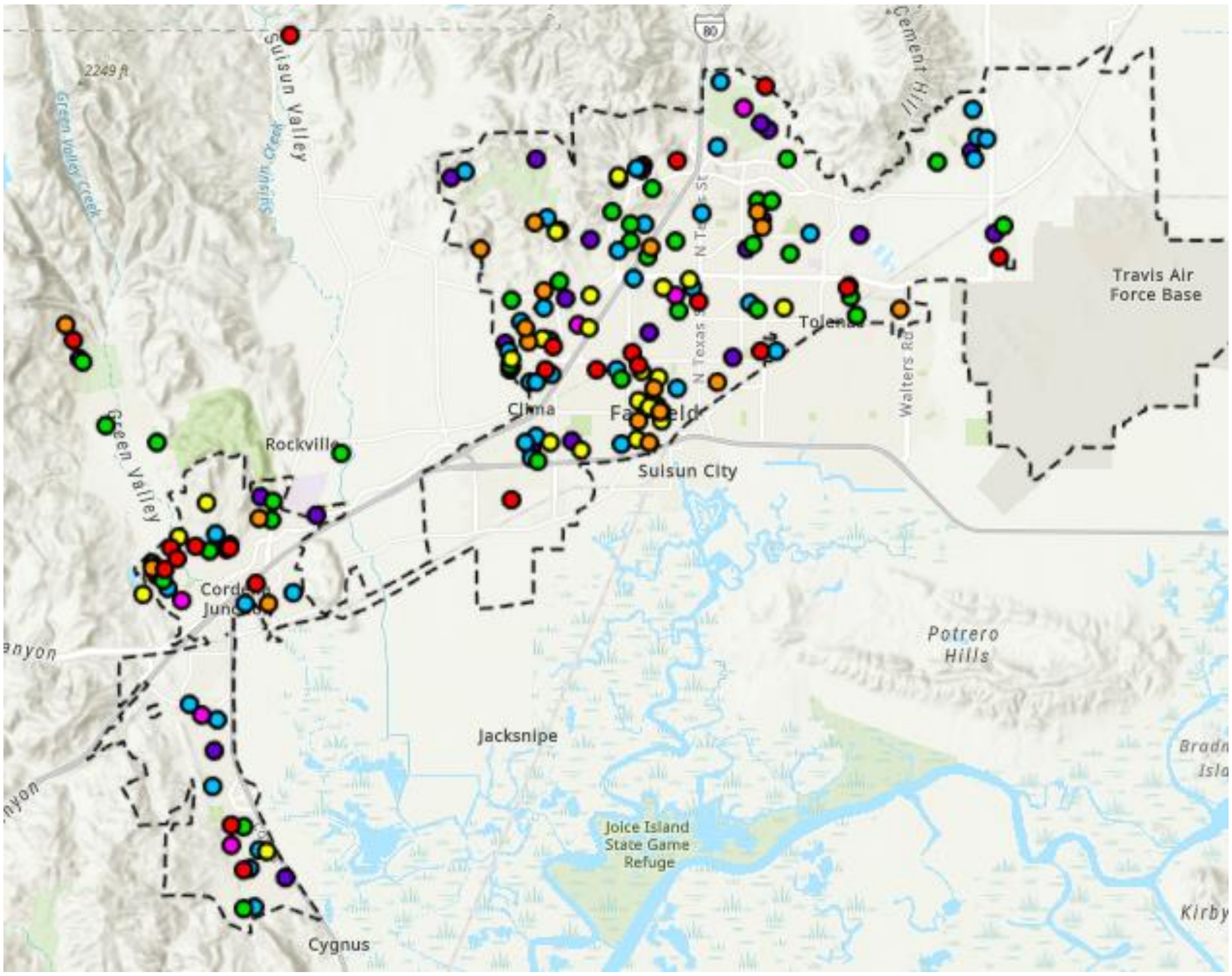
AT&T | Comcast Business | Comcast xfinity | DirectTV | T-Mobile | Valley Internet

Figure 7. Locations of 180 Responses by Broadband Provider

Broadband Costs and Performance

Respondents were asked how much they paid for broadband and related services along with basic service characteristics. These were "best guesses" by the person responsible for choosing and paying for the service. Variance would diminish with a large number of responses but should be assumed high in this situation. Actual performance was recorded automatically via a speed test integrated into the survey. But performance will vary over time based on network congestion and other factors.

Therefore, we report descriptive statistics, including average, maximum, median, and minimum speeds, and use approximate language.



● Up to 11 ● Over 11 up to 28 ● Over 28 up to 50 ● Over 50 up to 100 ● Over 100 up to 300 ● Over 300 up to 500 ● Over 500

Figure 8. Geographic Distribution of 176 Responses by Speed Tier in Mbps

The geographic distribution of survey responses in terms of aggregate throughput is illustrated in Figure 8. Lower speed and higher speed connections were generally distributed across the city, adjacent to each other. Speeds under 25 Mbps download and 3 Mpbs (25/3) were considered slow-speed connections, as designated by federal agencies such as the Federal Communications Commission (FCC). This benchmark is used as a baseline for broadband funding programs including the

American Rescue Plan Act (ARPA). The data analyzes aggregate speeds, combining the download and upload speeds, using 28 Mbps as a cut-off for low-speed connections.

Connections below 28 Mbps aggregate were most clustered in the core of the city, near City Hall, the Vintage, and Woodcreek neighborhoods. This seems to be an issue of affordability/costs rather than availability. It may also be related to the age of access network infrastructure in this area. Figure 9 shows the statistical distribution of connection speeds from the survey. While over 20% were below the current 25/3 Mbps standard for broadband, over a quarter had throughput between 100 and 300 Mbps. Nearly 20% of test results were at least 300 Mbps. Effectively two thirds were "true broadband" (50 Mbps or faster) and over three quarters met the baseline standard.

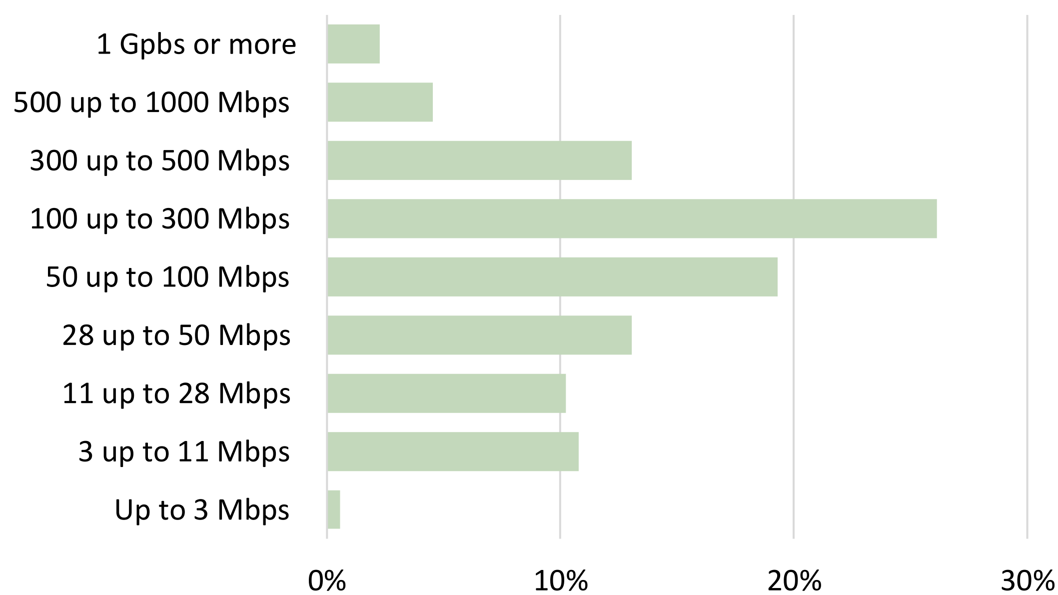


Figure 9. Aggregate Throughput of Broadband Connections by Percentage of 176 Responses

The median monthly recurring cost was $90, and the average was over $100, as detailed in Table 1, so most respondents paid more than the median. The most any respondent reported paying for broadband was $1,000 per month (this was a mid-sized manufacturing organization with a symmetrical 1 Gbps service) and the least was $10 (from a household respondent who reported being connected via a cellular device) . Actual average download speed of 141 Mbps and upload speed of 45 Mbps were about 40% of what respondents reported providers offered. Median speeds were substantially slower than and different from average offered, which means most connections were faster than 74 down and 11 up. The slowest speeds were 1 Mbps down and 0.1 Mbps up. The average cost per Mbps per month was nearly $5 so most respondents paid substantially more than the median of $1.12. Typical per Mbps per month costs for fiber services are around $0.30.

Table 1. Descriptive Statistics for Broadband Cost and Performance Among Survey Respondents

Statistic	Monthly Recurring Charge	Contract Speed[5]		Actual Speed		Latency	Cost Per Mbps/Mon
		Down	Up	Down	Up		
Responses	158	125	118	176	176	176	$159.00
Maximum	$1,000	1,200	1,200	824.39	1,580	1,050	$269.11
Average	$104.29	341.74	120	141.14	45.42	91.8	$4.90
Median	$90	100	20	77.42	11.56	57.0	$1.12
Mode	$50	100	10	3.93	5.87	59.0	N/A
Minimum	$10	1.00	0.51	1.05	0.10	9.0	$0.02

Table 2 compares basic costs and performances for broadband providers. Comcast costs respondents about 20% more than AT&T but provided nearly two and three quarters higher speeds. The cost per Mbps per month from AT&T approached twice

[5] Contract Speed refers to the “up to” speed as contracted with the respondent’s service provider.

the cost of Comcast's connections. T-Mobile reportedly had the lowest cost per Mbps and was over 25% faster. We presume that the cost for Valley Internet, which is a wireless internet service provider, was related to a remote location where there were no wired connections available. Households paid about $50 per month less than organizations for more bandwidth. Organizations paid an average of $6.69 per Mbps per month while households paid $4.59.

Table 2. Average Reported Cost and Tested Speed by Provider for 180 Responses

	Monthly Recurring Cost			
Provider	Broadband Only	All Services[7]	Aggregate Throughput[6]	Cost per Mbps/Mon
AT&T	$89.09	$152.36	83.82	$7.69
Comcast	$110.58	$169.98	224.53	$4.07
T-Mobile	$50.00	$50.00	104.52	$1.20
Valley Internet	$122.00	$122.00	13.75	$5.21
Direct TV	$50.00	$175.00	27.50	$3.64

Reliability, Satisfaction, and Willingness to Pay

Respondents were asked how frequently their broadband was out or slow, and about their perception of major aspects of their broadband service. Almost 60% indicated their broadband was never out for a day or more. Nearly 50% said it was never out for two or more hours. Over a third experienced outages of at least an hour at least once a month. Half of respondent had regular drops in performance. See Figure 10 for a complete picture.

[6] Aggregate throughput is the total actual download speed plus actual upload speed.

[7] All Services refers to "bundled" services in addition to broadband which may include cable, telephone, or other services in addition to broadband.

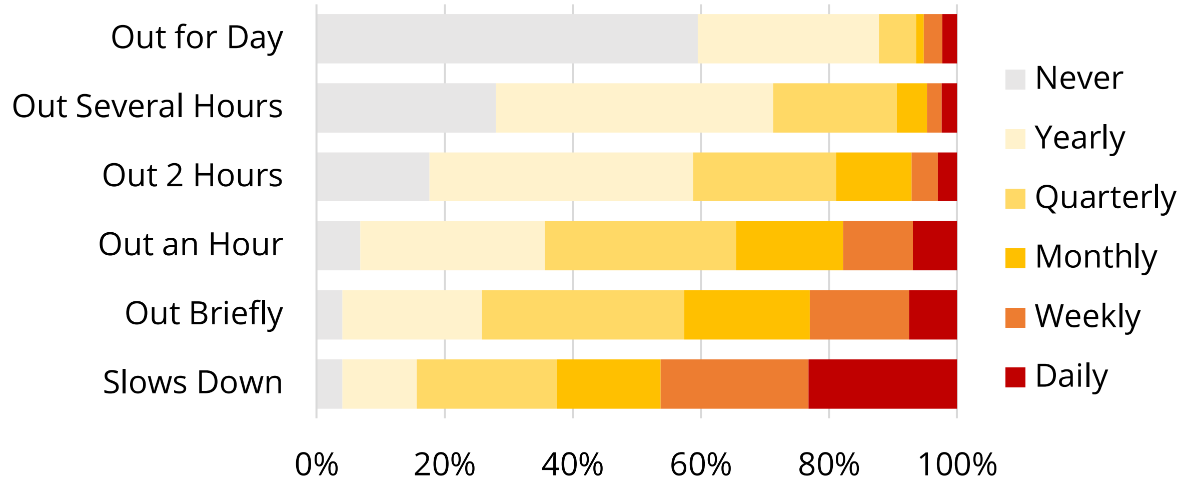


Figure 10. Frequency of Performance Issues by Percentage of 174 Responses

Generally, as shown in Figure 11, respondents indicated that their broadband was good. Most responses were positive regarding speed and reliability. Price was the only factor with which respondents were generally dissatisfied, with over half indicating it was bad or terrible and nearly 30% saying it was either good or excellent. Respondents were most ambivalent about support. More than a third felt it was good and bad and more than a quarter felt it was neither good or bad or were unsure about the quality.

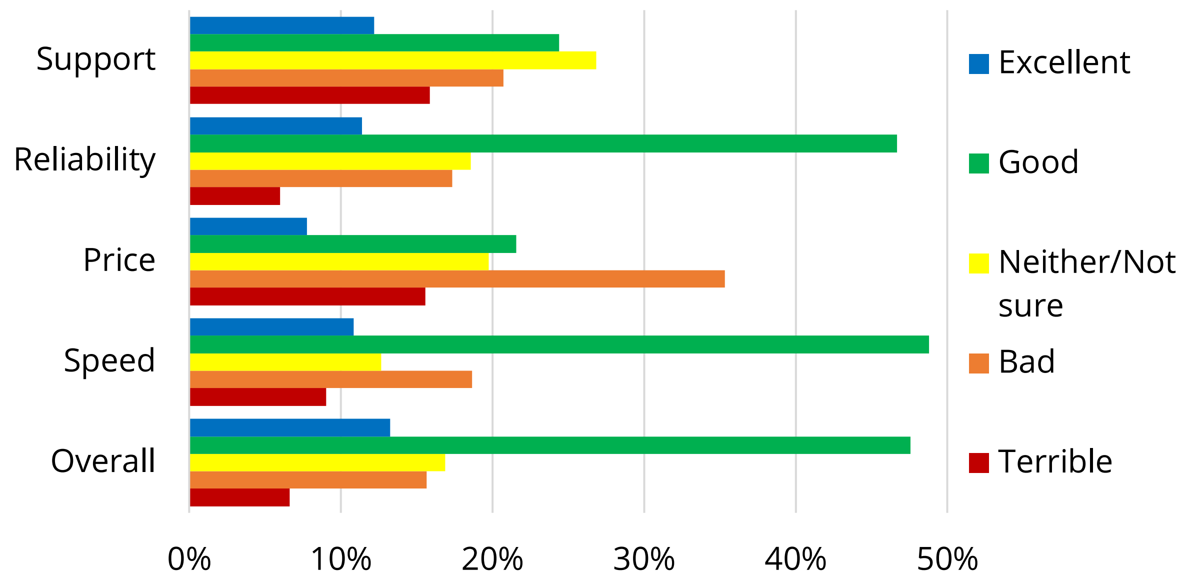


Figure 11. Perceptions of Various Aspects of Broadband Service by Percentage of 167 Responses

Respondents were asked how much they would be willing to pay for several tiers of internet speeds ranging from 10 Mbps to 1 Gbps. Response options provided basic context for each broadband tier:

- Slow, 10 Mbps: enough for checking email
- Basic, 25 Mbps: enough for surfing the web
- Real, 50 Mbps: enough for video calls and conferencing
- Fast, 300 Mbps: enough multiple games or videos simultaneously
- Super fast, 1,000 Mbps: enough anything and lots of it

Nearly three quarters of respondents would not pay anything for "broadband" that was slow (10 Mbps or less). See Figure 12. Thirty percent, in contrast, were willing to pay $100 or more per month for a gigabit of service. Over a third of respondents were willing to pay at least $50 per month for 300 Mbps. Less than half were willing to spend $25 or more on real (50 Mbps) broadband. While gigabit connections are commonly available for less than $100 per month in competitive markets, "real" broadband (faster than 25/3) is at least $40 and commonly over $80 in non-competitive markets.

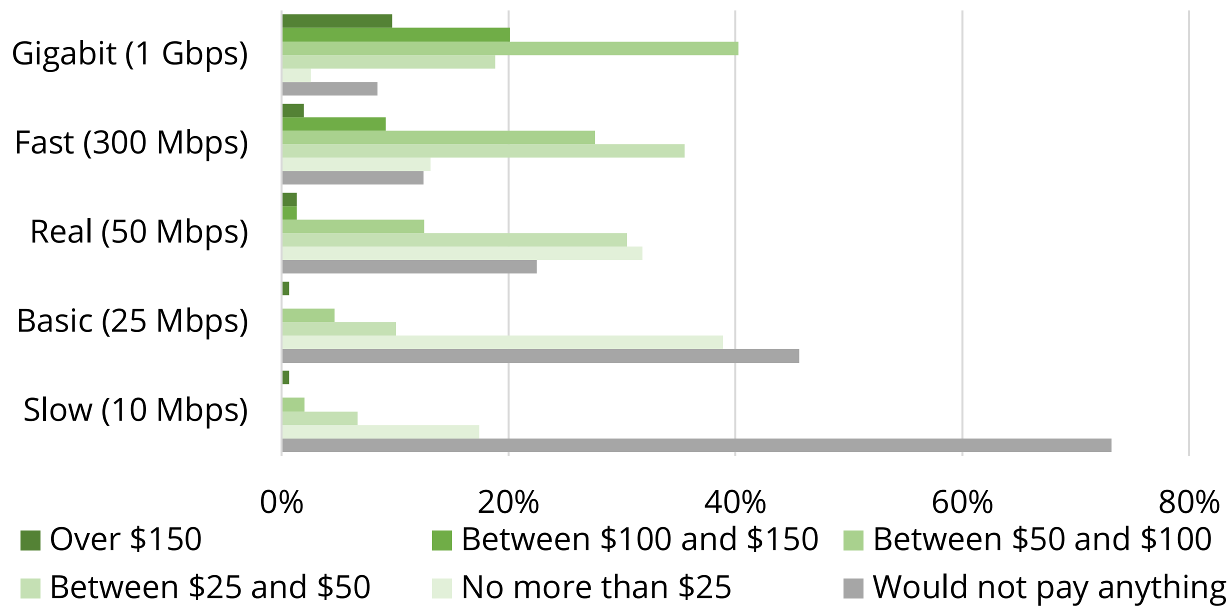


Figure 12. Percentage of 154 Respondents' Willingness to Pay for Various Broadband Speeds[8]

Broadband Uses

Over half of respondents worked from home at least once a week. In contrast over half spent time on home business or performed contract "gig" work a few times a year or less. Respondents did these activities either regularly or infrequently with relatively few doing them occasionally. While responses were similar for school or training, about a fifth of respondents did these activities monthly or a few times a

[8] In the survey, each response option had a brief, practical description of each speed's capabilities. Slow internet, for example, was "enough to check email."

year. Over three quarters respondents consulted a healthcare professional that frequently. Over 10% did so weekly. Figure 13 illustrates these findings.

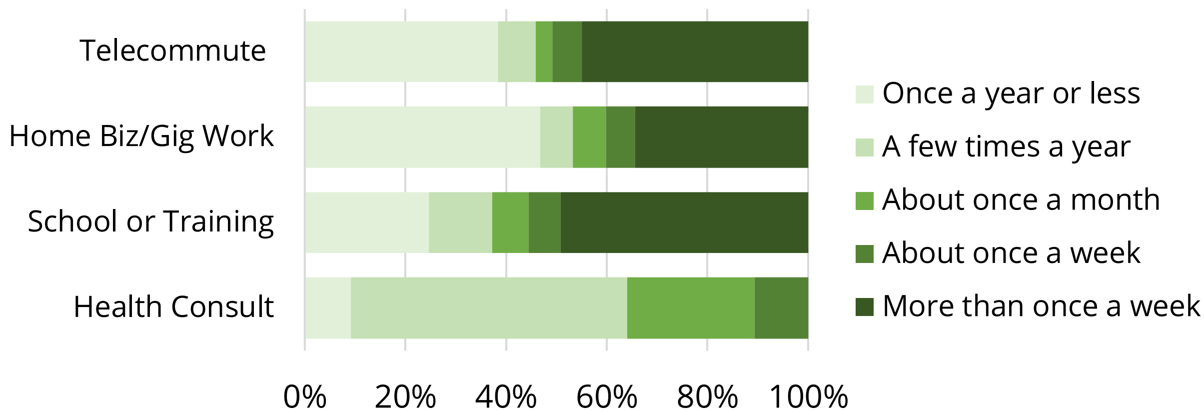


Figure 13. Frequency of Opportunity Indicator Activities by Percentage of 131 Responses

Internet was most important to respondents for general interest information and buying things, as shown in Figure 14, with 96% and 94% indicating internet to be extremely or very useful for those purposes. In contrast, over a third said it was little or no use for generating income or selling things. Internet was also important for personal communication, hobbies and special interests, and personal improvement. About three quarters said internet was extremely or very useful for entertainment and recreation. About 10% indicated internet was of little or no use for entertainment and personal improvement.

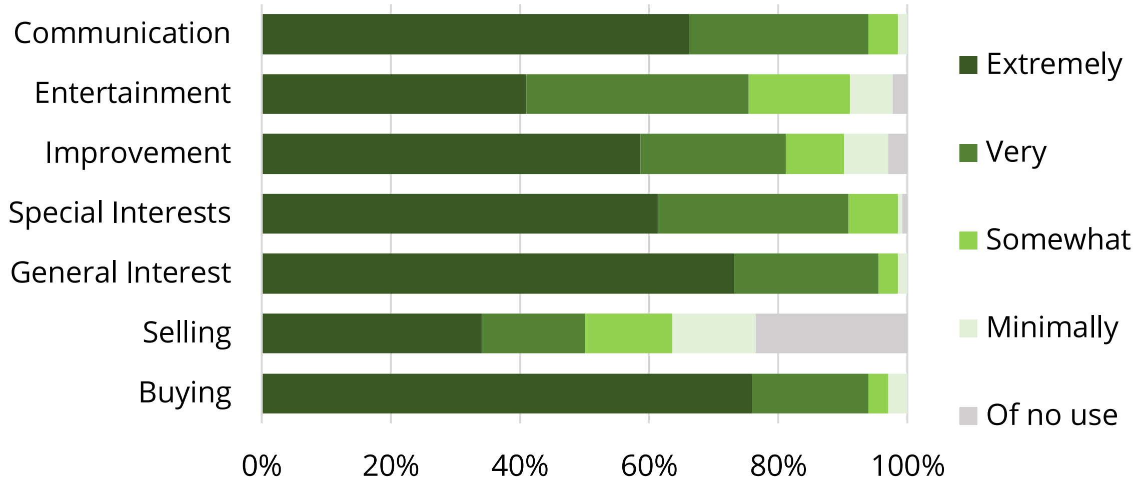


Figure 14. Value of Broadband for Various Purposes by Percentage of 134 Responses

For responding organizations, as illustrated in Figure 15, internet was at least helpful for all functions. It was most critical for management, selling, and supporting customers with 86% indicating it was either essential or very important. Buying and hiring was also very reliant on broadband. Inbound logistics, producing goods and services, and outbound logistics seen as essential or very important by about three quarters. About a fifth indicated it was only helpful for outbound logistics (getting products or services to customers). No respondents indicated the internet was of no use for any business function.

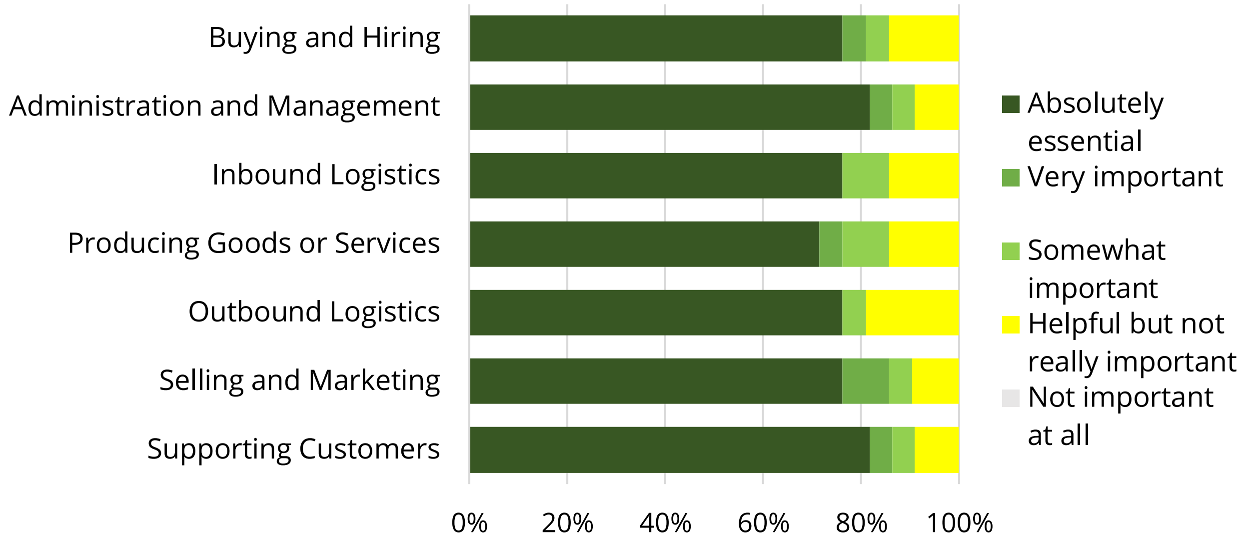


Figure 15. Importance of Internet for General Business Function by Percentage of 22 Organizational Responses

Organizations experienced a range of issues related to using the internet, as shown in Figure 16. About half respondents felt it was somewhat to very difficult to get technology services and solutions. One respondent of 21 said it was practically impossible to find technology personnel. More than a third felt it was difficult to find employees with basic digital skills. Alternately, more than a third did not have an issue finding technologists, and about a quarter of respondents did not have any issues with technical capabilities.

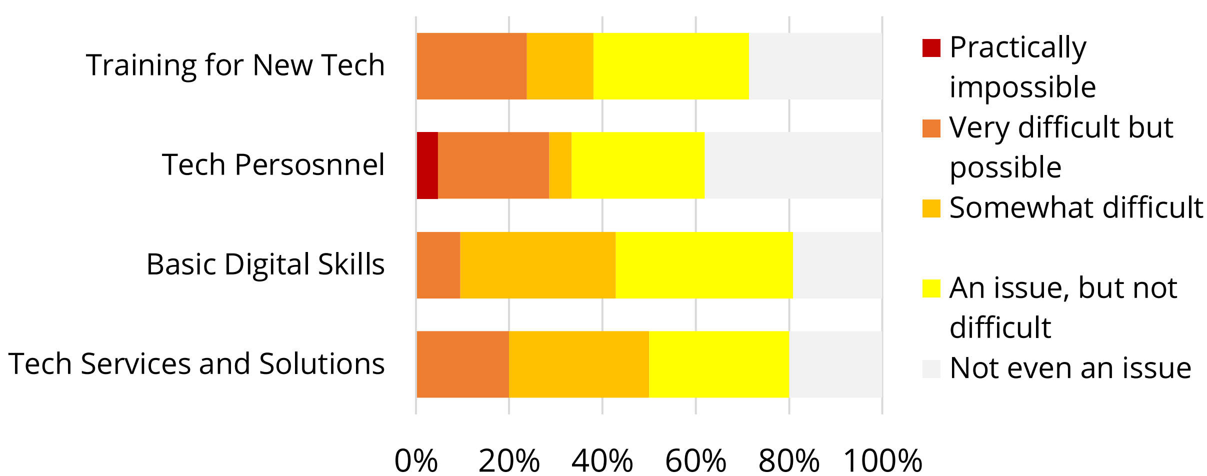


Figure 16. Difficulty of Getting Various Technical Capabilities by Percentage of 21 Responses

Almost two-thirds of responding organizations would move for better broadband as represented in Figure 17. The question did not ask respondents to specify whether they would move to another location within Fairfield or to a location outside of the City. More than a third said they probably or definitely would not move. No respondents were on the fence: they either did or did not consider broadband an important location factor. Companies in retail, healthcare, transportation, and other services seemed most likely to move for better broadband.

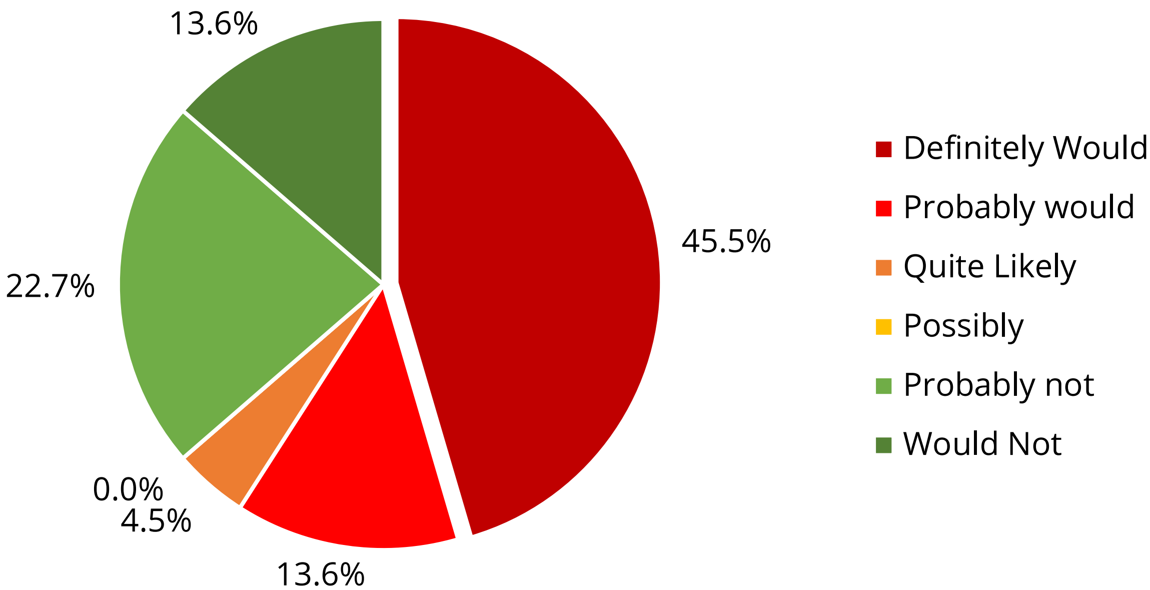


Figure 17. Likelihood of Moving to Get Better Broadband by Percentage of 22 Responses

Respondent Comments

One hundred and nine respondents out of the 158 that completed the survey answered the final "catchall" question. While a few comments were positive, most were about the lack of options, low speeds, and high costs. Several cited specific challenges for school and work due to low speeds. Many noted lack of home broadband options, particularly that they only had AT&T digital subscriber line (DSL, a relatively slow type of broadband connection nominally providing 25 Mbps[9]) available. A few specifically decried Comcast's customer service. At least one commenter noted having no options for wired broadband. Costs were the most common issue but at least twenty comments focused on low or inconsistent speed.

Conclusions and Implications

Generally, affluent consumers (relatively older and more educated) in Fairfield have reasonably fast broadband. Unfortunately, younger residents with lower levels of educational achievement did not respond so we cannot draw any conclusions about their connectivity. Options and costs were the major issues for respondents. While respondents generally indicated low willingness to pay—many said they would not pay more than $50 for 50 Mbps, which is common in non-competitive markets—they were actually paying relatively high monthly bills for their internet. Although broadband speeds were acceptable, the cost per capacity was rather high—over 10 times the average costs typical of fiber-based connections in competitive markets.

Uses among consumers and issues for employers suggest Fairfield may have a shallow pool of technical talent. Households were less likely to use the internet for making money, personal improvement, and entertainment than other purposes. Telehealth and, to a lesser extent, remote or gig work seem to be areas in which people could make greater use of the internet. Connectivity was a critical issue for many organizational respondents, particularly for management and customer service, which combined with lack of options may be a cause for concern.

[9] See the City of Fairfield Broadband Development Plan (Aug 2020) for additional information about broadband technologies and associated speeds.

STAKEHOLDER INPUT

With guidance and support of City personnel, Magellan Advisors gathered input from 22 individuals, representing 16 organizations. Generally, this consisted of three group discussions—anchor industries, corporate/industrial areas, and downtown and residential areas—and interviews with representatives of Solano County government, economic development, neighboring cities, schools, and small business and workforce development. Input was on current connectivity, short-term plans, long-term goals, and general issues or major trends impacting need for broadband and related services.

Current Connectivity

Stakeholders generally indicated that connectivity options were limited. Several noted that Comcast had recently extended services, specifically into areas along Air Base Blvd. and Solano Town Center mall, which improved options, performance, and reliability.

At Solano Town Center mall, connectivity was identified as a major issue. AT&T is the only service offering and according to management, they do not want to invest in any additional infrastructure. As a result, tenants within the mall have been quoted $5,000 to $10,000 as costs to install fiber to a single location. In Solano Town Center's central office, users cannot connect to wi-fi, but instead must have their devices connected via hard wire due to the limited bandwidth on the property.

New business models for tenants at locations like Solano Town Center include streaming events like online gaming competitions and beauty or fashion shows, requiring a growing need for bandwidth. Although the mall attempted to provide Wi-

Fi throughout the center, regular outages and low bandwidth has made this challenging. Management recently penned a deal with Comcast to provide service to the entire center. They will be coming in to run connections to all tenants at no charge and will be the only service offering, replacing current AT&T connections.

In other areas with more limited options, businesses reported paying $600 per month for 50 Mbps connections as reported by the owners of an auto dealership near Auto Mall Parkway. Business and industry locations along the freeway and in the Cordelia area seem to have the highest costs and most limited options. Anchor institutions indicated having adequate but costly connectivity, except for governmental/public network services (CALNET[10] and CENIC,[11] specifically).

Numerous critical business functions rely on connectivity, according to those we interviewed. Both the criticality and number have increased since the pandemic. For example, participants representing automobile dealers and breweries reported similar requirements, although for different functions. Dealerships increased their reliance on online systems for inventory, sales, and services for finding information, processing transactions, tracking contacts and processes, etc. Brewers large and small used online systems for hiring, marketing, and procurement. The schools had handed out over 750 hotspots, which cost $40 per month **before** a state subsidy, for students to connect to education. Should funding for this program end, or if students

[10] CALNET is the State of California's statewide enterprise network. See https://cdt.ca.gov/services/calnet/ for more information.

[11] CENIC is a non-profit organization that runs the high-capacity, statewide California Research and Education Network (CalREN). See https://cenic.org/about for more information.

do not return devices upon leaving the school system, these hotspots may not be available in the future.

Larger organizations’ requirements emphasized administration, logistics and process monitoring, while smaller companies’ requirements were driven by marketing, sales, and security. Institutions and service businesses moved strongly toward online content and virtual service delivery. Smaller companies also needed connectivity as a customer amenity and for other customer facing purposes. Smaller organizations relied relatively more on mobile cellular connections that use cell phones and other mobile devices in lieu of broadband options whereas larger companies used dedicated lines. Stakeholder input indicated that some people can't get good internet, others can't afford it, and a relatively large portion don't know how to use it.

Short-term Plans

Several participants’ short-term plans had been substantially impacted by COVID. Smaller, service-oriented organizations were wrestling with less customer demand and workforce challenges. Consequently, they had moved to reduce face-to-face interactions. Their plans focused on adapting to and recovering from the pandemic. Industry seemed to generally have strong demand but faced challenges getting materials/products as well as workforce. They were generally planning to capitalize on their geographic position to reach markets economically. A similar approach was evident on the workforce side, drawing in and developing raw talent from around the region.

All participants expected to increase or at least sustain technology spending and use in the short-term. There seemed to be funding to support this, particularly for small businesses. Several participants had no specific short-term plans because they had recently upgraded their connections and/or systems. If anything were impeding broadband use, it was lack of clear, economical solution options—including the talent to implement them.

Long-term Goals

Many private sector participants had major developments among their long-term goals. They were planning substantial commercial and industrial improvements but also foresaw major residential development. Where short-term plans were to hold steady or incrementally increase, stakeholders' long-term goals are for major changes.

For several participants, particularly downtown, residential, and small business stakeholders, the general, long-term goal was for Fairfield to be a regional hub for commerce, hospitality, retail, and transportation. Food and food tech industries were seen as key target industries for Fairfield to develop, especially through links to agriculture assets in Suisun Valley and through UC Davis. Although healthcare stakeholders did not directly provide input, other stakeholder representatives noted the strength of that sector, and its important role in the region. The costs of broadband and related technologies, the limited options, and need for reliability were seen as key barriers. One participant noted that availability and cost of high reliability, high-speed connectivity was a top concern of companies considering the area.

Major Issues and Trends

Along with the general growth trends, the major issue for Fairfield seems to be resilience. This is particularly important in terms of network reliability, but the issue is primarily focused on environmental and related threats. Safety and security are major issues. Wildfire directly impacted Fairfield in 2020 in the form of evacuations and operational interruptions. Communications need to accommodate and mitigate such situations by enabling coordination, monitoring, and alerting with a high-level of reliability. This seems to be an issue for residents and industry, as primary options are limited and there is essentially no back-up.

The resilience issue extends to other utilities. PG&E's public safety power shutdowns have profoundly impacted businesses and others. Industry is especially reliant on power, and it is difficult to get a permit for a petroleum-fueled generator in California. The City has good water resources, including a 36" pipe direct from Lake Berryessa and reclaimed waste water. Connectivity is necessary to manage and market power and water, especially to increase resilience, and connectivity requires power. Network infrastructure can and should facilitate improvement of other utilities and can be economically co-developed.

Digital inclusion is an important issue for Fairfield, for industry as well as residents. Current and future residents need skills and devices as well as connectivity to participate in the digital economy. Like most any community, there are also persons experiencing homelessness and other profound challenges in Fairfield who are critically disconnected. Consumer businesses, particularly food services and hospitality, have become connectivity providers even as internet has changed how they do transactions, manage accounts, and reduce loss. Manufacturers and distributors require these things, too, and they increasingly require a digitally skilled workforce. We clearly heard from stakeholders in Fairfield how digital transformation can make organizations more effective and efficient, more competitive, productive, and innovative, and resilient, if they have the connectivity and workforce.

3. Gap Analysis

ASSET GAPS

The asset assessment via review of existing data and employee interviews was included in the August 2020 Broadband Development Plan. The City's assets have not changed appreciably since then. There were several plans and projects that may impact broadband development or create new requirements for it. The major asset gap for the City itself is related to its microwave network, which is in need of a refresh or replacement. The microwave industry is constantly in a state of flux with acquisitions and mergers due to product maturity. Furthermore, at times, the microwave has proven to be unreliable due to severe weather conditions even though the system was intended for very high, "99.999%" reliability.

The City is addressing this gap by migrating sites off microwave to leased circuits. Fairfield's current microwave network is due for replacement within the next couple of years, and the cost associated with that replacement is approximately $540,000. As of this report, the City paid a total of $21K per month to connect 14 sites, including a dozen sites with 1 Gbps AT&T Dedicated Ethernet connections, which cost $1,600 per month per site. **See Table 12. Prospective Telecommunications Savings by Phase** in Appendix A of this report. Other major stakeholders, including neighboring cities, faced similar gaps: They had adequate but not stellar and rather costly connectivity. The cost of these connections could generate greater return as investments in City owned infrastructure, allowing the City to transition away from leased line services.

SERVICE GAPS

Generally, Fairfield had true broadband from at least two providers—AT&T and Comcast. A few responses suggested that DirectTV and T-Mobile also provided broadband services, although it was not clear if these companies were reselling AT&T services or they had their own infrastructure. It may be informative to follow up with these respondents to identify exactly how they were connected. There were gaps in expectations as survey respondents thought their connections were twice as fast as actual speeds. While having only two providers may not be a gap relative to other communities—it is a common situation—it may be seen as a gap in competition and control. The incumbent providers have no reason to improve prices or services nor does the community have means to directly improve broadband costs, coverage, or speed. Some communities with similar issues have pursued municipal broadband initiatives to address these gaps, including building City-owned infrastructure to attract new investment and increase competition, creating new offerings for residents and businesses.

Gaps in availability seemed very localized, presumably due to providers not extending access infrastructure to specific locations. Lower speeds appeared to concentrate in the older, denser parts of town, specifically the Heart of Fairfield but also the Green Valley area. Responses were not uniformly low. Some indicated reasonably high speeds—100 to 300 Mbps range. **It is not uncommon for locations a block apart or on opposite sides of the street to have different broadband options for many reasons, ranging from cost of construction to service territory boundaries.** Major locations, including sites around the Solano Town Center mall and in key industrial areas, were not fiber served. Some locations, including individual businesses within Solano Town Center, faced costs over $10,000 to close these gaps. In other locations, like Auto Drive Parkway, business owners have been told that their existing conduit connections from the building to the street are owned by an incumbent provider and cannot be used by others, resulting in the need for construction by any other provider who could serve them. Stakeholders said that the costs for this construction were simply too high to make it a viable option.

Broadband Mapping

In addition to collecting information directly from stakeholders in Fairfield via the survey and targeted outreach, Federal and State broadband mapping resources provided information about potential gaps in service coverage within Fairfield.

The National Telecommunications and Information Administration (NTIA) maps indicators of broadband need, including inputs such as Ookla speed test results, the US Census Bureau's American Communities Survey broadband adoption rates, and Federal Communications Commission (FCC) data about service provider territories. The image below shows that there are a few locations in Fairfield that may have a need for additional broadband based on these indicators, shown in light red on the map. While these areas are not severely underserved, as is the case in many rural locations where the map shows dark red pockets of need, it appears that there are lower than normal speeds in these locations. Based on Census data, these are primarily low-population commercial areas, including several locations near Solano Town Center, Suisan-Fairfield Cemetery, and NorthBay Medical Center.

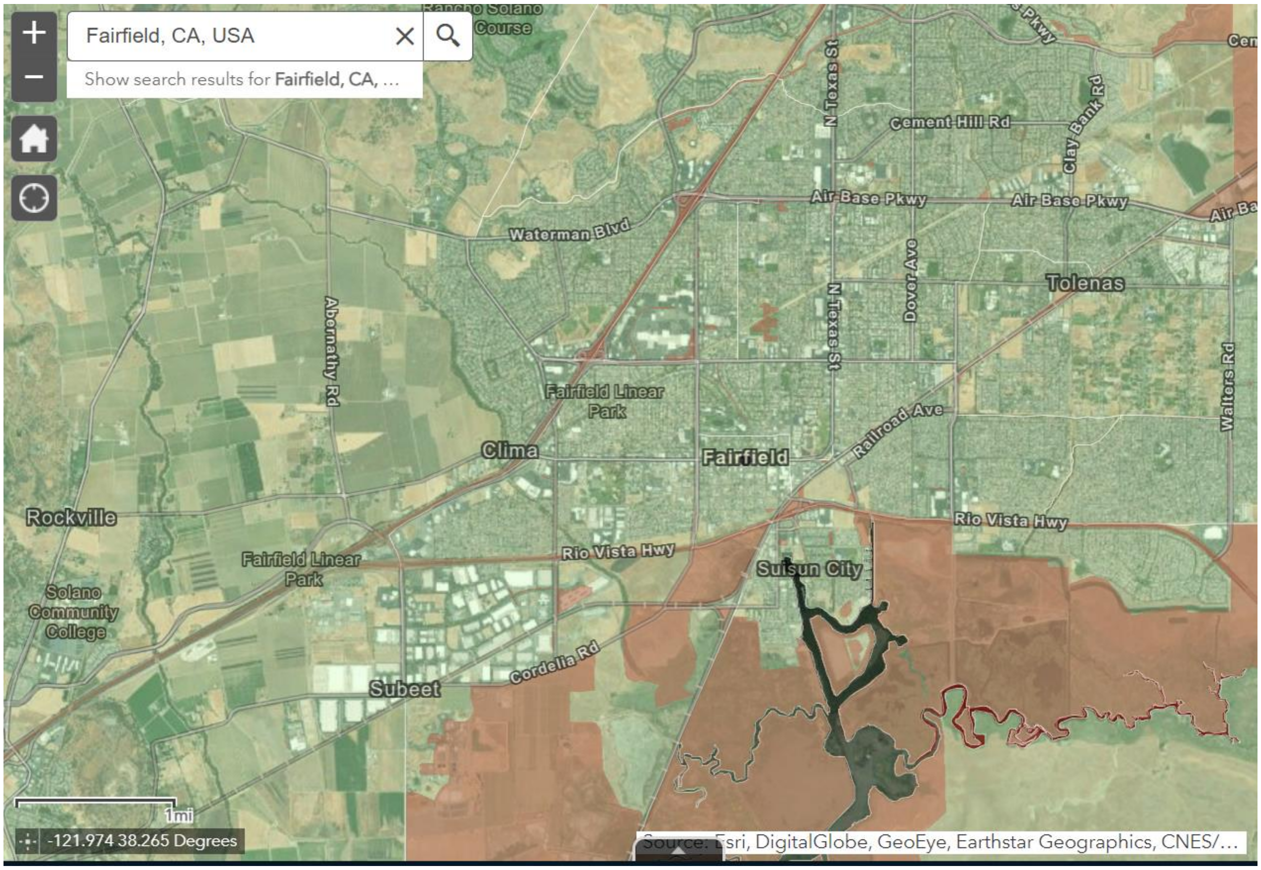


Figure 18. NTIA Indicators of Broadband Need Map

Interestingly, the State of California Public Utilities Commission (CPUC) broadband map does not indicate the same areas of need. Shown below, the CPUC's map displays Served (green), Unserved (yellow), and Priority Unserved (red) locations in Fairfield based on fixed service with minimum speeds of 25/3 mbps. The red and yellow pockets occur sporadically throughout the City.

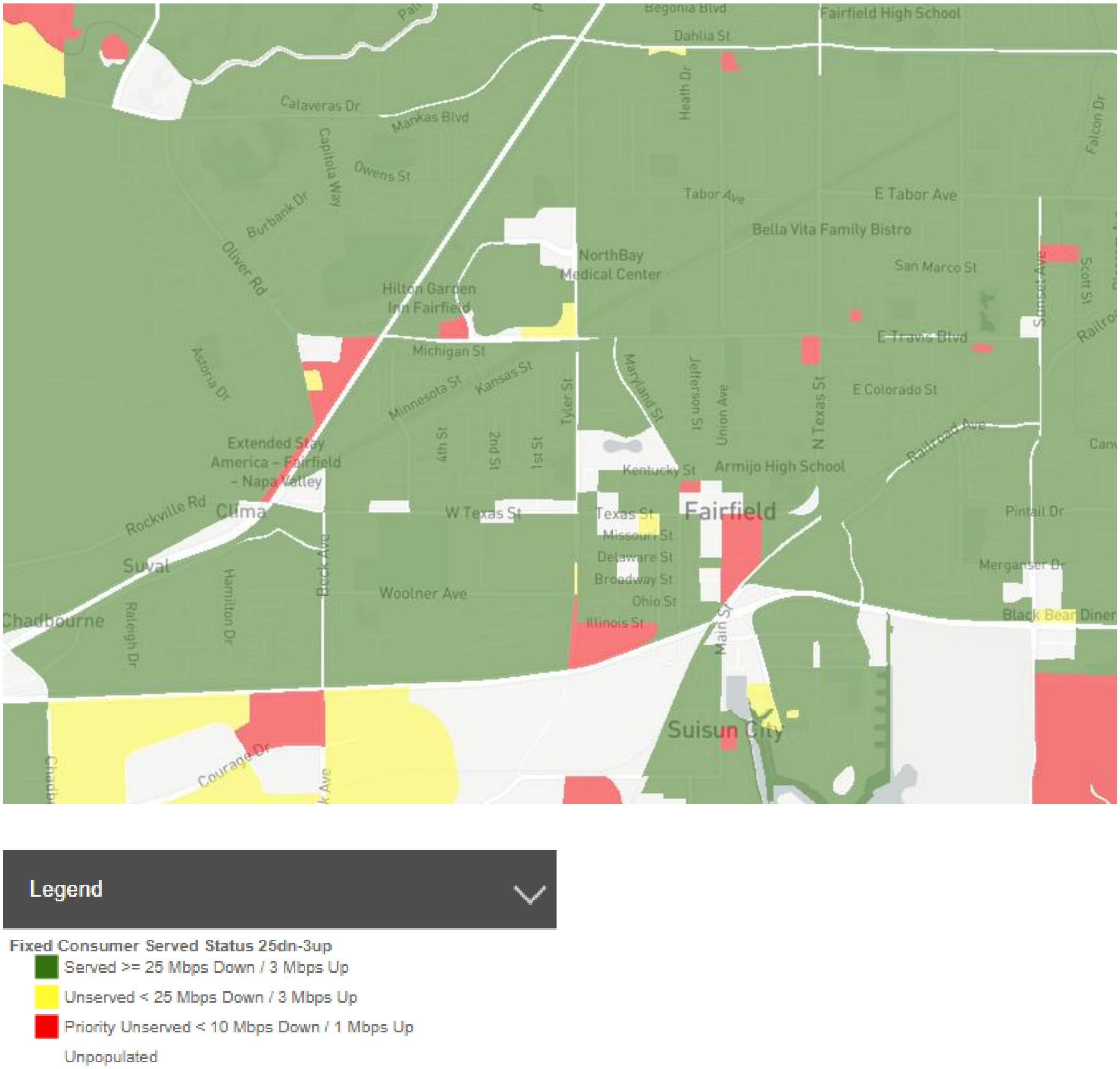


Figure 19. CPUC Broadband Map

CAPITAL PROJECT AND DEVELOPMENT PLANS

Capital projects, which include facilities or transportation initiatives such as roadway or waterline improvements, can offer opportunities to lower the cost of broadband deployment. As of September 2021, there were 52 CIP projects that could potentially enable broadband development.

Most of these were quite small but some seemed to span significant distances. Specifically, installing automated signals at multiple intersections, especially those that need interconnections for adaptive traffic signal control, could be a prime opportunity to deploy horizontal assets. Eight planned capital projects could have Wi-Fi integrated into them and 6 might be executed in a way that accommodates sites for wireless technologies (i.e., 4G/5G, CBRS, Terragraph, etc.[12]).

City of Fairfield Public Works staff identified four areas that were potential focus areas for broadband development based on other plans and priorities[13], illustrated in Figure 20, overlaid conceptual network design routes (see the Conceptual Network Design section, below, for more details). These segments are anticipated to have fiber infrastructure installed in the next 2-4 years.

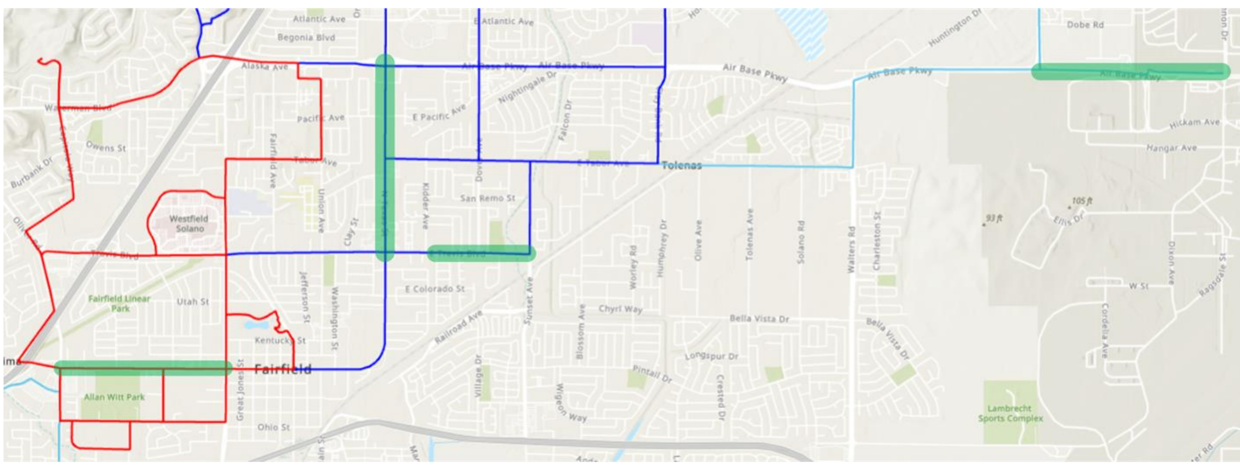


Figure 20. Potential Focus Areas for Broadband Development Based on Public Works Plans and Priorities

[12] These are next-generation wireless protocols. 5G is much more than cellular phone. CBRS is lightly licensed spectrum for wireless broadband. Facebook developed Terragraph for extremely high-frequency (60 GHz) bands.

[13] These locations were selected based on the figure displayed on page 6 of the Policy and Broadband Development Plan (Magellan-Advisors, August 2020).

As detailed in the 2020 Broadband Development Plan, effectively all of Fairfield's development plans could accommodate broadband. Many effectively require broadband. For example, plans to activate the Heart of Fairfield as a retail destination require Wi-Fi as an amenity and broadband for business operations. Streetscaping and other physical improvements to the area are prime opportunities to deploy network infrastructure.

Integrating broadband infrastructure in northeast Fairfield development, as another example, would greatly reduce broadband development costs. The distribution and access infrastructure should be conditioned into the developments, which would extend the City's network for nominal costs. The result is a valuable real asset that could be used to provide new broadband options and a new revenue stream for the City. Specifically, the new Cannon Rd alignment could be an ideal route to feed fiber to major new employment centers.

COMMERCIAL AND INDUSTRIAL AREAS

Stakeholder input indicated some broadband gaps in industrial areas and some commercial. As with residential broadband, gaps seem to be very local, to specific areas and even sites. Tenants face high upfront costs for providers to build connections. In some cases, such as Solano Town Center, business owners were quoted up to $10,000 for construction of laterals to connect their sites to the existing fiber in the right-of-way. The provider owns that infrastructure, essentially locking out other providers and locking businesses in. We heard about such issues specifically in areas around the mall, between US Hwy 12 and Cordelia Rd, between Lopes and Red Top. Generally, any areas planned for industrial development should have network infrastructure fully integrated into them. Existing areas must have abundant fiber infrastructure and service options to be competitive locations.

Commercial enterprises, particularly food services, hospitality, and retail, require broadband for multiple critical applications, but generally have two options at best. They too can face large upfront costs to physically build network connections. Apartment complexes and other multi-dwelling units, which are often located adjacent to commercial areas, face similar issues. It can be quite costly to retrofit densely subdivided properties for fiber to the premises. As with industrial, plans for commercial and high-density residential areas must have broadband to be viable locations. Tenants demand it.

NETWORK INFRASTRUCTURE AND SERVICES

There appears to be some unmet demand for broadband, cellular coverage, and related network infrastructure and services but it is not overwhelming. Most telecommunications companies are market takers, not market makers, which means they invest based on demand, not to generate it. This means that few investments are made in new infrastructure that serves communities where demand hasn't reached an obvious tipping point, allowing internet service providers to achieve a rapid return on any investments they make by capturing a large market share.

In keeping with this premise, incumbent providers have demonstrated little interest in investing in Fairfield. There is anecdotal evidence that Comcast recently extended its infrastructure at the mall and in other commercial areas to meet business demand. Input suggests broadband and related services are adequate but far from ideal for business. Retail consumers seem to primarily want lower costs.

Magellan Advisors believe this input is the tip of the proverbial iceberg: Fairfield's development is being profoundly limited by "adequate" broadband. Business and industry appear to have unmet requirements to support basic operations, which means they don't have the abundant connectivity necessary for tech innovations that would give them a competitive edge. The older, relatively more educated households that responded to survey were unhappy about costs, which suggests younger and lower-income households don’t have affordable broadband options.

Network infrastructure development will be a direct investment in the community that is critical to the City’s plans. It will be a catalyst for retail and services to recover and grow in new directions. Abundant broadband will attract new industry as it enables existing industry. Digital transformation and telework depend on it. Abundant broadband can be a catalyst for major investment by internet service providers and similar companies that directly support these other outcomes as well creating primary benefits in the form of lower costs and more options for broadband services.

4. Business Model Options

Selecting the right broadband business model for local government is highly dependent on several factors that will suggest the most appropriate option for the organization. For example, understanding the community needs, knowing the competitive market factors that define what infrastructure options fit well within the community, and determining organizational and operational capabilities of the local government all play into the selection process. Equally important is an understanding of the financial commitments and risk and reward that participating organizations are willing to support to fund and sustain a successful broadband initiative.

Figure 21. Inputs to Selecting the Right Broadband Business Model

The commonly implemented business models fall on a continuum that ranges from low risk, low investment options to higher risk, high investment options. Figure 22 (below) illustrates this continuum. Moving along the continuum of business model options involves increasing degrees of risk and reward: risks in terms of financial, operational, and regulatory risk; rewards in terms of community benefits, revenue generation, and over potential for profit. Moving "up" the continuum generally requires increasing levels of investment and implies greater local government participation in the delivery of broadband services. Public policy and infrastructure only options are considered "passive" business models, where the government does not operate a broadband network as compared to "active" models such as Government Services Providers, Open Access Providers, and Retail Provider Options, where the government operates a broadband network. Public-private partnerships are not classified as a specific business model but instead fall along the continuum because these partnerships take many forms. Local governments must determine which business models meet their organization's risk/reward tolerance to achieve the community's broadband goals.

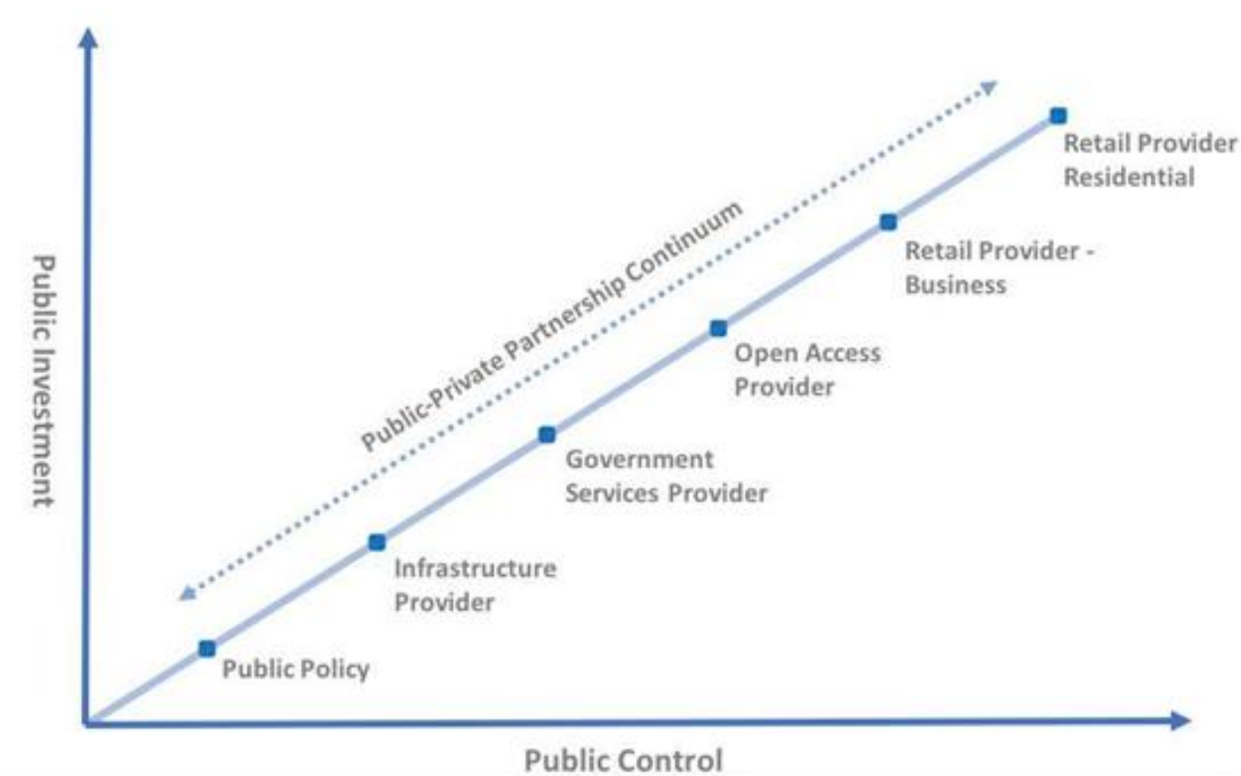


Figure 22. Continuum of Municipal Broadband Business Models

In many cases, multiple options may be selected by an organization; however, in some cases, a local government will not utilize multiple models, as they may conflict with one another. For example, local governments generally implement broadband-friendly public policy with any of the business models, as these policies will complement all other business model options. Conversely, a local government would not likely implement a retail model and public-private partnerships together, as these would lead to competition between the local government and one or more private partners.

MAINTAIN STATUS QUO

Fairfield could choose to take no action and rely on market forces to meet the needs of the community. The City should be advised that because most telecommunications companies are market takers, not market makers, they invest based on demand, not to generate it. This means that few investments are made in new infrastructure that serves communities where demand hasn't reached an obvious tipping point, allowing internet service providers to achieve a rapid return on any investments they make by capturing a large market share. In Fairfield's case, the likely outcome of this scenario is that little investment will be made, especially in areas that are low-income or low density. This creates challenges for solving issues of equitable access for the community.

WORKING WITH CURRENT PROVIDERS

The City could open and maintain dialogue with incumbent internet service providers in Fairfield about their plans and needs for continued investment in the community. While this approach is unlikely to disrupt the existing broadband environment in Fairfield, it could lead to constructive improvements in services for residents and businesses. We encourage the City to develop strong relationships with incumbent providers to demonstrate willingness to work with them on their goals; however, as stated above, ultimately the business case will determine their willingness to invest and areas that will not bring sufficient revenues to cover their costs are likely to remain underserved unless some incentive is offered.

ESTABLISH PROGRAMMATIC APPROACHES

The City could provide incentives for private investment in network infrastructure by assisting providers with pursuing funding opportunities to build new assets in Fairfield. Although most grant programs are targeted at more rural, underserved communities, it is possible that Fairfield could be eligible for some future funding opportunities that could attract the interest of providers. Having a public partner in these situations is often beneficial, and Fairfield could leverage that position to ensure investment is targeted in a way that aligns with the City's goals.

PUBLIC PRIVATE PARTNERSHIP

Fairfield could establish relationships with internet service providers (either incumbent or new entrants) in which a variety of business model options are possible, including for the City and the partner to co-invest in new infrastructure. This option has many varieties and could be explored through a competitive RFI or RFP process to engage interested parties. Resultant agreements might include sharing of revenue for City-owned assets in exchange for a private partner to oversee network operations and management.

Prospective Partners

While conducting this study, Magellan engaged with a variety of service providers, several of whom showed interest in partnering with or providing services in the City of Fairfield. The opportunities for Fairfield range from interest in deploying 5G wireless through pole attachment agreements, to working with fiber infrastructure providers to expand a presence and connect City facilities, to leveraging City assets to connect users with high-speed end user wireless broadband. Interest and opportunities are detailed in the below chart.

Table 3. Prospective Network Service Provider Partners

Provider	Services	Interest	Opportunities	Next Steps
Monkeybrains (formerly Common Wireless)	Wireless ISP	High	Use of facilities in City for towers. in-kind fiber, connectivity.	Engage with Monkeybrains as soon as possible about opportunities to partner.
Sifi	Fiber ISP	High	Submitted unsolicited proposal to install fiber throughout the City	Continue discussions about partnership opportunities.
Zayo	Fiber Infrastructure	Medium	Connect facilities, in-kind fiber, bring in partner for camera storage. Work with Common to build WISP network.	Engage with Zayo as soon as possible about opportunities to partner
Sonic	Fiber and Cable ISP	Medium	Bring in new competitive provider to market. Utilize City assets and policies to expand broadband.	Implement broadband-friendly policies that will attract more interest from Sonic and similar smaller ISP's.
Comcast	Cable ISP	Low	Conduit leasing, joint trenching	Continue engagement about business demand as density increases
CenturyLink		Low	Demand from large anchors, conduit leasing, joint trenching	Engage large businesses about demand for role as network anchors
ATT	Wireless & 5G	Low	Pole attachments and in-Kind Fiber	Implement Dig Once & Telecom Ordinance, Negotiate MLA

Provider	Services	Interest	Opportunities	Next Steps
Verizon	Wireless & 5G	Low	Pole attachments and in-Kind Fiber	Implement Dig Once & Telecom Ordinance, Negotiate MLA
Sprint/ T-Mobile	Wireless & 5G	Low	Pole attachments and in-Kind	Implement Dig Once & Telecom Ordinance, Negotiate MLA

Monkeybrains

Monkeybrains, formerly Common Networks, provides high-speed broadband via last mile wireless to residents and small businesses in the cities of Alameda, San Leandro, Santa Clara, San Joe and Sunnyvale, with plans to expand into other regions including unincorporated Alameda County. Common previously expressed interest in expanding its infrastructure and service offerings to the City of Fairfield. Fairfield's location between the Bay Area and Sacramento coupled with its density makes the City an advantageous location for a new service territory.

The company commonly partners with communities to gain access to assets that include school buildings, towers, parks and recreational facilities, and city buildings. Partnership could take a variety of forms including asset lease agreements for the use of publicly-owned property. Although they primarily provide residential service, they could also provide benefits to businesses.

Pros of this partnership agreement include expanded residential and commercial service offerings in Fairfield with minimal investment form the City. Potential cons include handing over control of the use of public assets.

Sifi

Sifi Networks is a privately owned company based in New Jersey that funds, builds, and deploys fiber optic infrastructure. In general, SiFi uses an "open access" model whereby multiple service providers can use the network to deliver retail internet and complementary telecommunications and entertainment services. SiFi partners such as Nokia and Henkels are leaders in their areas of expertise, however SiFi has not yet executed on a project here in the states to date. Sifi has approached several cities in California with unsolicited proposals to deploy network infrastructure at little or no cost to the cities. Agreements have been struck with the cities of Fullerton, Simi Valley, Placentia, Rancho Cordova, and Pittsburg.

The City of Fairfield received an unsolicited proposal from Sifi proposing construction of fiber infrastructure using microtrenching to create a more competitive broadband market. While the details of this proposal are not entirely clear, Sifi has worked with other cities to establish in-kind agreements in which the cities provide accelerated permitting, waived fees, and streamlined construction schedules for cost savings in return for Sifi providing services to connect City facilities, free or reduced cost public wi-fi, and other community benefits.

Pros of this partnership agreement may include expanded service offerings to the community with little investment from the City. Cons include disruptions to the public right-of-way for microtrenching and little control over where service if offered.

Zayo

The Zayo Group is a nationwide fiber infrastructure company with long haul, middle mile and last mile fiber infrastructure throughout the US and the state of California. Zayo provides communications infrastructure services, including fiber and bandwidth connectivity, colocation and cloud infrastructure to its customers. Zayo considers itself a “Tier 1 ISP.” Its customers or “partners” range from large communications companies such as Verizon and ATT, to community stakeholders, local governments and large bandwidth consumption businesses.

Zayo indicates that it maintains a close relationship with Solano County. The County is a Zayo customer that utilizes a route on Union Street. Zayo's assets in Fairfield are detailed in the asset assessment and include a variety of routes, strand count and above and underground assets.

Fairfield has been active as of late for Zayo, particularly from an enterprise standpoint. As with common, Zayo sees the value of Fairfield's position as a beltway from the Bay with a lot of residential movement and representatives noted that "lots of businesses are moving there as well from bay area".

Zayo is interested in learning more about the City's specific connectivity and bandwidth needs, as well as the City's appetite for managing a network. The City should engage in additional conversations with Zayo about how the provider could develop a partnership that allows it to garner a business case that benefits both the City and Zayo including access to enterprise customers or additional Zayo partners including a possible partnership with Common Networks. A partnership between the City of Fairfield and Zayo could range from building and deploying and managing with Cisco equipment built in, dark fiber assets, IRU lit services, or fiber swaps.

One additional advantage that Zayo brings is the company's existing partnerships, including a key partner that can support the video storage needs of the City's large camera system. Zayo maintains relationships with wireless providers who utilize their network for backhaul, allowing them to gage what large wireless providers such as T-Mobile and Verizon may plan to do in Fairfield. Zayo can utilize this knowledge and understanding of City needs to create opportunities that bring a successful network plan for all.

Pros of this partnership arrangement may include fulfilling the needs of municipal broadband requirements as well as expanding services within the community. It is unclear at this stage what investment this would require on behalf of the City. Cons include the City having little control over which areas are served and potential for handing over the use of some publicly owned assets.

Sonic

Sonic is an ISP and telecom carrier based in Santa Rosa, CA. Sonic operates as a competitive location exchange carrier (CLEC) in the San Francisco Bay Area, Sacramento, and Los Angeles. It provides a range of copper, DSL and fiber-based IP services including voice and data. Sonic currently has a presence in the City of Fairfield; its current infrastructure in Fairfield comes from the lease of dark fiber from a colocation in AT&T's central office. It delivers copper based e-services through that POP including leased copper, DSL and ethernet over copper to deliver voice and internet. However, representatives from Sonic indicate that Fairfield is out of the company's core area and that it has no fiber deployment plans or engineering plans in Fairfield.

Although Sonic does not currently have plans to expand into Fairfield, it does encourage the City to continue to develop and implement broadband-friendly policies that attract new competitive broadband providers to the region. Sonic believes there are three primary levers of deployment-centered policy that the community could engage in including a Dig Once policy, a trenching policy that includes microtrenching standards, and procurement policies that encourage new market entrants.

Because a partnership with Sonic is unlikely, no pros and cons have been identified.

Comcast

Comcast is part of a communications conglomerate that includes NBC and Universal Pictures. Originally a cable television system operator, it grew through acquisitions including Time Warner Cable in 2014. It is headquartered in Philadelphia, PA, and now provides a full range of telecommunications, including enterprise network services and voice services. Comcast indicates that anywhere they provide services, they can deliver 1Gbps broadband.

While Comcast has historically been focused on residential service, it is now pursuing opportunities to coordinate with cities on economic development by offering service to industry parks, downtown areas, in-fill, and housing developments. Generally, Comcast looks to deploy in areas with business density. Representatives from Comcast state that density in Fairfield is not currently high enough to prompt additional investment.

However, Comcast is interested in opportunities to use or lease conduit or to drop its own conduit during road and utility improvements. The company's representative also mentioned that Comcast has overhead along a lot of the Linear Park trail and would like to have an annual encroachment permit for routine maintenance/small jobs.

Pros of this arrangement include ensuring that the public right-of-way is not unnecessarily disrupted by coordinating with Comcast to deploy infrastructure. Cons are that no additional investment will be made in Fairfield to provide new services.

Centurylink

CenturyLink is a global technology company headquartered in Monroe, Louisiana that offers communications, network services, security, cloud solutions, voice and managed services. The company is a member of the S&P 500 index and the Fortune 500.

CenturyLink owns fiber infrastructure in Fairfield and already serves some larger businesses, including the Jelly Belly factory off of Highway 12 in the southwest of the City. According to representatives from the company, there are no immediate plans to expand infrastructure or service offerings at this time. CenturyLink states that it has researched the cost of deployment within the City and based on the current environment, the business model does not produce an ROI that justifies expansion.

However, CenturyLink is open to further conversations with the City about the possibility of bringing more services and infrastructure to Fairfield. In particular, if the City or another large entity became an anchor on their network, CenturyLink would be able to expand its services to other smaller businesses. Additionally, as more businesses decide to move to Fairfield, a critical mass of demand could give CenturyLink good cause to reevaluate options for expanding its infrastructure and service offerings.

Pros of this arrangement include potential for fulfilling the broadband needs of the City for municipal functions. Cons include having little control over which areas are targeted for investment in new broadband infrastructure and the need to aggregate demand before that investment takes place.

Wireless Providers

Nationwide wireless cellular providers including AT&T, T-Mobile/Sprint, and Verizon are already operating in Fairfield and, with the coming of 5G, are likely to be expanding their assets over the next several years. The cellular services these companies provide is not considered broadband, although 4G and 5G LTE can achieve broadband speeds.

AT&T currently serves the City itself with a dedicated ethernet switch, as well as offering residential internet services in some locations (see Market Assessment section of this Plan). While representatives of AT&T expressed a high level of interest in the wireless and broadband policies being developed by Fairfield, the company did not divulge any plans for providing additional wireline services in the City.

Similarly, T-Mobile/Sprint and Verizon both expressed interest in the new policies that will affect their rollout of 5G facilities, but neither has plans for providing broadband via wireline connections.

However, these wireless providers and the third parties that provide fiber to backhaul mobile data are likely to be excavating public rights-of-way to deploy additional fiber that will support 5G small cell facilities in the coming years. They will also be interested in using City assets such as streetlights for mounting new devices.

Pros include opportunities to partner with these wireless providers for mutually beneficial joint builds, permitting considerations, and in-kind use of assets that support the community. Cons include having little control over investment and potentially handing over use of publicly owned assets.

Criteria for Partnership Evaluation

There are several guidelines that the City should consider when evaluating opportunities for partnerships with telecommunications providers. Generally, as discussed above, Fairfield should seek provider partners who will actively participate in community and economic development as well as work with the City to achieve its network vision.

Non-Exclusivity: The City should not enter into any exclusive agreements. Non-exclusivity allows for a more competitive environment in which the City can partner with multiple entities to get the most benefit from use of assets.

Cost Savings for City Operations: Proposals that include connecting City facilities to reduce telecommunications expenditures could be highly advantageous. Many partners in similar agreements have been willing to connect City facilities at no cost, sometimes even handing over ownership of assets such as fiber strands. Such arrangements should be strongly considered.

Benefit to the Community: Ultimately, partnerships with the private sector are strongest when they provide as many benefits as possible to the community. Providers may be willing to provide no- or low-cost services to areas in need, small businesses, or public spaces such as libraries that benefit students with no broadband at home. Support for Smart City applications may also be offered. Community benefits such as these should be weighed heavily during the evaluation process.

New investment and infrastructure: Where possible, the City should give preference to providers who are deploying new infrastructure that follows newly adopted guidelines and follows the City's new standards for wired and wireless infrastructure. The two simple reasons are that (a) this represents new investment rather than milking legacy infrastructure to avoid additional costs and (b) new infrastructure will be better aligned with public interests, higher-capacity, and more reliable.

Construction Methods and Timelines: Some partners may propose quick, minimally invasive construction methods to speed deployment and lower costs. Magellan strongly recommends that Public Works take part in discussions about the specifics of these construction methods and that timeframes for deployment are specifically stipulated in contracts to ensure that City streets are properly restored and that the community is not inconvenienced by drawn out construction.

Revenue Sharing: As stated earlier in this report, partners may offer revenue sharing for the use of City assets. The percentage will vary depending on the terms of the agreement; Magellan has seen anywhere from 5% to 60% in favor of the City. In any case, as with all proposals, revenue sharing estimates should be heavily vetted including assumptions for take rates and ramp periods and should be evaluated against fair market rates for the use of City assets.

CITY-OWNED ISP

The most aggressive option the City has is to invest in its own broadband infrastructure and offer dark fiber or lit services via a City of Fairfield Broadband Utility. This option will require the most investment and risk but will give the City the most control over how infrastructure is deployed, ensuring equitable access and targeting areas that are most in line with Fairfield’s needs. This option is modeled in the network design (Section 5) and financial analysis (Appendix A) of this report to demonstrate the financial feasibility of a Fairfield Broadband Utility.

5. Conceptual Network Design

As discussed in the previous Broadband Development Plan, options for improving broadband range from passive, policy-only approaches to actively providing retail broadband services. Generally, these involve progressively more risk along with potential for rewards in the form of revenue and socioeconomic outcomes. Return on network investment, while generally excellent, is uncertain. Some preliminary estimates are necessary to inform decision-making and guide more detailed analysis and planning. The conceptual design describes what a Fairfield Broadband Utility network might be based on the City's goals and related connectivity needs and opportunities. **A full financial analysis of the Fairfield Broadband Utility can be found in Appendix A.**

A conceptual design is a "straw man" model to estimate network costs and revenue potential, rather than a "proposal" or "recommendation." It provides a basis for capital budgeting and strategic planning. It is our understanding that the City of Fairfield may own infrastructure but will not become a retail provider. Therefore, its options are either a dark fiber or open access business model. A dark fiber approach involves simply leasing out a real asset—strands of fiber optic cable. Open access involves additional equipment, lighting the network, and providing services. Neither involves access infrastructure for retail broadband, which would also require major investments in operations and staff.

Networks can be described as part of a technology suite or stack (see Figure 23). A complete tech stack includes devices and software applications, which are generally provided by the network end-user or another party. ISPs have software and systems to operate their services. A complete network design provides detailed specifications of the lower portions, the foundation, of the tech stack. As conceptual design for a wholesale, infrastructure-only utility, only the physical and facilities layers are generally addressed here.

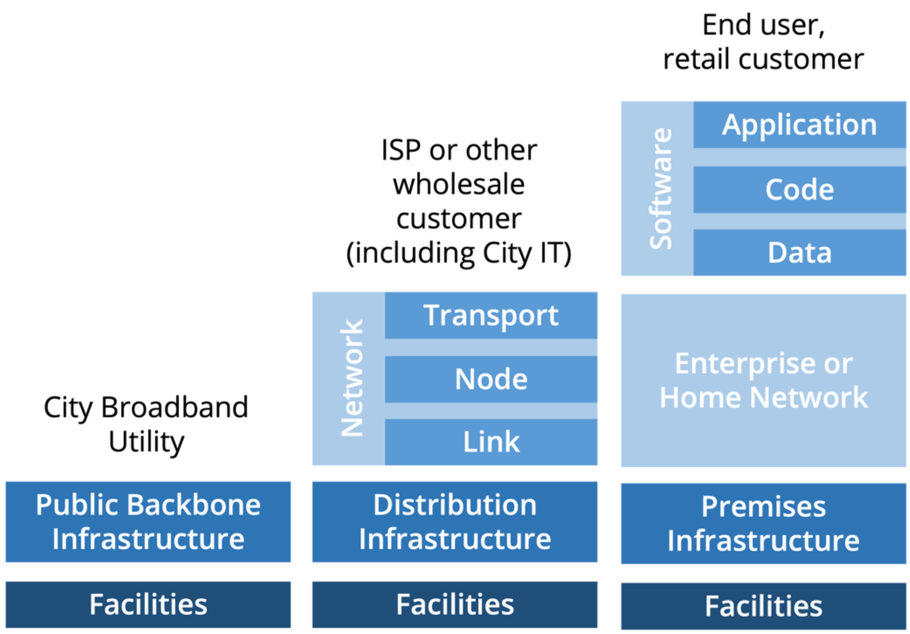


Figure 23. The Tech Stacks for Fairfield Broadband, Retail Providers, and Users

Under the wholesale, infrastructure-only business model, network service providers and major enterprises or institutions, including the City itself, are the customers. The broadband utility develops, maintains, and manages backbone infrastructure. Distribution and access infrastructure are generally handled by the wholesale customer. Customers use the backbone for their core and feeder networks and possibly as distribution infrastructure. The network will handle numerous wholesale customers, especially if it is carefully managed: A conduit can be leased to a single customer or, on the other extreme, portions of a backbone cable could be leased to hundreds of customers.

The design allows the network to be extended by others—community institutions and retail internet service providers—as they use Broadband Utility infrastructure as part of their stack(s). A large, multi-site enterprise, for example, could lease fiber strands and attach its own equipment. Or a provider could build fiber or radio access infrastructure in particular areas or locations, interconnected via the backbone. Conceptually, customers pay to connect their assets via the Broadband Utility. Lit services would make this much easier and valuable to most prospective customers but would require capital and operating expenditures. In this design, the physical network and facilities can be securely shared among multiple customers/users, controlled by the Broadband Utility, but the Broadband Utility does not light the network.

NETWORK ARCHITECTURE

The Broadband Utility network will be designed as a backbone for passive optical network (PON) and active Ethernet. The basic requirements are to interconnect distributed customer access equipment and commercial data centers and retail ISPs. Fiber should be deployed in a ring topology to minimize impact of an equipment failure or fiber cut. The basic architecture is interconnecting rings—like a length of chain—of high-capacity fiber cable in underground conduit with access points (hand holes, pull boxes, vaults) at regular intervals. The routes follow major thoroughfares, as well as some secondary streets where appropriate to complete a ring. There are a few spurs to connect water facilities and wireless tower infrastructure. The rings are grouped in four phases for analysis and estimating purposes. The routes are designed to connect as many City and community assets as practical with this architecture. Therefore, the conceptual network design is very extensive and intended to generate maximum cost estimates for budgeting and planning purposes.

Fiber Backbone

Magellan Advisors recommends high strand-count (e.g., 432-strand) fiber cable for the backbone. The revised conceptual backbone is entirely underground because this approach is the most conservative design in terms of costing and risk avoidance. It also tends to be more aesthetically acceptable**. We do not recommend aerial deployment for the network backbone due to high ongoing costs and the need to keep the backbone resilient, protected from the elements and accidental disruptions in the public right-of-way; aerial should be used only in areas where conduit can't be laid or for last-mile connections in the distribution network. Underground has a higher initial cost to build, however is less costly to maintain** (although this varies by specific method: bore verses trench verses direct bury/micro-trench). The design includes two separate conduits ducts with shared access points (hand holes). We provide cost estimates for two 2-inch conduits and two 4-inch conduits.

Generally, 2-inch conduit can be bored or direct buried. The cost of 4-inch conduits is substantially higher because it requires much more extensive excavation. Ultimately, it may be appropriate or necessary to deploy aerial fiber or use other methods. Connections can be flexibly allocated and secured across this infrastructure. Therefore, it may be unnecessarily constraining to physically separate commercial and institutional uses. These and other modifications should be expected based on financial and practical issues defined as the planning proceeds.

The conceptual design is for "backbone" network infrastructure, the purpose of which is to interconnect and support multiple other networks. Typically, broadband networks have a core network that forms a ring between a few key sites. Core sites contain the most powerful equipment to connect the local network to the global network. They must be secure, with high reliability power, preferably centrally located. At least one, ideally two, sites must connect to high-capacity dedicated internet services, ideally via different providers with fiber following separate routes, for bulk IP.

Fiber Distribution Infrastructure

The backbone will traverse the utility service area to connect distributed customer access equipment, or hubs. Feeder lines, which are also typically deployed in rings, connect the core sites to distribution hubs. Distribution lines are branches from the hubs and access lines drop off the distribution lines—hence the term “fiber drops”—into customer premises. Major sites can be directly connected to the core. These lines are referred to as “laterals” rather than feeders. Radio access networks (RANs) may also be used as broadband distribution infrastructure, with cell sites as hubs. The 432 strands of fiber in one cable of backbone infrastructure may be used for a feeder network and/or laterals, as well as core network. The particular use of specific fiber strands is a matter of how they are spliced together and where they terminate.

Under wholesale business models, customers may be responsible for distribution infrastructure, as shown in Figure 24. This includes deploying hubs as shelters and/or cabinets at strategic points of presence (POPs) throughout the service area. The network provides redundant feeder fiber connections to hubs. ISP POPs may consist of powered cabinets, prefabricated shelters, or existing structures with sufficient space for equipment racks and other components. The conceptual network is designed to connect to retail ISPs at one or more locations across its service area and to accommodate internet connectivity via diverse routes to multiple upstream service providers for fault protection.

The City may provide some access infrastructure for lit services for internal purposes. The backbone routes cover many City assets and systems, including traffic, surveillance cameras, SCADA, and AMI, saving operating costs and supporting increased functionality and operational benefits. The conceptual design accommodates connections to such assets and provides a basis for estimating costs to physically connect them to the backbone. See the Financial Analysis section, below, for a discussion of these components and estimated costs.

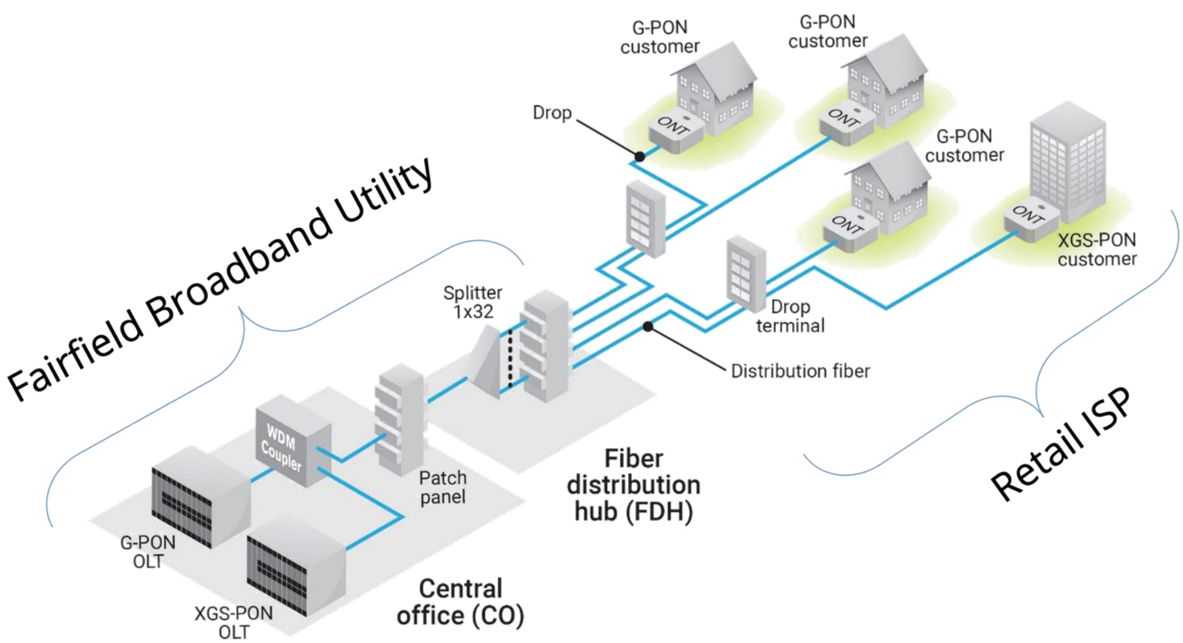


Figure 24. Passive Optical Network Structure Divided Between Fairfield Broadband Utility and Wholesale Customer Retail ISP

Feeder and Distribution Fiber

Feeder fiber extends from the POPs to neighborhoods and business districts. Feeder fiber connects Optical Line Terminal (OLT) ports to passive splitters located in outdoor cabinet enclosures called fiber distribution hubs (FDHs), placed strategically throughout the service area. Splitters may also be located within the access POP itself. In areas where aerial fiber deployment may be used, FDHs may be placed aerially or transitioned from the aerial pole to a ground mounted FDH. Feeder fibers are sized based on the demand forecast and sizing of each enclosure to ensure that each service area is well equipped for both PON and Active Ethernet services. These details are normally identified in the detailed engineering design process.

Distribution fiber extends from the splitters in the FDHs to network access points (NAPs) which provide access to the individual fibers required for customer connections. NAPs may be attached to aerial strand, located in ground level pedestals or placed in underground vaults or hand holes located near the sidewalk or curb in residential neighborhoods or business districts. Fiber distribution to NAPs will be sized based on the service area density to provide service to between 8-12 premises per NAP.

Fiber Service Drops

Fiber drops connect from each NAP to the customer premise equipment that delivers broadband service. At the customer premise, the drop cable terminates in a protective “clamshell” enclosure attached to a home or building for storage of slack and connection to the home equipment. Drop fiber may be installed aerially or underground, typically for a flat fee. Providers may charge additional drop costs for special circumstances such as burying fiber through difficult landscapes or under driveways.

Network Equipment

The network equipment required to deliver broadband services to customers is comprised of several functional groups and multiple components within each group. Each functional group and a brief overview of how it is used to deliver service to the end customer follows below. Retail ISPs may operate a mix of access network consisting of both PON and Active Ethernet services. The diagram below demonstrates the functional components of the network and how customers connect to the network to receive services.

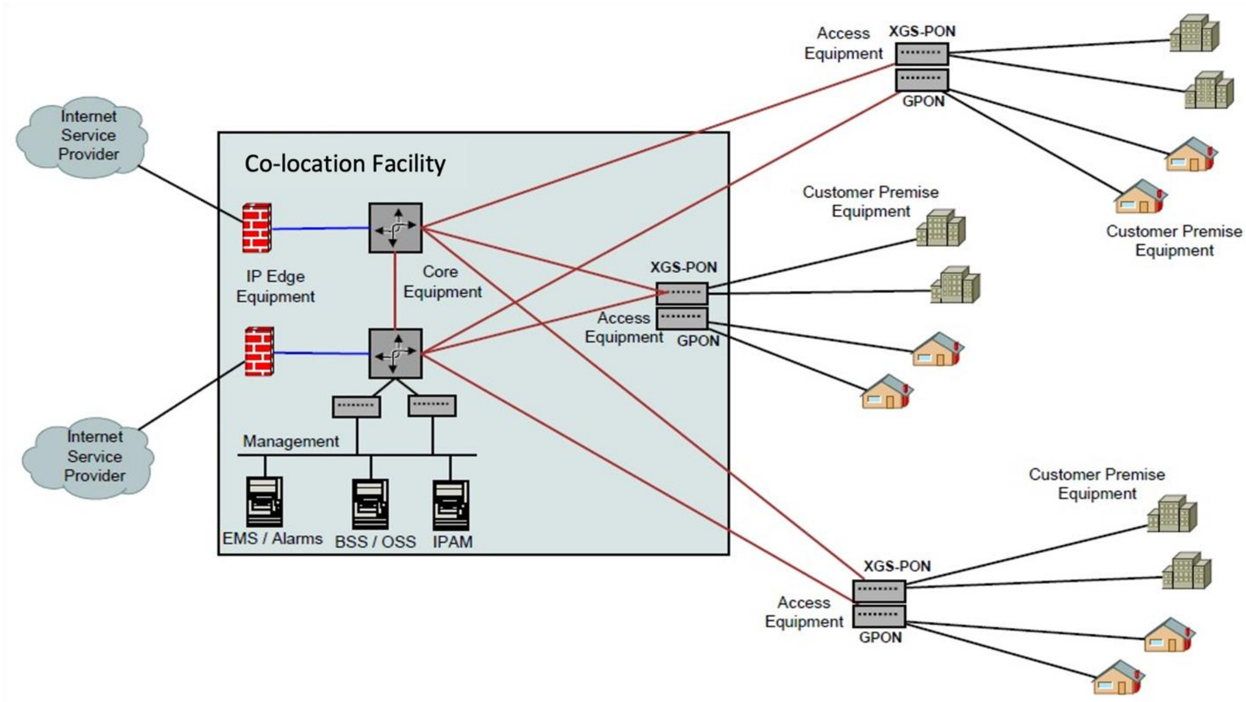


Figure 25. Passive Optical Network Broadband Model

Core Equipment

The core equipment aggregates traffic from all access equipment, connecting customers and routing their data to and from the IP edge equipment or other end-point destinations. Standard network protocols provide link redundancy and dynamic traffic re-routing in the event of an equipment failure or fiber cut. Core equipment can easily support thousands of customers and hundreds of gigabits of traffic throughput at deployment and will accommodate future system growth through the addition of service modules, optical interfaces, and/or software licenses. Figure 25 shows the key components and how they are integrated into a broadband system.

Optical Network Terminal

An Optical Network Unit (ONU), sometimes called an Optical Network Terminal (ONT), serves as the demarcation point between the retail ISP's fiber network and the router or firewall connecting to the customer's local area network (LAN). There are two general methods for installing ONTs. The first method involves mounting an outdoor rated ONT on an exterior wall of the structure and extending service wiring inside the premise. The second method involves extending the fiber into the premise and installing an indoor-rated ONU inside.

In either case, the ONT is typically installed somewhere near the fiber entrance and an AC power source. The ONT terminates the fiber based PON signals and provides customer access to their services through traditional copper interfaces. XGS-PON ONT's supporting greater than 1 Gbps data service may also support optical small form-factor pluggable (SFP) interfaces for connection to enterprise-class LAN equipment.

Internet Protocol Edge (IP Edge) Equipment

Separate from the core switches, the Broadband Utility should maintain an "internet perimeter." The internet perimeter will include internet routers and internet firewalls to be used to manage routing throughout the network. Firewalls will be utilized to protect critical back-office systems, including provisioning, network management, data storage, and other information. The Utility's two core switches will be interconnected to two internet routers providing redundancy for internet services in the event of a single interface or equipment failure. As mentioned above, the Utility should acquire bulk IP from at least two providers using diverse paths, one of which should be a Tier 1 provider.

Wireless Access Infrastructure

While the Broadband Utility would not deploy or operate radio access network or other wireless infrastructure under the model in this plan, it is important to consider this infrastructure in the design to accommodate cellular and fixed wireless ISPs and capitalize on the Broadband Utility's assets.

Wireless broadband can operate as mobile or fixed service. Although cellular connections can approach broadband speeds, mobile wireless broadband is still in its infancy, as discussed below. Fixed wireless can be used to connect remote locations or sparsely populated areas (see Figure 26), where DSL or cable service would not be economically feasible, via long-range directional microwave antennas. As discussed below, most of these connections are built on proprietary technologies, although they generally extend Wi-Fi and similar standards.

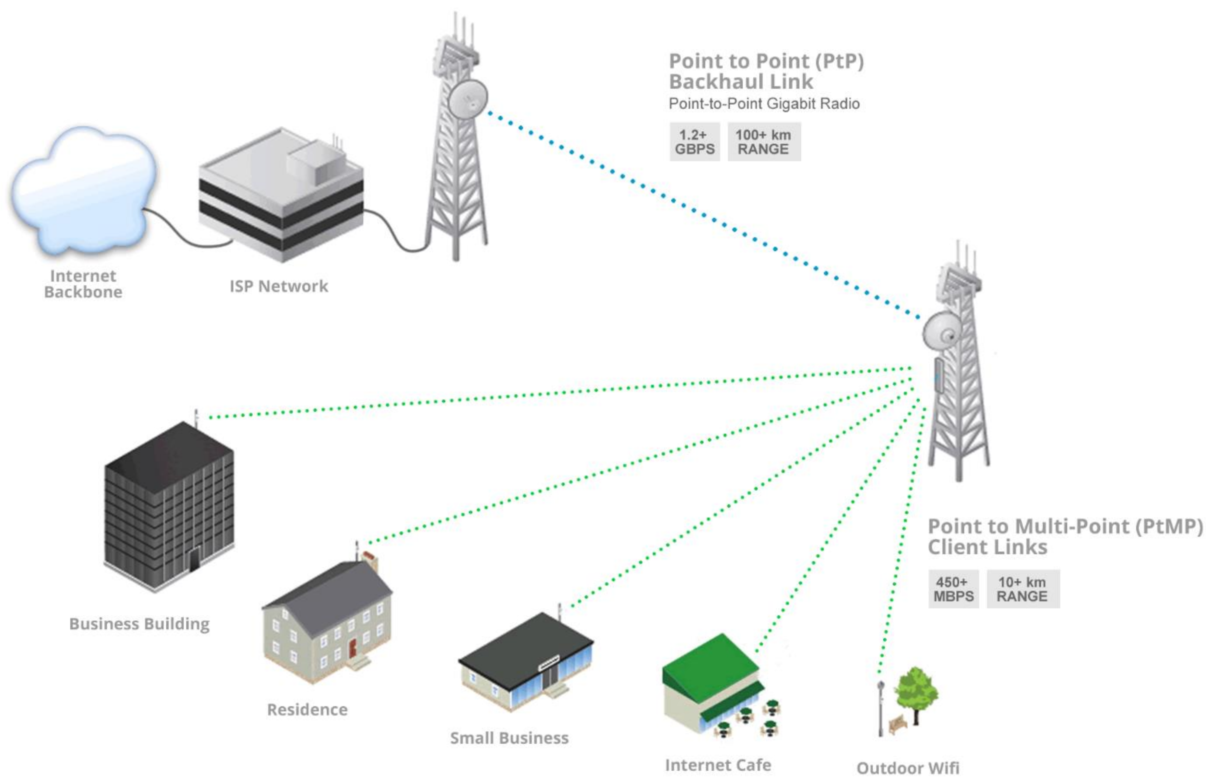


Figure 26. How Wireless Networks Connect Communities

Coverage and speed are an intrinsic trade-off for wireless technologies. The farther a signal travels, the less information it can carry. High frequency signals, which have inherently high capacity, travel shorter distances than lower frequency signals (at the same power level). Lower frequency signals cover terrain and penetrate physical objects more effectively than high frequency signals. Spectrum in the lower frequency ranges offer better non-line-of-sight solutions, whereas the higher spectrum ranges need a more line-of-sight solution. Line-of-sight requires the transmitting antenna to be able to "see" the receiving antenna with limited trees and buildings in the way to be effective.

Terrain, then, plays an important role in the network design. Radio signals do not get over mountains or hills very well, nor does certain spectrum do very well in penetrating through buildings, foliage, or water, including rain and snow. The farther away the transmitter and the receiver are from each other, the less bandwidth is available. Transmitter sites need a means of connecting to the network, whether via fiber or microwave, to another site where it then transitions to a wireline fiber network. Fiber can be costly to install in remote locations. Electrical power, security and access are also considerations when locating appropriate tower sites. A propagation analysis to determine appropriate tower locations for Fairfield's specific terrain would be part of a wireless high-level design to be conducted in the future.

Cellular Mobile Wireless

Mobile wireless connections operate from antennas on towers that create wireless cells across a geographic area. Connectivity is maintained as devices move from wireless cell to wireless cell. The base of each tower site is connected to other tower sites and the internet, optimally via fiber optic cables. Today, 4G transmits data at around 12/5 Mbps.[14] With each new generation, more wireless applications become possible as more data can be carried across the airwaves.

[14] Several providers have announced they will discontinue 3G services in 2022.

5G networks operate multiple frequencies using millimeter wavelengths to offer anticipated download/upload speeds of 1 Gbps. The networks are designed to provide increased efficiencies while decreasing latency and to improve the performance of connected devices that define the Internet of Things (IoT), including autonomous vehicles, healthcare monitoring technologies, ultra-high-definition video, virtual reality, and many more applications ripe for development.

With limits in ROI and physics, the reality of 5G as the all-encompassing gigabit solution is beginning to fade. A mature 5G network will take time and continued investment by carriers. The information is speculative on when larger, national cities will begin to see 5G deployments, but if the investments in current infrastructure are any indicator areas like Fairfield should expect a long wait.

We note that there is an ongoing issue with 5G as it relates to airports, which may have an impact on Fairfield due to its proximity to Travis Air Force Base. Major mobile network carriers including AT&T and Verizon have agreed to postpone the rollout of 5G around airports after the Federal Aviation Administration (FAA) cited concerns about 5G C-band interference with some older aircraft's radioaltimeter equipment. These concerns are currently under review by the FCC, but there have been no new recommendations or additional information to date. There is not sufficient data to recommend any policy changes at this time. Magellan Advisors will inform the City of Fairfield of any new information that becomes available.

Fixed Wireless

Fixed wireless services allow consumers to access the internet from a fixed point while stationary, and typically requires an external antenna with direct line-of-sight between the distant wireless transmitter and the customer building-mounted receiver. Speeds are generally comparable to DSL and cable modem. These services have been offered using both licensed spectrum and unlicensed devices. To deliver a fixed wireless solution, providers need to consider:

- Available and appropriate spectrum – not all spectrum is created equal
- Tower locations and siting
- Terrain and other sources of interference
- Backhaul options

  Bandwidth requirements

Fixed wireless can be deployed as point-to-point (PtP or P2P) or point-to-multipoint (PtMP or P2MP). PtP involves a one-to-one relationship between antennas at different locations. It is typically used for interconnecting sites, such as a headquarters or main buildings, to a remote facility. Internet service providers typically use this approach for connecting to customer locations where they do not have wired infrastructure. End-users typically use it as a backup or secondary connection or for non-critical sites because the connections have less capacity than fiber and are susceptible to environmental degradation from foliage, weather, and other factors. PtMP involves multiple—even hundreds of—users' antennas connecting to a single, central base station. This model and infrastructure are very similar to cellular but with much more bandwidth and without the mobility.

As illustrated in Figure 26, PtP and PtMP are complementary technologies. PtP can be used to interconnect PtMP base stations as well as for remote sites (although fiber is preferable due to its capacity and reliability). The networks require Line of Sight (LOS) or near Line of Sight (nLOS) to operate. The systems utilize proprietary protocols and specialized devices to achieve the long ranges and high throughputs. Different vendors' products may not interoperate with each other.

Citizens’ Broadband Radio Service (CBRS)

The FCC set aside the 3550-3700 MHz (3.5 GHz) spectrum in 2015 under a new, shared spectrum approach. There are three tiers of CBRS users, diagrammed in Figure 27. Current, incumbent, tier 1 spectrum users, which include US military, fixed satellite stations, and, for a limited time, wireless internet services providers (WISPs) are protected from interference by other users. Ten Priority Access Licenses (PAL) for 10 MHz channels between 3550 and 3650 MHz in each county was auctioned off by the FCC in July 2020. These licensees are protected from interference by other users but may not interfere with incumbent users. A licensee may aggregate up to 4 PALs. Any portion of the spectrum may be used without a license for General Authorized Access (GAA), but this may not interfere with incumbent or PAL users.

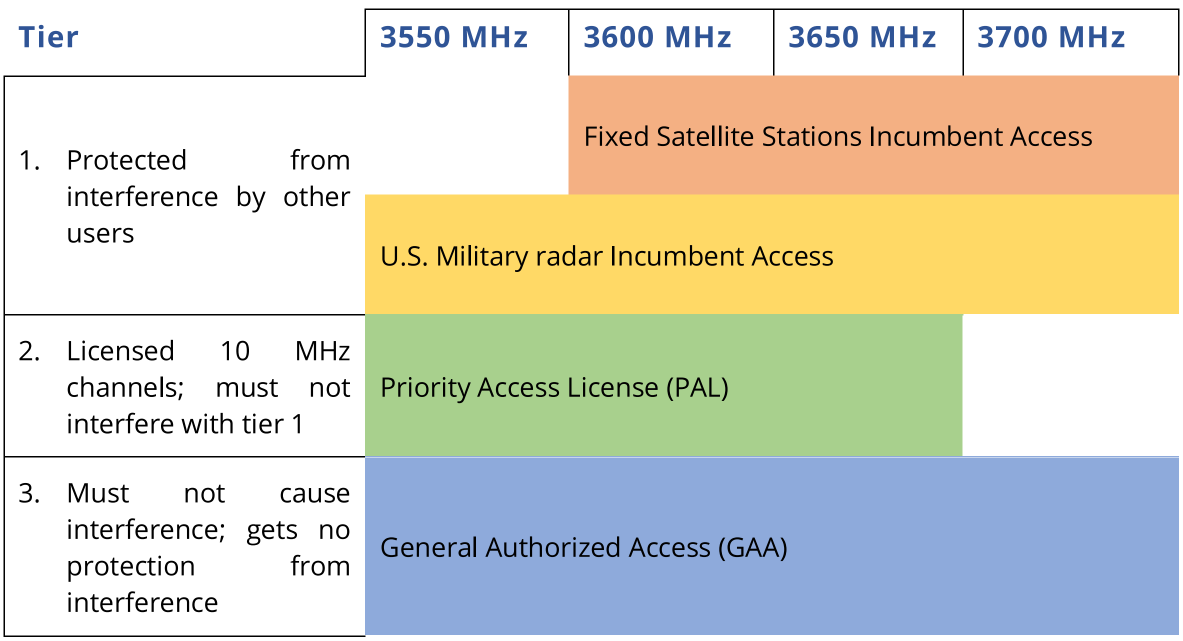


Figure 27. CBRS User Tiers

CBRS uses will be managed by a Spectrum Access System (SAS) with which all Citizen Broadband Service Device (CBSD) base stations must be registered. There are two classes of CBSD. Class A base stations, which can transmit at 1 watt of power, are meant for smaller-scale indoor, enterprise, or campus use. Class B base stations can transmit at 50 watts, giving them much greater range. Strategically placed radio signal sensors will ensure that uses do not interfere with each other, particularly military radar.

Another important characteristic of CBRS is the Long Term Evolution (LTE) protocol is commonly used with the spectrum. LTE is also used for 4G cellular data service, so it is widely implemented in user equipment. CBRS involves different spectrum, but some smartphones have antennas that operate in the CBRS bands. It is reasonably easy and economical to add CBRS/LTE to devices without changing their operating characteristics or systems. Therefore, there are few barriers to end user adoption.

The combination of CBRS/LTE in base stations and user equipment is a radio access network (RAN). A RAN has a network core (an Evolved Packet Core or EPC) that authenticates and authorizes user equipment and manages connections to multiple base stations. This allows for mobile roaming from base station to base station without loss of connectivity and makes RANs very secure. The downside of a CBRS/LTE RAN is that some entity must operate EPC and the SAS. These are relatively inexpensive services that can be purchased from vendors or run on private servers.

Low-Power Wide Area Networks (LPWAN)

Although not broadband, LPWAN technology should be considered in any network infrastructure plans. It is generally used to connect many small devices over a large geographic area. Water meter reading is a prime example of a LPWAN application. These are message-based networks, meaning end devices send small packets of information to an LPWAN gateway that then sends the data via a wired network to monitor or tracking software. Real-time control of the devices is very limited but other, similar technologies exist that allow for remote control.

There are numerous standards for LPWAN with varying degrees of openness and propriety. The proprietary technologies were first to develop and currently have the largest installed bases. The open standards for LPWAN are still evolving. The major open standards are extensions of other standards, specifically 5G and Wi-Fi. The costs and flexibility of open standard based systems tend to be much better than proprietary technologies, although proprietary technologies may perform better in the short-term.

Wi-Fi

Wi-Fi, which was originally termed “Wireless Fidelity,” is an open standard that was developed to connect computers to a local area network (LAN) via unlicensed radio spectrum (the same frequencies used for cordless phones, garage door openers, and other non-network wireless devices). Generally, Wi-Fi is a PtMP technology: Wi-Fi access points connect multiple devices within limited range, typically no more than 150 feet indoors and up to 1,500 feet outdoors. There are multiple standards or versions of Wi-Fi. Some can provide up to 1 Gbps of throughput. Other new Wi-Fi standards are intended to cover large areas with minimal power requirements.

Wi-Fi coverage and speed depends on multiple factors such as buildings, foliage, and other physical barriers, interference from other spectrum users, radio spectrum used, transmission power, type of antenna(s), and weather. New versions of the Wi-Fi protocol operate at greater distances and/or speeds. It can be deployed PtP to interconnect sites and is being adapted for LPWAN applications.

Wi-Fi access points are often integrated into routers that interconnect the Wi-Fi network (also called a service set identifier or “SSID”) to other networks, including a broadband connection to the internet. This is typically referred to as a “hotspot” or Wi-Fi zone. Multiple access points can be interconnected to each other as well as a router to cover a larger area. A Wi-Fi network can even be extended over multiple otherwise independent routers via a centralized server to create “community” Wi-Fi. The latest version, Wi-Fi 6, improves these functions as well as expands the spectrum and increases speeds for Wi-Fi connections.

Today, many organizations use Wi-Fi to provide wireless connectivity throughout a building or campus. Many cities and counties have deployed public Wi-Fi in zones that extend into parks, other public spaces, and even throughout the community. Wi-Fi hotspots are common at hotels, restaurants, and public buildings for public access, and are widely used in homes and businesses for private access. The conceptual network is designed to accommodate Wi-Fi as well as other wireless technologies but does not include them. While the Broadband Utility could offer public Wi-Fi, we assume any such equipment would be provided separately by the City or other entity.

Radio Access Network model

To accommodate all the above forms of wireless connectivity, and thereby maximize the number, types, and value of wireless providers as customers, Magellan Advisors recommends the City of Fairfield plan around the Radio Access Network (RAN) model, diagrammed in Figure 28. Under this model, the Broadband Utility would lease co-location facilities, fiber backbone, poles, towers, and other assets to private companies to deploy and operate RANs. The particular type of RAN would depend on the equipment providers deploy.

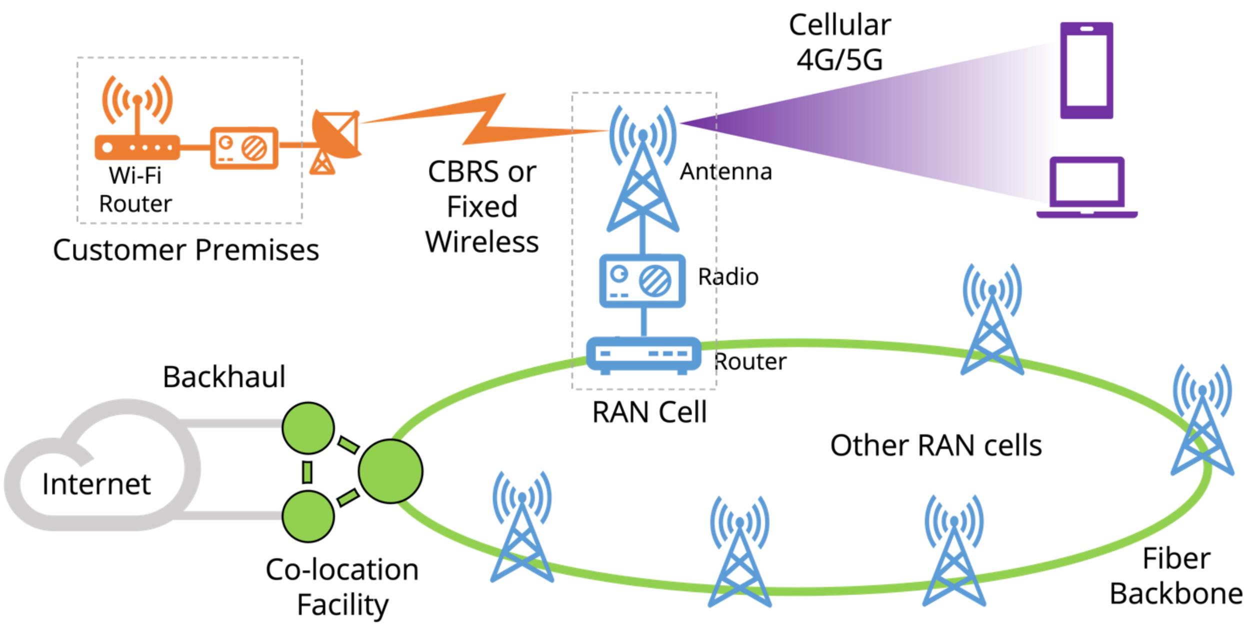


Figure 28. The Radio Access Network (RAN) Model

The key issue for the Broadband Utility is to develop City assets and facilities to accommodate RANs. The fiber backbone must route past poles and to towers. Poles will need to be assessed and possibly upgraded to support small cell infrastructure. Tower sites will need secure, multi-tenant huts for providers to deploy their gear (these huts may also serve as fiber hubs, depending on location). Providers may need the backbone to route to their central office and will definitely need interconnection to their regional/national networks.

RANs are much less costly that fiber networks. They are more flexible, too, but have much less capacity and lower reliability. Mounting facilities can be the largest cost for RAN because antennas need to be above the surrounding terrain. Aesthetics is also an important issue because, as boxes on poles and towers, cell sites are not particularly attractive. People want connectivity but may object to cells in their neighborhood. More practically, there have been recent issues with 5G interfering with airplane navigation, as discussed on page 55 of this document, although there have been no updated recommendations or guidelines from the FCC regarding these issues. The City already has configuration modifications that are required due to Fairfield's proximity to Travis Air Force Base.

Since RAN operators are among the Broadband Utility's prime customers, it should work to address cell site costs and issues and facilitate RAN development. Improving streetlight poles with fiber and working with TAFB to develop cell sites are two specific examples. The City may want to extend the network to reach all area cell sites.

Co-Location Facility and Core Network

Modern, carrier-class networks are typically structured in a hierarchical manner, with a core network interconnected a few key sites. Core network sites are key to operations and reliability as they feed major sites. The Utility will need a central office (CO), data center, or headend facility to provide an interconnection hub for retail ISPs. The CO will house core and edge equipment for ISPs serving customers within the area. Other carriers can be co-located in these sites so circuits and traffic can be connected and routed to the rest of the world.

Two of these sites, including the CO, should have dedicated internet access to different providers using separate network routes out of the area, ideally to both Sacramento and San Francisco. Equipment and facilities requirements are reasonably modest—primarily separate, secure cages for providers and major network users to place equipment, along with environmental controls and clean, reliable power. The Utility may add equipment to provide lit services, up to and including transport, edge processing, hosting, and other services, as appropriate, but that functionality is beyond the scope of this design.

The City of Fairfield has several prospects for a CO and co-location facilities.

- Railroad stations can be good locations because substantial fiber routes are in the railbeds.
- The FAST Transit Center may also be a good location because it is adjacent to the freeway, which is where the State of California is likely to route middle-mile fiber through CalTrans.
- The Public Works Corporation Yard is another prospect.
- While the City's data center in the Police Department would be a core network site, it must have limited access so is not a good co-location site.

  The City may want to partner with network service providers or corporate real estate companies. Many co-los are private facilities.

6. Phased Implementation Plan

The conceptual design is divided into four phases, each consisting of one or more physical rings, for analysis and planning purposes. Figure 29 is an overview of the entire conceptual design, broken into phases and including service area, showing city facilities for reference. Note that service areas overlap. The backbone would cover Fairfield's densely populated areas but would not reach all parts of the City. Distribution infrastructure could stretch well beyond the service areas.

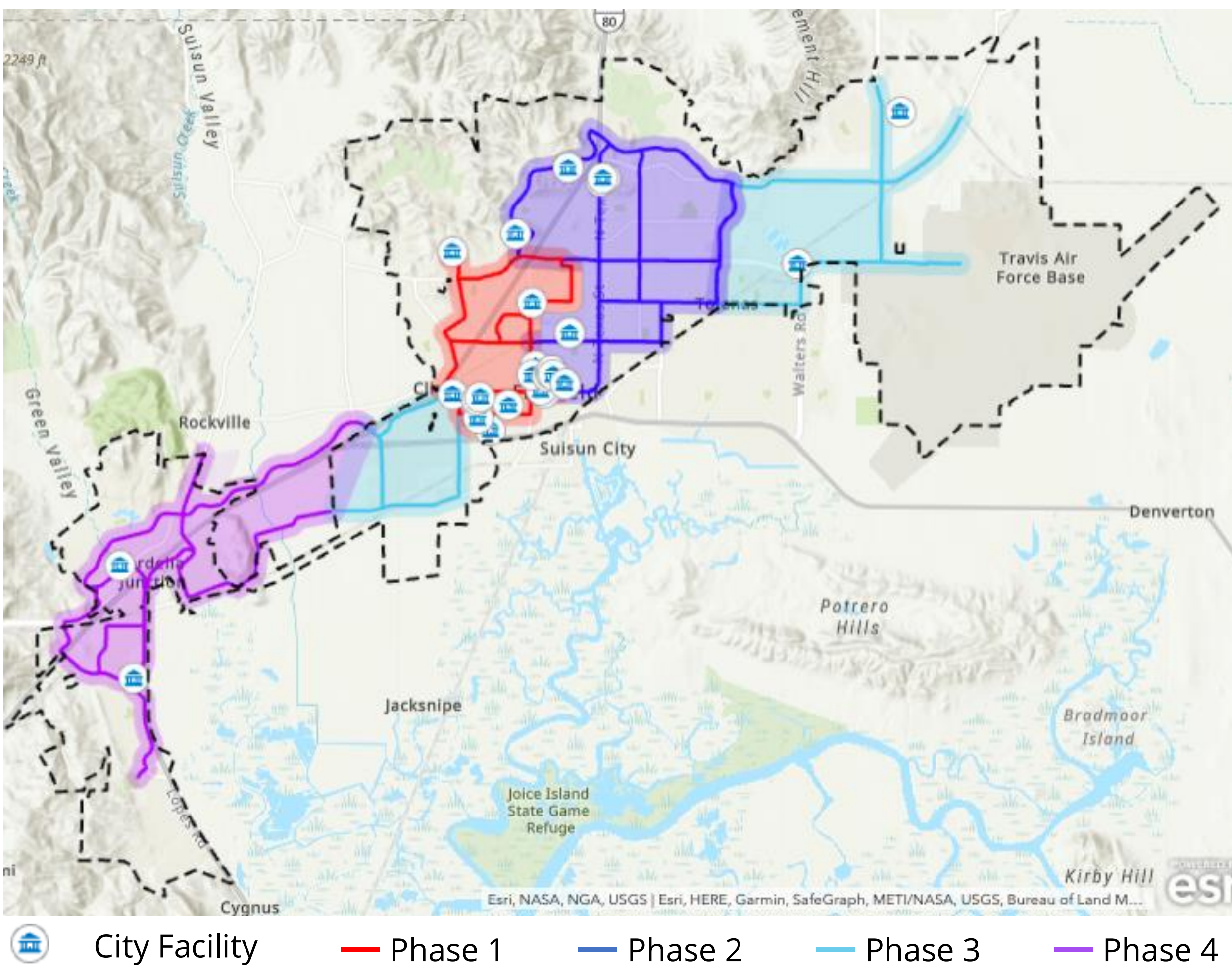


Figure 29. City of Fairfield Fiber Backbone Conceptual Design Showing Phases/Rings and Their Service Areas Along with City Facilities

The phasing has two basic purposes. One is to provide a basis for estimating costs and coverage, including potential revenue, over time. The other is to establish a foundation for strategic decisions—whether and how to proceed—and implementation planning. The phases are not fixed recommendations for the sequence of development. Instead, they are "lengths of chain"—sets of interconnected fiber rings—designed to connect as many sites as reliably, with as much capacity and flexibility, as economically as possible. Table 4 provides coverage and distance estimates by phase. They can be combined or sub-divided as appropriate or necessary. The design has a total of 67.5 route miles.

Table 4. Backbone Coverage and Distance Estimates by Conceptual Design Phase

Type of Site	Total Sites	Phase 1	2	3	4	All
City Facilities	**29**	**18**	**8**	**2**	**2**	**28**
Other City Assets						
CCTV Cameras	339	201	90	44	30	326
Major Tower/Microwave Sites	4	1	1	0	0	2
Parks	26	4	8	1	3	15
Poles	18,245	3,435	4,234	1,704	2,005	10,350
Sewer Lift Stations	2	0	1	1	1	2
Signal Cabinets	101	27	43	18	22	100
Streetlights	9,480	1,472	2,035	781	873	4,781
Water Telemetry Sites	44	3	8	6	2	15
Total	**28,241**	**5,143**	**6,420**	**2,555**	**2,936**	**15591**
Other Stakeholder Assets						
Cell Sites	37	9	13	5	3	25
Schools	38	7	11	1	1	19
Total	**75**	**16**	**24**	**6**	**4**	**44**
Fiber Route Miles	67.5	13.4	19.2	16.1	18.9	

The assets included in this analysis are directly adjacent to the backbone, or within “drop distance” (750 ft.). We recommend that the City of Fairfield conduct a full assessment of assets, including proofing, which can be done concurrently with the detailed design engineering of the network.

Some assets are within drop distance of multiple phases and are therefore counted multiple times. For example, the City Housing authority is in both Phases 1 and 2, and the Transit Center is in both 1 and 3. The last column in Table 4 shows the non-duplicative total for all phases.

Only the North Bay Regional Treatment Plant is not within drop distance. A substantial portion of water telemetry sites, streetlights, poles, and parks are beyond the backbone, which suggests opportunities for aerial fiber and small cell wireless. The backbone would need to be extended significantly to reach all cell sites and schools.

Each phase or ring defines a “service area” consisting of addresses that could be served from the backbone via a limited amount of additional distribution and access infrastructure. As shown in Table 5, Phase 2 would reach the most consumer addresses. Because service areas overlap, some prospective customer sites are in multiple service areas. The non-duplicative sum of all service areas is included in the “All” column**. The largest service area in terms of prospective customers is Phase 2, which covers a third of the City’s business and residential addresses**. All told, services areas as defined by the conceptual design encompass two-thirds address points within the City. The backbone extends to areas in the far north and south of the City, so those addresses could be reached by distribution infrastructure. The conceptual design would need to be extended to practically include the Rancho Solano neighborhood. Additional backbone may be needed to serve the Gold Hill and Vintage neighborhoods.

Table 5. Number of Prospective Customers per Service Area

Type of Site	Total Sites	Phase/Service Area 1	2	3	4	All
Residential	32,855	5,379	10,952	3,699	2,813	21,382
Commercial	4,864	1,101	1,184	388	336	2,653
Total	**37,719**	**6,480**	**12,136**	**4,087**	**3,149**	**24,035**

The phases, as well as exact fiber routes, are expected to evolve with changing needs and opportunities. The most efficient approach to network infrastructure involves developing opportunistically, in conjunction with other improvements or investments. Other goals or priorities may require portions of the network to be built sooner or later. Specific routing requires a field survey of existing infrastructure and facilities, which are elements of a high-level design, the next step in the broadband planning process. This conceptual design provides a basis for more detailed planning.

Phase 1

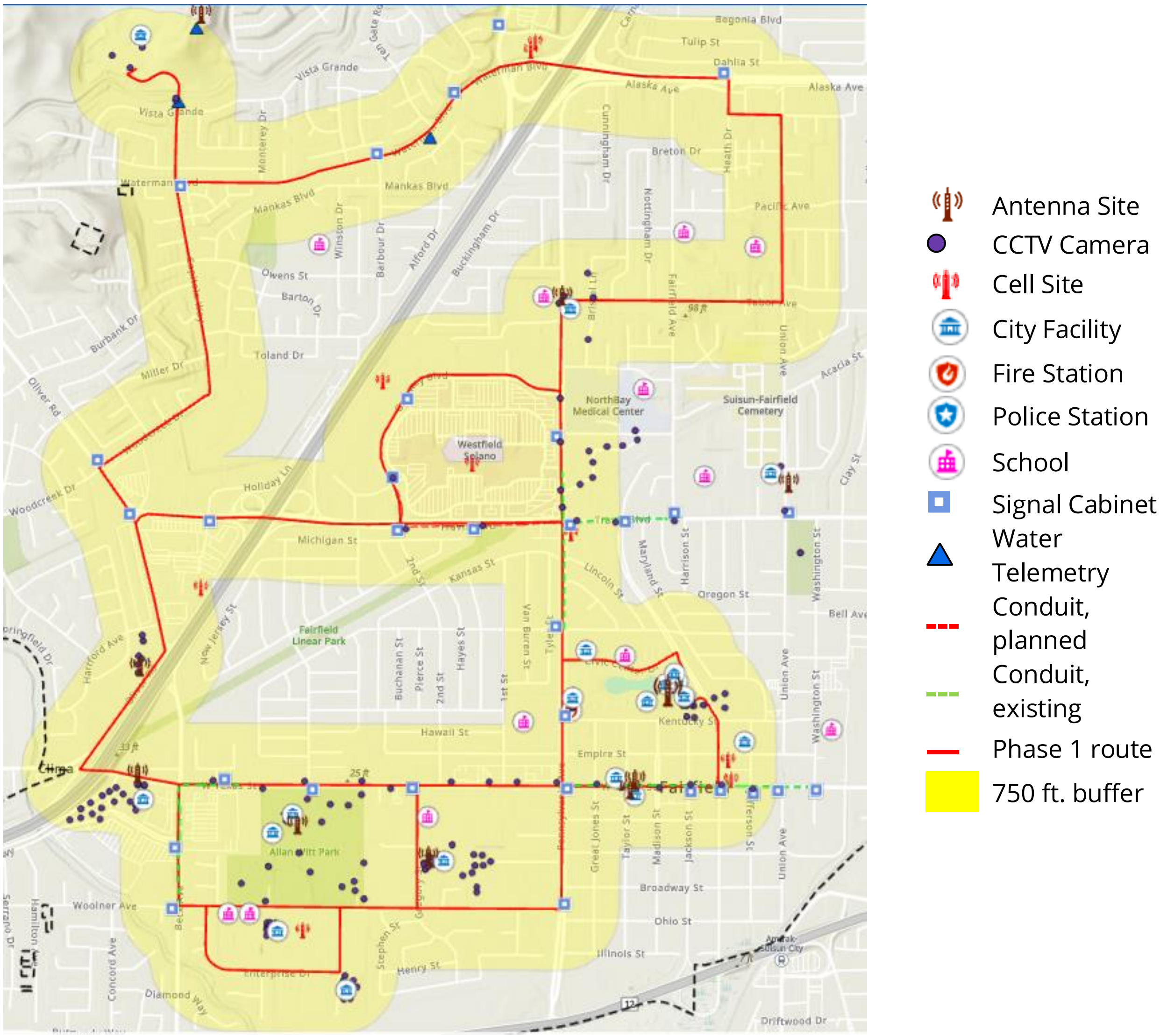


Figure 30. Phase 1 Detail with 750 ft Buffer

Phase 1, which covers the Heart of Fairfield, illustrated in Figure 30, would connect most City facilities. It passes the second highest number of other municipal assets and has the second largest service areas. Yet, it involves the fewest route miles, therefore providing more connects per mile than the other rings. For these reasons we have designated it “phase 1.”

Phase 2

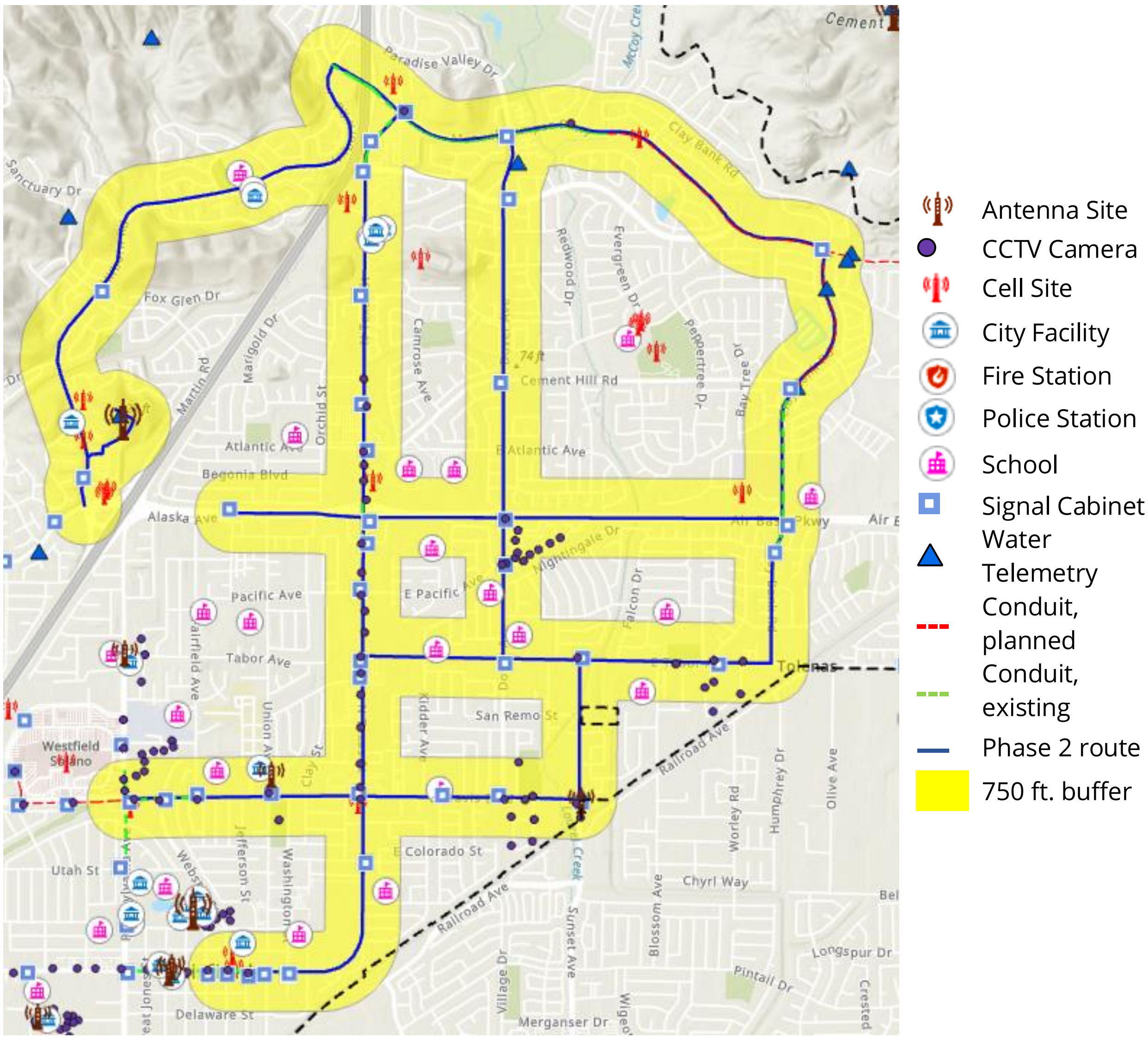


Figure 31. Phase 2 Detail with 750 ft Buffer

Phase 2 builds on Phase 1 and connects the most sites (including City sites, which are shown in Figure 31, businesses, and other customers) of any of the phases/rings. The detailed map images (Figures 29 – 31) show that many sites, including municipal assets, are not just within drop distance, they sit right on the network route(s). While not shown in the illustrations to avoid clutter, many streetlights are along these routes, well within the buffer zone. City-owned streetlights, sewer and water lines, and other infrastructure could be leveraged to extend wired and wireless broadband into nearby homes, offices, and shops, although this would require additional costs for wireless equipment that is not included in this analysis. While we were unable to include PG&E's utility poles in this design, we know they are common in Fairfield's neighborhood and go underground at major thoroughfares, which is where the fiber is routed.

Phase 3

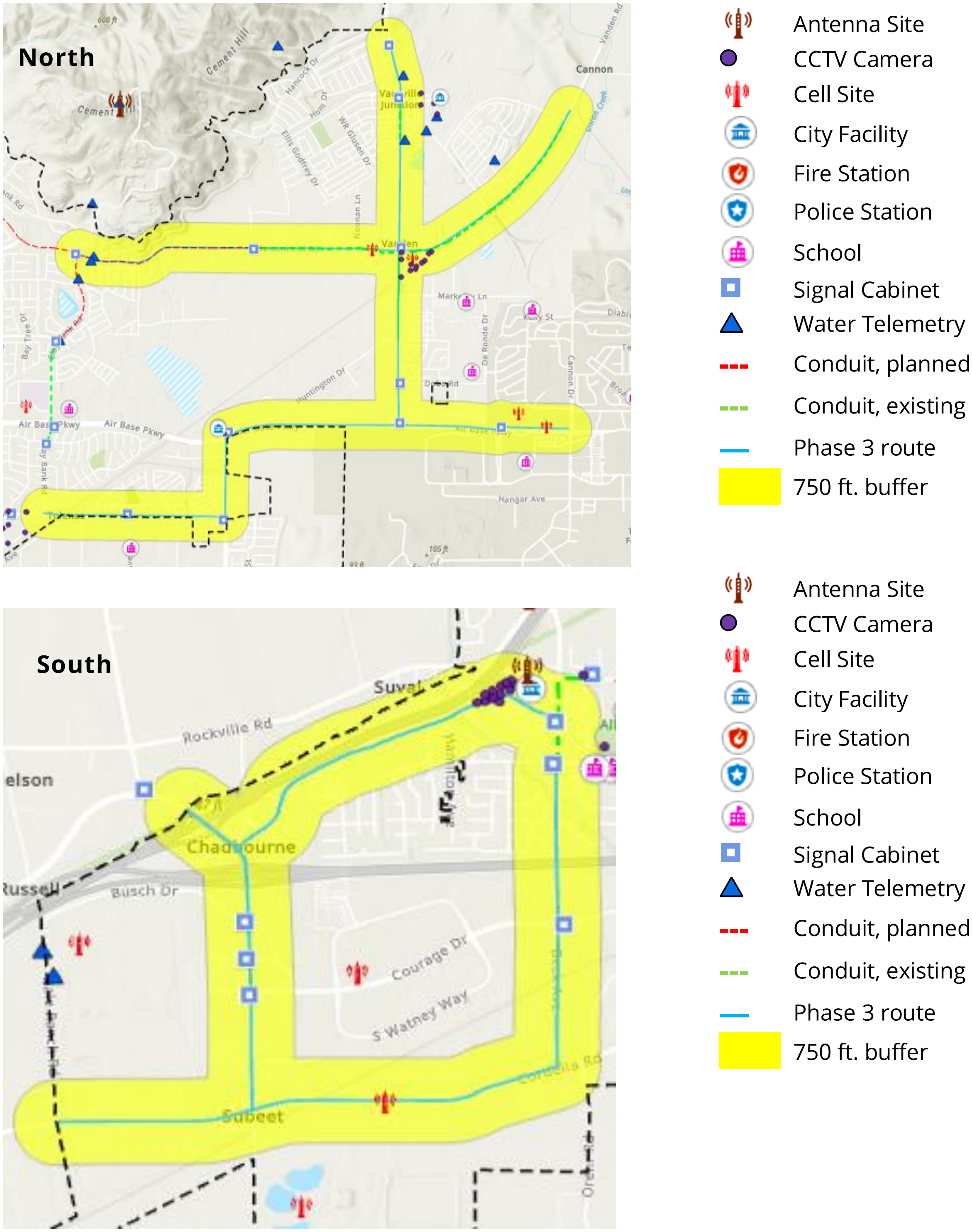


Figure 32. Phase 3 North and South with 750 ft Buffer

Phase 3 is actually two separate rings, extending the network to the north, and south into the industrial area between US Hwy 12 and Cordelia Rd.

Phase 4

Cordelia and surrounding area are covered by Phase 4, including parallel paths from south Fairfield through unincorporated areas.

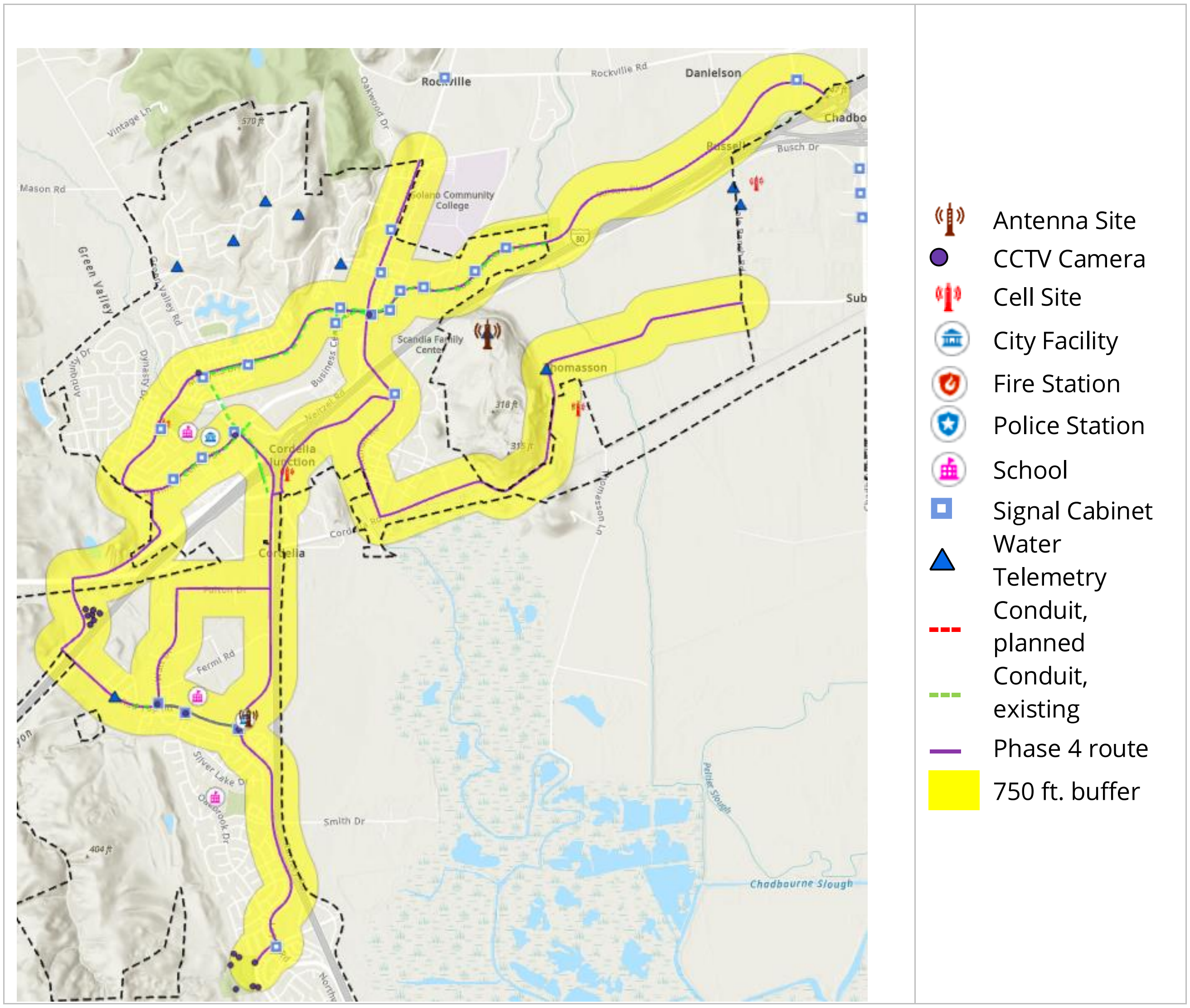


Figure 33. Phase 4 Detail with 750 ft. Buffer

The conceptual design covers most of Fairfield. It reaches the City's economic base. Fiber extends through commercial and industrial areas and to the edges of residential areas on the far ends of the City. It is designed to function as core and feeder network for private providers as well as the City and other community anchors, not distribution and access, so the coverage is reasonable. Prime areas to extend this design are Rancho Solano, Green Valley, Gold Hill, and Paradise Valley. The Hawthorne Mill and areas north of the new train station appear to be prime greenfield opportunities for network infrastructure.

Phasing and Routing Considerations

As noted, the phases and routes identified in this Plan are expected to adapt with public priorities and specific opportunities. The following are particular opportunities to consider. There are a myriad of other considerations for broadband development. A focused, detailed yet comprehensive, inclusive planning process and dedicated, capable staff are essential for identifying and balancing the full range of factors.

Connecting Cell Sites and Industrial Areas

If the City decides that economic development and/or revenue are top priorities, it may prioritize development of industrial areas and modify the conceptual design to extend to cell sites. While the conceptual design has many of these areas within the buffer area, quite a few are outside. For maximum resilience, the network should extend so locations can be connected via two separate demarcation points on a ring. Multiple sites may need to be on the same dark fiber ring. For example, two strands in every cable might be allocated to a ring interconnecting all of a provider's cell sites. Major industries, especially any that operate large compute facilities—data centers, hosting services, server farms, etc.—may want similar dedicated physical rings. Presuming they're willing to pay a premium for such connectivity, the City may prioritize development to meet their needs.

Prospective Pilot Project

The pace and scale of broadband development is limited only by resources and vision. It may make sense to begin with a small-scale project. The Texas Street corridor, both West and North, from I-80 to Air Base Pkwy is a prime opportunity. The area contains three of the four opportunity areas identified by City of Fairfield staff. This would put fiber directly through the Heart of Fairfield, allowing numerous municipal assets and private sites to be connected, as shown by the blue and red fiber lines displayed in Figure 34.

The Heart of Fairfield has several features that make it a good pilot area. First, there are a lot of prospective consumers in the corridor, making it attractive to potential wholesale customers. City assets are densely located in the area, providing means to deploy network infrastructure as well as many applications for it. Fiber in the corridor can be extended to create several small rings, which could then be extended to the full extent of the City, and to interconnect with planned state middle-mile network in the I-80 corridor.

The City could explore this option further by releasing a Request for Information (RFI) to engage interested parties who would be willing to partner on such a project. This may include potential customers and community organizations, potentially through a survey instrument to gage demand, as well as potential internet service provider partners who may wish to serve the area.

An RFI and/or survey process would allow Fairfield to collect enough information to understand the likelihood of success of such a project without fully committing to build out the entire City. The pilot project could be deemed successful if enough customers sign up for the service to maintain sustainable revenues that capture an acceptable return on investment.

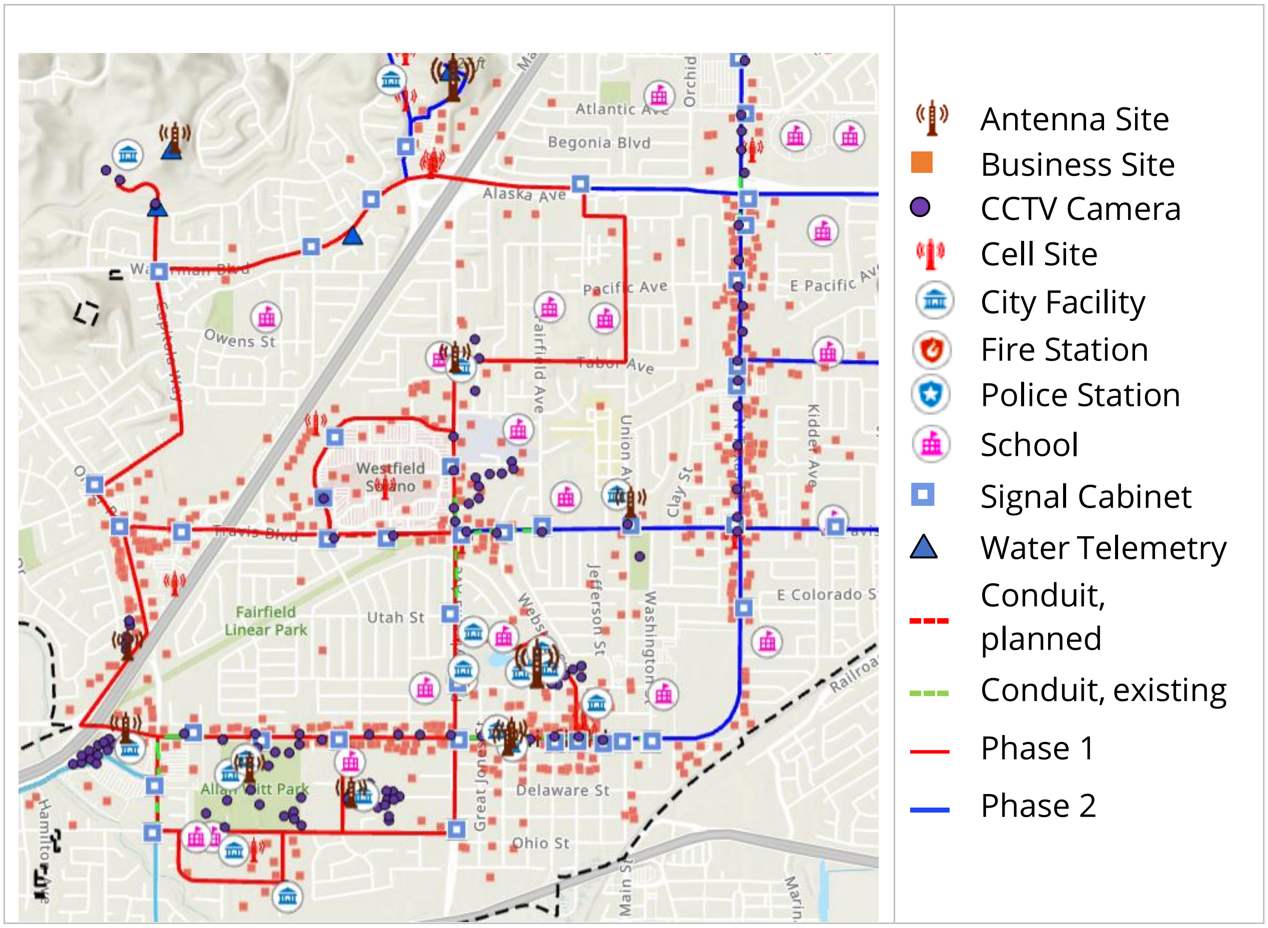


Figure 34. Heart of Fairfield Pilot Area

7. Recommendations

DECIDE ON A BUSINESS MODEL

The City of Fairfield has several options for considering the development of broadband including:

- **Status Quo:** Fairfield could choose to take no action and rely on market forces to meet the needs of the community. The City should be advised that because most telecommunications companies are market takers, not market makers, they invest based on demand, not to generate it. This means that few investments are made in new infrastructure that serves communities where demand hasn't reached an obvious tipping point, allowing internet service providers to achieve a rapid return on any investments they make by capturing a large market share.
- **Working with Current Providers:** The City could open and maintain dialogue with incumbent internet service providers in Fairfield about their plans and needs for continued investment in the community. While this approach is unlikely to disrupt the existing broadband environment in Fairfield, it could lead to constructive improvements in services for residents and businesses. This option has no risk for the City.
- **Programmatic Options:** The City could provide incentives for private investment in network infrastructure by assisting providers with pursuing funding opportunities to build new assets in Fairfield. Although most grant programs are targeted at more rural, underserved communities, it is possible that Fairfield could be eligible for some future funding opportunities that could attract the interest of providers. Having a public partner in these situations is often beneficial, and Fairfield could leverage that position to

ensure investment is targeted in a way that aligns with the City's goals. This option has no risk for the City.

- **Public Private Partnership:** Fairfield could establish relationships with internet service providers (either incumbent or new entrants) in which a variety of business model options are possible, including for the City and the partner to co-invest in new infrastructure. This option has many varieties and could be explored through a competitive RFI or RFP process to engage interested parties. Resultant agreements might include sharing of revenue for City-owned assets in exchange for a private partner to oversee network operations and management. This option has little risk for the City.
- **City-Owned Utility:** The most aggressive option the City has is to invest in its own broadband infrastructure and offer dark fiber or lit services via a City of Fairfield Broadband Utility. This option will require the most investment and risk but will give the City the most control over how infrastructure is deployed, ensuring equitable access and targeting areas that are most in line with Fairfield's needs. This option is modeled in this report to demonstrate the financial feasibility of a Fairfield Broadband Utility.

Fairfield must decide which of these business models is most aligned with the City's goals and priorities and pursue the option that is the best fit for its community.

PARTNER TO MAXIMIZE BENEFITS

The City of Fairfield should partner with the range of stakeholders, including all City departments and potentially internet service providers, to get the most possible benefits from any broadband initiative that the City undertakes. If Fairfield decides not to create its own broadband utility, it could establish partnerships with one or more ISPs for expansion of privately-owned broadband assets to better serve the community, often in return for the use of public assets to assist with the costs of deployment. The City could entertain conversations with a variety of interested parties about these options, as identified within this report.

ADDRESS DIGITAL INCLUSION

The internet and related technologies are critical means of production in today's economy. Access is important but it is the way access is applied that determines its value to individuals, families, organizations, and society. Knowledge is essential for effective use. Magellan Advisors recommends making digital inclusion an integral part of the Utility and focusing on businesses and institutions as "customers" as well as "channel" partners for such programs. The City could also pursue additional digital inclusion efforts by getting involved with groups with a track record of tackling this task[15] including programs through the National Digital Inclusion Alliance and the International Telecommunications Union.

MAINTAIN UP-TO-DATE BROADBAND POLICIES

Fairfield recently updated policies related to wireless and 5G small cell facilities, dig once policies, and master licensing agreements with various telecommunications organizations. These policies, as well as others that relate to the use of the public right-of-way, utility coordination, and expansion of wired and wireless broadband

[15] Digital inclusion resources include the International Telecommunications Union (https://www.itu.int/en/mediacentre/backgrounders/Pages/digital-inclusion-of-youth.aspx) and the National Digital Inclusion Alliance (https://www.digitalinclusion.org/).

should be maintained and updated accordingly on a regular basis to ensure that the City is maximizing opportunities to expand broadband access for its community.

This includes considerations such as the recent legislation through the State of California's SB 378, which would require a local agency to allow, except as provided, microtrenching for the installation of underground fiber if the installation in the microtrench is limited to fiber. The bill would also require, to the extent necessary, a local agency with jurisdiction to approve excavations to adopt or amend existing policies, ordinances, codes, or construction rules to allow for microtrenching.

TRACK FUNDING OPPORTUNITIES

Fairfield should track available funding opportunities for grants and loans to offset costs of deploying additional broadband infrastructure. Although there is a windfall of public funding available through a variety of federal and state programs, most of the funds are targeted at communities with lower population densities and less robust broadband service than Fairfield. As shown in the maps in the Gap Analysis section of this report, there are few areas of the City that strongly demonstrate the need for grant funds and in the current competitive funding environment, it is unlikely that Fairfield will qualify for many programs.

There are a few programs, however, that Fairfield should track as eligibility and guidelines are still emerging. These include the Local Area Technical Assistance (LATA) grant funding through the CPUC, which could provide up to $500,000 for planning and engineering of a network. Additionally, the Last Mile funding program through a Federal Funding Account (FFA) created by Senate Bill (SB) 156 includes a new $2B grant program focused on building broadband Internet infrastructure to

communities without access to Internet service at sufficient and reliable speeds throughout California. This program allocated $17M in funding for Solano County.

Based on the CPUC map contained in this report, there are some small pockets of Fairfield that may be eligible for funding through this program. Furthermore, the Broadband Loan Loss Reserve Fund authorized by SB 156 could support necessary borrowing by the City to construct broadband infrastructure, although the fund is not yet operational.

The City should continue to track new and emerging programs, keeping in mind that Fairfield's eligibility will likely be restricted for many of them.

EXPLORE OPTIONS FOR A PILOT PROJECT

The Texas Street corridor is a prime opportunity to deploy fiber directly through the Heart of Fairfield, allowing numerous municipal assets and private sites to be connected. The number of prospective customers makes this area attractive for investment. The City should explore this option further by releasing a Request for Information (RFI) to engage interested parties who would be willing to partner on such a project. This may include potential customers and community organizations, as well as potential internet service providers. An RFI process would allow Fairfield to collect enough information to understand the likelihood of success of such a project without fully committing to build out the entire City. The pilot project could be deemed successful if enough customers sign up for the service to maintain sustainable revenues that capture an acceptable return on investment.

BUILD A CITYWIDE BACKBONE

If the pilot project is successful, the City of Fairfield could consider developing a Broadband Utility to provide dark fiber leases and wholesale lit services. To provide these services and for the City's municipal operations, the Broadband Utility should build fiber backbone rings throughout the city, focusing on major commercial and transportation corridors, industrials areas, and neighborhood entry points.

Rather than following the conceptual design, we recommend building the backbone in a more methodical, targeted manner. Plan to extend the backbone from the Cannon area, through the Heart of Fairfield, along both sides of Interstate 80, to south Cordelia. Capitalize on any capital improvements in the public rights of way, including CalTrans and Utility projects as well a road widening and streetscaping. Work with Solano County, neighboring cities, the school district and other anchor institutions to prioritize development.

Start with the Texas St corridor, from the freeway and Transit Center, through Heart of Fairfield, up North Texas to Air Base Blvd, possibly with pilot projects along West and/or North Texas streets. Connect anchor industries—Phase 3 of the conceptual design—early in the process based on additional outreach and planning, along with City facilities. A secondary fiber route into the base and to prospective cell sites could be a prime opportunity for the Broadband Utility. If so, that project may be given priority but plan to extend the network throughout the City is short order. Finalize development priorities and sequencing as part of a high-level design and conduct a physical inventory of existing assets. Continue to build opportunistically, leveraging capital projects, private developments and work by utilities in the public right-of-way.

Due to the ongoing costs of aerial deployment, we recommend that all new fiber assets be installed underground except in areas where this is not feasible.

DETERMINE WHETHER TO ESTABLISH A BROADBAND UTILITY

If the City decides to develop a Broadband Utility, it should be established as a separate unit with a broadband enterprise fund and year 1 staff. To maximize return on investment and value for residents, the Utility should manage all the City's network assets, including vertical assets. Those assets should be developed as a comprehensive infrastructure, flexibly provided to commercial, institutional, and wholesale broadband customers. Magellan Advisors recommends developing infrastructure expeditiously in response to specific requirements of prospective customers. This approach fully capitalizes on current market opportunities and limited municipal resources.

The City itself should be the Utility’s primary customer and partner. Under this approach, the Utility would be responsible for providing physical infrastructure to the City, like any other wholesale customer but at no direct cost. City IT personnel would use the Broadband Utility to extend and strengthen the City’s WAN, as they would any vendor. Traffic Management and Utility Division would also be customers of the Broadband Utility.

The Public Works Department should be responsible for construction and maintenance of the backbone facilities, which may then be contracted to private companies, in lieu of direct payment by City departments to the Utility. The Utility should be responsible for adds and changes in strand allocation and for physically splicing strands. Consider out-sourcing the Broadband Utility operations to a private company, particularly one that commits to building and extending the backbone as discussed here. Alternately, the various City departments could pay the Broadband Utility for services and the Utility then handle all maintenance, which would most likely require additional operating capital.

Appendix A: Broadband Utility Financial Analysis

Magellan Advisors used our Broadband Financial Sustainability Model to analyze the business and financial sustainability of a wholesale broadband utility. Cost and coverage estimate for the financial analysis come from the conceptual design. The purpose of this analysis is to lay out the cost components and potential revenue streams and show how they interrelate. As this is a very preliminary analysis many key factors—customer willingness to pay for specific services, as well as equipment, labor, and materials—have not been specified to a level at which meaningful expense and revenue projections are possible. It is necessary, therefore, to make assumptions to cover general factors.

The basic assumptions are that the network would be deployed per the conceptual design, one phase per year, and that customers will take services at a consistent rate over time, with a few major leases. In all scenarios, the City makes an initial capital investment of $10M, per the City Council's initial allocation of American Rescue Plan Act funds, but no other capital contributions. The rest of the costs would be covered via debt financing at market rates.

The City could also consider use of the Broadband Loan Loss Reserve Fund recently established by the State of California's Treasury to fund costs of financing the deployment of broadband infrastructure by local agencies or non-profits, including payment of costs of debt issuance, obtaining credit enhancement, and establishing and funding reserves for payment of interest and principal. It is early in the process and the California Public Utilities Commission (CPUC) has not yet developed the regulations that will be associated with the Loan Loss Reserve Fund, so we recommend that Fairfield track the development of program rules.[16]

This analysis includes five business scenarios for two models—dark fiber only, which is basically an asset leasing business, and a lit service model. Scenarios include dark fiber only, lit services only, and hybrid dark fiber-lit services. Each of these involves additional assumptions, which are stated where applicable and explicated as necessary.

CAPITAL COSTS

The capital costs for the Fairfield Broadband Utility can be generally broken down into costs for constructing the network "backbone" and costs for at least one central "co-location" facility, where the Utility's network physically interconnects with other networks. The lit services model also requires "last mile" infrastructure from the backbone into customer premises, which can vary greatly depending on business and physical factors, and additional improvements to the Utility's "central office," elevating it from a barebones co-location facility to a fully outfitted data center. Equipment requirements for lit services can vary greatly, too. For the purpose of this analysis, we generally assume "worst case scenario" for capital costs to provide conservative estimates.

[16] Full text of Senate Bill 156, which established the Broadband Loan Loss Reserve, can be found at:
https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220SB156

Backbone Construction Costs

The estimated total costs to build the entire backbone, including two underground 2-inch conduits, hand holes or junction boxes, and one 432-strand fiber cable are $33.2M. See Table 6. Labor is over 73% of the costs. Materials, including a single 432-strand fiber cable, is about 9%. Design and engineering are less than 2%. Twenty one percent of costs are in Phase 1, 29% in Phase 2, 23% in Phase 3, and phase 4 is about 27%. The estimated average cost to build the backbone is $91.39/foot or $482,539 per mile.

Table 6. Estimated Backbone Constructions Costs for Two 2-inch Conduits and One 432-strand Fiber Cable

	Phase				
Cost Component	All	1	2	3	4
Design and Stamp	$545,437	$107,823	$154,094	$129,454	$151,901
Labor	$24,286,098	$5,194,778	$7,032,738	$5,593,644	$6,367,585
Materials	$2,946,892	$585,406	$829,786	$699,311	$817,501
Total with 20% contingency	**$33,225,025**	**$7,044,044**	**$9,589,123**	**$7,681,000**	**$8,774,003**

If the City wished to construct the backbone with two (2) 4-inch conduits, the overall costs would be nearly double, as shown in Table 7. Labor costs increase an estimated $20.6M and materials are about $3.5M, more than twice the costs for two 2-inch conduits. While the conduit size nominally doubles, the additional benefits and revenue potential is marginal and is simply isn't enough to justify the additional costs.

Table 7. Estimated Backbone Constructions Costs for Two 4-inch Conduits and One 432-strand Fiber Cable

Cost Component	Phase All	1	2	3	4
Design and Stamp	$545,437	$107,823	$154,094	$129,454	$151,901
Labor	$44,926,779	$8,883,598	$12,712,717	$10,663,976	$12,520,148
Materials	$6,452,071	$1,280,448	$1,825,108	$1,534,198	$1,798,418
Total (with 20% contingency)	**$61,654,620**	**$12,196,855**	**$17,445,390**	**$14,637,810**	**$17,182,280**

Co-location Facility Costs

In addition to backbone construction costs, the City of Fairfield should budget approximately $100K to $150k for each co-location facility, assuming (a) these are City-owned properties and (b) they support only dark fiber. The costs cover retrofitting facilities with a secondary entrance directly into the co-lo, backup power, environmental controls, and separate cages with racks for providers and other wholesale customers.

The Broadband Utility should have at least one, ideally two, co-location facility in addition to and separate from the City's data center. If the Broadband Utility provides bulk IP and/or lit services, one of the co-location facilities would serve as its central office. This facility will need a secure area for the Utility's equipment. No network equipment is required for dark fiber co-location. Equipment would be required for any additional functions/services other than leasing fiber strands.

Lit Fiber Co-location Facility and Network Equipment

Lit service transports data across network infrastructure, essentially allowing customers to simply plug their equipment directly into the network and get connectivity. The transport can be to the internet, cloud services, a data center for access specific hosted services, and/or interconnection between sites. Unlike retail broadband, transport is dedicated bandwidth for each customer.

Customers can get one or more lit fiber strands dedicated to them, or the Broadband Utility could multiplex numerous customer's traffic on a few fibers by subdividing the laser light into different colors, which are called lambdas. Lambdas are physically separate and secure channels operating on different light wavelengths. A single fiber can practically accommodate at least 64 lambdas but this number will increase as photonic technology continues to improve.

Lit service is more convenient and practical for the customers but also multiplies revenue opportunities for the Broadband Utility. Service can be costed at 1.8 times the cost of a dark fiber, and has broader range of uses, particularly if the network terminates in a co-location facility with multiple carriers. A single customer might have lit service for internet access, site interconnection, and cloud/data center access. And lit infrastructure can accommodate many more customers. All of this requires additional equipment and services, including:

- Edge routers, Distributed Denial of Service (DDoS) threat mitigation
- Multi-Protocol Label Switching (MPLS)/Ethernet service core
- Access switches
- Switches, Firewalls, Servers
- Element managers, monitoring, out-of-band system
- DHCP, DNS, authentication
- Critical spares and unplanned needs

A data center to house equipment is somewhat more than a dark fiber co-lo. Lit services also require customer premise equipment (CPE) and professional services as well as bulk IP, which is resold to customers as internet access. Customer billing, fiber management, and network operations systems are necessary for offering lit services. We estimate upfront capital expenses for lit services, including full data center retrofit and software, would be just under $3.1M and annual operating expenses, not including salaries, would be just over $450K.

Drop and Lateral Construction Costs

Sites will require physical connections to the backbone. These can be either "drops" or "laterals." A lateral is for dark or lit service. Laterals are typically a 96-strand fiber cable in conduit connected to backbone conduit at a junction box, running to a splice point, and extending some distance 36" underground to a demarcation point on the customer premises. We estimate the cost of a 250-foot lateral would be about $33.5K to add to the backbone and a 1,000-foot lateral cost over $100K. In contrast, fiber-to-the-premises drops typically costs $1,500 to $2,000 using 12 or 6-strand cables, from optical splitters in network hubs, which can be relatively small (less than 24" a side) boxes, to an external termination box at the customer premises.

Several City facilities are co-located so only require a single lateral. Specifically, ring 1 will pass through the data center in the Police Station, which connects with five other sites via campus fiber. The Aquatics Center and Sports Center are co-located, as are Fire 41, Public Works Inspector's Office, and Dickson Hill Storage Facility. Only North Bay Regional Treatment Plant is not within the buffer. For the purpose of financial modeling, all signal cabinets and four tower sites will be connected. Only parks and water telemetry sites within the 750-foot buffer are fiber-connected.

Table 8. Estimated Costs for Laterals to City Facilities

Cost Component	Laterals 250-foot	1,000-foot
Design and Stamp	$505	$1,660
Labor	$23,078	$74,276
Materials	$4,797	$10,091
Unit Cost (with 20% contingency)	$33,449	$101,241
Quantity	154	13
Sub-total	$5,151,186	$1,316,127
Grand Total	**$6.5M**[17]	
Cost/Foot	$133.80	$101.24

Therefore, we used a count of 154 laterals of approximately 250-feet and 13 approximately 1,000-foot lateral. The total costs for all laterals, laid out in Table 8, are estimated to be $6.5M, assuming laterals would be underground, with 20% contingency. Labor would be approximately 85% of the costs and materials would be just around 15%.

These are very conservative cost estimates provided for budgetary purposes. Costs for drops and laterals could be substantially reduced by deploying aerial or micro-trenched fiber. Similar costs may be applied to estimate costs of connecting other sites. These laterals are entirely for municipal purposes, therefore should be included in the capital budget. As described below, the laterals will offset $213,816 per year in telecom costs to 12 sites by end of year 4, while providing much greater bandwidth and reliability for an additional 155 sites.

For lit services, we assume that each customer will require only a drop, not a lateral, but use $5,000 as the per drop cost to account for any upward variance in costs to reach some customer premises. As discussed below, we estimate the Broadband

[17] Although estimated to the dollar, the overall cost estimate is approximate.

Utility would get 30% of businesses within 750 feet of the backbone to subscribe to lit services. Additions and extension to the backbone, particularly for road crossings, may be necessary to reach all customer sites. The cost of such extensions would be in the same range as laterals.

OPERATING COSTS

A key characteristic of the infrastructure-only wholesale business model is relatively low overhead and operating costs. Payroll can account for 90% or more of on-going costs for a broadband enterprise. Equipment licenses, maintenance, refresh, and upgrades create recurring costs and large periodic costs. Management and marketing are much less for wholesale. Limiting operations to underground backbone also greatly reduces on-going costs.

Management and Marketing

The City of Fairfield should plan to add a broadband director on day one. The director will need a part-time marketing manager by the end of year one. The director should have some experience with or knowledge of broadband and fiber but must have strong understanding of facilities leasing and maintenance. The director will be responsible for overall organizational performance, focused on finances and governance.

The marketing manager would be responsible for identifying and managing lessees, so should know the community well and have basic knowledge of the broadband industry. The marketing manager may also work with wholesale customers to promote their internet services to the community. The Utility should budget for marketing and other professional services as appropriate. We use $20K per year as an estimate for events, materials, and services, including research, social media, and web presence.

Table 9. Management and Marketing Staff

Position Title	Initial Fully Loaded Cost	Full-Time Equivalent Employees			
		Year 1	Year 2	Year 3	Year 4+
Broadband Director	$249,000	1.0	1.0	1.0	1.0
Marketing Manager	$161,468	-	0.5	1.0	1.0

Operations and Maintenance

A network infrastructure manager should be hired on day one. This individual will be responsible for any customer adds, changes, or moves to the backbone. The Broadband Utility must purchase a fiber management system and should have a maintenance fund to cover repair costs. Costs for software vary greatly so we recommend budgeting approximately $75k for one-time costs with annual fees of 15%. Major maintenance or repair tasks—anything requiring excavation—may be contracted out or may be handled by Public Works. For the purpose of this analysis, we assume the City funds maintenance and repairs in lieu of network service charges or lease payments. Just to be conservative, we assume the Utility will need dedicated full-time network engineer by year four.

Table 10. Operations and Maintenance Staffing

Position Title	Initial Fully Loaded Cost	Full-Time Equivalent Employees			
		Year 1	Year 2	Year 3	Year 4+
Network Manager	$166,638	1.0	1.0	1.0	1.0
Network Engineer	$114,923	-	0.5	0.5	1.0
Maintenance Tech	$83,319	0.5	1	2	3

Other operating costs, beyond salaries, include facilities leases and maintenance. For the purpose of the financial analysis, we assume these are covered by the City in return for “free” connectivity but as noted below, we do not include municipal cost savings in the analysis. As discussed above, various equipment and systems are required for lit services, which generates additional operating costs. The Broadband

Utility should budget approximately $450K to $500k per year for operating expenses under any services model with a total of around 700 customers.

TOTAL COST ESTIMATE

The levels of the cost components described above are contingent on decisions to be made about the Broadband Utility's infrastructure and services. The "straw man" conceptual network would cost approximately $75.6M over five years to build and operate, as summarized in Table 11. It should be emphasized this is a "worst case" estimate, including 20% contingency on construction.

Table 11. 5-year Total Estimated Conceptual Network Costs

Cost Component	5-Year Total
Conceptual network construction, including central office/co-location facility	$46,867,269
Laterals to city sites	$6,467,313
Drops and equipment for lit services	$5,631,298
Operating Expenses	$4,916,968
Debt Service	$11,703,811
5-year Grand Total	**$75,586,658**

In practice, the network should be built in a more focused, opportunistic manner, aligned with other capital improvements to address clear demand by commercial, institutional, and provider customers. This approach will substantially reduce construction and financing costs as well as maximize revenue.

COST SAVINGS

The City of Fairfield should be Broadband Utility's first customer. The network can essentially replace the City's current infrastructure and services. As discussed above and detailed in the 2020 Broadband Development Plan, the City relies on a microwave backbone for much of its municipal network. Much of this infrastructure has reached the end of its useful life and needs to be replaced. The fiber will provide greater capacity and reliability than the microwave infrastructure (and the tower space can be used for other wireless services), as well as eliminate the replacement costs. It was not clear as of the writing of this report what the microwave network cost might be.

The City leases circuits from AT&T (1 Gbps dedicated Ethernet) to many of its sites and Comcast Business broadband to one site. The fiber infrastructure would replace all of these. The total annual savings from all phases would be approximately $214K, broken down by phase and sites in Table 12. The City also pays $5,176 per month for dedicated internet access (from two providers for redundancy), which could be cut in half while getting faster, even more reliable connections (based on the conceptual network design). These direct savings are complemented by indirect savings from replacing the microwave network and expanding connected sites.

Table 12. Prospective Telecommunications Savings by Phase

Phase/ Ring	Sites	Annual Savings
1	5	$79,416
2	3	$57,600
3	3	$57,600
4	1	$19,200
Total	**12**	**$213,816**

While the intention is for the City to realize these savings, we do not incorporate them into the financial model. The cost savings identified here are, of course, only for the City of Fairfield. Under this plan, other community anchors could substantially reduce costs and improve connectivity. A key consideration here is the level(s) of service the Broadband Utility might provide. While many anchors may be able to use dark fiber, others may not have the need or staff, but they may be interested in dedicated internet or transport services. Other prospective wholesale customers——could reduce risk exposure as well as costs. Therefore, the aggregate public financial benefit from the network could be many times the City's direct savings.

CUSTOMER SEGMENTATION AND GROWTH

The overall purpose of the Fairfield Broadband Utility is to make municipal operations and other aspects of the local economy more flexible, productive, and resilient. It can also generate revenue for the City and get broadband options for the community. The Broadband Utility does this by providing infrastructure.

As a dark fiber provider, the Fairfield Broadband Utility has a limited customer base. Its major customer will be the City itself, but that will not generate revenue—we assume the City provides construction and maintenance resources in lieu of lease fees (and it owns the infrastructure). The Utility can also serve other anchor institutions, particularly the County and School district. We do not want to assume the Utility gets this business and we do not have detailed information about their willingness to pay for dark fiber. Therefore, we do not specifically include any potential revenue from these sources in the model. Rather, we include revenue from "generic" dark fiber customers.

The Broadband Utility's primary customers for dark fiber will be internet service providers and other network service providers. Broadband, cellular, and other network infrastructures are expanding at a robust pace, even if this expansion is generally not occurring in Fairfield, and there is a great deal of private and public funds flowing into the sector. More generally, Fairfield continues to grow albeit slower than the nation and state (until recent years). Given these factors, we expect sustained baseline broadband demand growth.

Lit services will have much greater appeal as they directly connect customers to services without additional investment on the customers' part for network equipment and carrier services. For the purposes of revenue projections, we estimate the Broadband Utility would be able to sell lit services to 30% of businesses within 750 feet of the backbone. While we presume that some types of business will value connectivity more highly than others, we do not have enough information for more detailed analysis. For example, businesses with multiple locations that need to be connected and centrally served or managed will find lit services more valuable than single-location businesses that use minimal online services.

The City's economic development strategy and regional development could profoundly impact the market for lit services. Food service and hospitality businesses have multiple applications that require connectivity, ideally segmented and often required for multiple locations. Remote workers, particularly those dealing with large amounts of content or data, require lots of bandwidth and numerous services and can expense connectivity. Retail and service businesses typically have numerous locations and increasing needs for connectivity. These are examples of market segments for lit services that might grow substantially based on the City's plans. The Broadband Utility would both facilitate that growth and allow the City to directly capitalize on it.

Demand in northeastern Fairfield will grow with real estate development, particularly employment areas north of Travis Air Force Base. Objectives for the Heart of Fairfield require network connectivity for many purposes, generally to support local food services, hospitality, and retail, and establish the area as a base for remote workers who need access to major metros. Manufacturing and related industries will undoubtedly require more connectivity, which may be the City's only weak point for this sector. South Fairfield has multiple development opportunities, including with Pacific Flyway Center as a major visitor attraction. The Utility should segment its market geographically, focusing on growth opportunities particular to each area: Heart of Fairfield, industrial areas, South Fairfield, North Fairfield/TAFB, North Texas St., etc.

As a wholesale provider, the Broadband Utility benefits from Fairfield's growth even as it enables it. Growth trends bolster the case for investment by ISPs and related firms. Therefore, the Broadband Utility should be actively promoting connectivity options, including digital inclusion, digital transformation, and Smart City initiatives, as well as tracking growth trends as marketing fodder. The City should work with community partners to aggregate demand. A key implication of this rationale is that the Utility's prime prospects for partners or wholesale customers are small, entrepreneurial ISPs. The Utility will need to proactively seek out such companies. The first step should be an RFI/RFQ process to identify prospective partners and wholesale customers.

PROPOSED RATE SCHEDULE

Wholesale revenue may generally come from either leasing infrastructure—conduit or fiber—or from a revenue share by wholesale customers, i.e., retail ISPs. The latter approach may be preferable because (a) it ensures the Broadband Utility and City have stake in providers' success and (b) providers only pay for actual revenue. Typically, where the Utility owns all infrastructure including access and distribution lines, revenue share is about 20% to 40% or around $30 per residential subscriber and about $90 per business subscriber.

The Fairfield Broadband Utility only provides backbone fiber under the targeted business model. Therefore, a lease revenue approach makes more sense. Lease rates can be a challenge to set due to evolving markets. Conduit (2-inch) in core urban areas outside major metros leases for $3.00 to $5.00 per foot. Generally, Magellan Advisors does not recommend leasing entire conduits because it reduces ability and flexibility to capitalize on the asset. If the City constructs two 4-inch conduits, the Broadband Utility should install inner-duct and lease one or more of those. We would not recommend leasing the entire 4-inch conduit unless it was to a private partner committed to building out fiber to the premises for the entire area.

Fiber leases can be boiled down to a cost per strand-mile. So, for example, a 10-mile long 432-strand backbone would have 4,320 strand miles, each of which could be leased separately.[18] Typically, fiber leases have a minimum distance amount and an annual maintenance fee. A wide range of discounts may be offered, including leasing an entire buffer tube within the cable, entire end-to-end strands (rather than a portion), entire rings, and/or for longer terms. If structured as a long-term (20 years or more) capital lease—also known as indefeasible right to use or IRU—lessees pay the entire lease amount upfront.

Based on our analysis of the Fairfield market and lease rates in other cities, particularly in California, we feel the rates stated in Table 13 are reasonable. For the purposes of revenue projections, we assume the Broadband Utility leases a dozen fiber strands across all 13.4 miles of Phase 1 backbone as an IRU on day 1. It also leases ten fiber strands to five customers (two strands apiece), for a total of 50 miles (averaging five route miles), at monthly rate. Further, we assume the Utility adds the same amount monthly leases per year for 4 years. It leases a dozen strands in each additional phase, one per year, for the next 3 years. Then the Utility leases an IRU for 24 strands in year 4. For this analysis, we assume revenue stabilizes by the end of year 5.

[18] Leasing a portion of a fiber strand can physically strand the rest of that strand. For example, if a 1-mile section of a strand is leased in the middle of a cable, the remainder on each end may be practically unusable. This is another reason for deploying fiber in rings: It reduces risk of stranded strands.

Table 13. Dark Fiber Lease Rates for Fairfield Broadband Utility Revenue Projections

Service Component	Cost	Per
Monthly Dark Fiber Lease	$150	Strand Mile
20-year Dark Fiber IRU	$3,500	Strand Mile
Minimum Lease	3	Strand Miles
Annual Fee	$250	Route Mile

Lit Service Fees

Even basic lit services can be priced many ways. Generally, customers pay separately for a circuit—a lit fiber or a portion thereof (a lambda)—to the central office, interconnection to other services or sites, and other services such as dedicated internet or firewall. Actual fees can vary greatly depending on market conditions, service levels, and other factors. For analytical purposes, we assume every lit customer represents $500 per month revenue for a symmetrical 1 Gbps connection with 1 Gbps of dedicated internet. Each customer is also assessed a $1,000 one-time installation fee, which may vary in practice depending on drop/lateral costs and other factors.

BUSINESS SCENARIOS

To fully inform strategic decision-making about the Broadband Utility, we provide four different scenarios based on the expenses and revenues discussed above. As with the conceptual design, the purpose isn't to recommend a specific approach. Rather, these scenarios represent a range of possible business outcomes for the Broadband Utility. The actual outcomes would undoubtedly be more complex. These scenarios reveal how various customer segmentations and associated revenues impact financial performance over time:

1. Lit services only, no dark fiber leases
2. Monthly dark-fiber leases and lit services

3. One Large IRU for dark-fiber and lit services
4. Two small IRUs for dark-fiber, monthly dark-fiber leases, and lit services
5. Two small IRUs for dark-fiber and monthly dark-fiber leases, no lit services

The first scenario includes only lit services, no dark fiber-leases. The next three scenarios show various dark-fiber business scenarios with lit-fiber services. Scenario 2 includes multiple small monthly dark-fiber leases, averaging four strands, five miles in length, beginning with 20 customers in year one and increasing 10% annually. The third scenario is the other extreme for dark-fiber: A single large IRU—100 strands over the whole backbone—along with lit services. Scenario 4 is middle ground between scenarios 1 and 2: two IRUs for 12 strands each, one for the entire backbone the second for half, along with monthly leases like scenario 1.

Table 14. 20-year Financial Performance Estimates for the Business Scenarios Compared

	Scenario				
	1	2	3	4	5
Service Revenue	$83,995,000	$113,502,500	$107,795,000	$117,773,900	$33,778,900
Capital Expenses	$42,885,669	$42,885,669	$42,885,669	$42,885,669	$35,597,371
Operating Expenses	$19,667,872	$19,667,872	$19,667,872	$19,667,872	$10,226,223
New Funding Needed	$45,484,371	$41,394,369	$41,394,369	$41,394,369	$35,597,371
Net Funding	$35,484,371	$31,394,369	$31,394,369	$31,394,369	$25,597,371
Debt Service	$46,312,759	$40,974,655	$40,974,655	$40,974,655	$33,408,648
End-of-Year Cash	$1,441,596	$4,826,001	$1,708,501	$4,826,001	$822,664
Cumulative Cash	**($24,871,300)**	**$9,974,304**	**$4,266,804**	**$14,245,704**	**($45,453,342)**

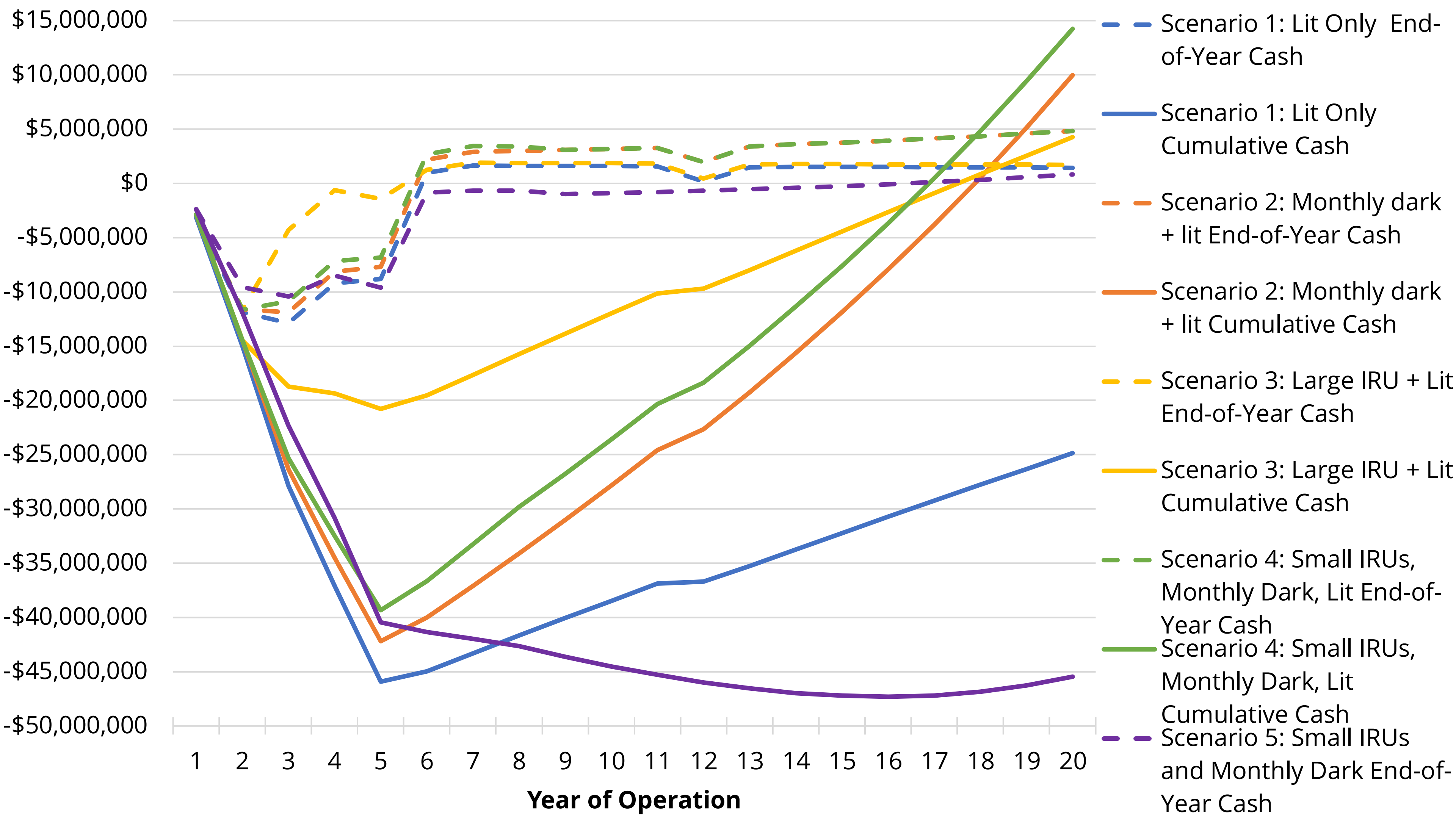


Figure 35. Overall Financial Performance of Business Scenarios Compared

In the first four scenarios, we project 30% of business locations within 750-feet either side of the backbone subscribe to lit services over four years as the backbone is built. Beyond year 4 there is no subscriber growth—lit revenue remains constant. Scenario 5 is basically scenario 4 without any lit services, which shows how a "dark only" Broadband Utility might perform.

All scenarios assume the entire backbone is constructed in four phases, one per year, per the conceptual design. All scenarios have the same staffing plans, although it is not recommended for dark fiber only models. The only cash contribution by the City for all scenarios is $10M, the amount initially allocated for broadband from American Rescue Plan Act funds by City Council. All other funds would be borrowed at market rates. The financial projections for the five scenarios are compared in Figure 35 and Table 14. Scenarios 2, 3, and 4 result in positive cumulative cash flow by the end of year 20.

All scenarios involve substantial debt, resulting in negative cash flow in the early years. Lit service alone, under the assumptions of 30% take rate by businesses within 750 feet of the backbone, never achieves positive cash flow. Scenarios 2, 3 and 4 reach breakeven in year 6. The second small IRU greatly helps as it adds a large chunk of revenue after the network is established and most capital is expended. Scenario 5 doesn't reach positive cash flow until year 17. The revenue from dark fiber leases simply doesn't cover the debt.

Scenario 4 has the strongest overall financial performance—generating over $14M in cumulative cash flow in year 20—due to the combination of small dark fiber leases, both long-term IRUs and monthly, and lit services. A single large IRU simply doesn't provide adequate cash flow. The fact scenario 5 eventually breaks even, while scenario 1 never does, suggests that a combination of dark and lit fiber services will be necessary for the Broadband Utility to be economically feasible.

There are several important considerations for these financial projections. First, there is no reason for the City to build the network per the conceptual design. Rather, the construction should be planned to address particular needs and opportunities, including public capital improvements and private connectivity requirements. Also, while we recommend placing two 2-inch conduits with hand holes 1,000 feet and splice points every 10,000 feet for most areas, some areas, such as the Heart of Fairfield, may need more. It may be necessary to route fiber to vertical assets (streetlights, towers, etc.) for providers to lease assets or services.

Additional cost would need to be covered by increasing the number of subscribers, rates, or other revenue factors. Dark fiber leases need to be carefully marketed in conjunction with and to providers because the user, such as a small business, doesn't get much benefit from it. Rather the consumer buys a suite of services that might include security and voice services as well as internet. Similarly, additional access infrastructure, such as aerial drops, would greatly expand revenue opportunities for lit services. Those services would need to be robustly marketed in parallel with network deployment to maximize revenue.

The business results for a Fairfield Broadband Utility depend on how the enterprise is launched and run as well as its infrastructure. Phasing and service offerings must be closely aligned with market dynamics and public priorities both in principle, as a public investment, and to generate maximum return. This analysis shows that the Broadband Utility can be economically viable even if these imperatives are not met, if it is developed according to a set plan. An effectively developed and run Broadband Utility should exceed the projected results.

Appendix B. Stakeholder Interviewees

Anchor Industries

- William Bernard, Hanlees Dealership Group
- Dave Corbin, Sunwise Auto Group
- Farshad, Anheuser Busch
- Jamil Zainasheff, Heretic Brewing

Commercial Real Estate

- Joseph Horrigan, Operations Manager, Solano Town Center
- Rohit Ranshaw

Downtown and Residential Developers

- Ben Reid
- Mark Salma, Developer, Tallen Capital Partners
- Alex Spangler, Tallen Capital Partners
- Carol Therien

Solano County

- Stewart Bruce, GIS Specialist
- Tim Flanagan, CIO
- Infrastructure Specialist

Solano Economic Development Corporation

- Sean Quinn, Interim Director

Travis Air Force Base

Fairfield-Suisun Unified School District

- Chris Clark, IT Director

City of Vacaville

- Keith McDonald, IT Director

Suisun City

- Rowland Roberts, IT Director

Workforce Development Board of Solano County

- Heather Henry, Executive Director

Appendix C. Glossary of Terms

3G – Third Generation	The third generation of mobile broadband technology, used by smart phones, tablets, and other mobile devices to access the web.
4G – Fourth Generation	The fourth generation of mobile broadband technology, used by smart phones, tablets, and other mobile devices to access the web.
5G – Fifth Generation	The fifth generation of mobile broadband technology, used by smart phones, tablets, and other mobile devices to access the web. It is believed that this technology will significantly increase bandwidth to users, up to 1 Gig.
ADSL – Asymmetric Digital Subscriber Line	DSL service with a larger portion of the capacity devoted to downstream communications, less to upstream. Typically thought of as a residential service.
ADSS – All-Dieletric Self-Supporting	A type of optical fiber cable that contains no conductive metal elements.
AMR/AMI – Automatic Meter Reading/Advanced Metering Infrastructure	Electrical meters that measure more than simple consumption and an associated communication network to report the measurements.
ATM – Asynchronous Transfer Mode	A data service offering that can be used for interconnection of customer's LAN. ATM provides service from 1 Mbps to 145 Mbps utilizing Cell Relay Packets.
Backhaul	Connections between the core or backbone network and the subnetworks, commonly mobile or wireless cell sites, allowing them to transmit data to and from the internet.
Bandwidth	The amount of data transmitted in a given amount of time; usually measured in bits per second, kilobits per second (kbps), and Megabits per second (Mbps).
Bit	A single unit of data, either a one or a zero. In the world of broadband, bits are used to refer to the amount of transmitted data. A kilobit (Kb) is approximately 1,000 bits. A Megabit (Mb) is approximately 1,000,000 bits. There are 8 bits in a byte (which is the unit used to measure storage space), therefore a 1 Mbps connection takes about 8 seconds to transfer 1 megabyte of data (about the size of a typical digital camera photo).
BPL – Broadband over Powerline	A technology that provides broadband service over existing electrical power lines.

BPON – Broadband Passive Optical Network	BPON is a point-to-multipoint fiber-lean architecture network system which uses passive splitters to deliver signals to multiple users. Instead of running a separate strand of fiber from the CO to every customer, BPON uses a single strand of fiber to serve up to 32 subscribers.
Broadband	A descriptive term for evolving digital technologies that provide consumers with integrated access to voice, high-speed data service, video-demand services, and interactive delivery services (e.g. DSL, Cable Internet).
CAD – Computer Aided Design	The use of computer systems to assist in the creation, modification, analysis, or optimization of a design.
CAI – Community Anchor Institutions	The National Telecommunications and Information Administration defined CAIs in its SBDD program as "Schools, libraries, medical and healthcare providers, public safety entities, community colleges and other institutions of higher education, and other community support organizations and entities." Universities, colleges, community colleges, K-12 schools, libraries, health care facilities, social service providers, public safety entities, government and municipal offices are all community anchor institutions.
CAP – Competitive Access Provider	(or "Bypass Carrier") A Company that provides network links between the customer and the Inter-Exchange Carrier or even directly to the Internet Service Provider. CAPs operate private networks independent of Local Exchange Carriers.
Cellular	A mobile communications system that uses a combination of radio transmission and conventional telephone switching to permit telephone communications to and from mobile users within a specified area.
CLEC – Competitive Local Exchange Carrier	Wireline service provider that is authorized under state and Federal rules to compete with ILECs to provide local telephone service. CLECs provide telephone services in one of three ways or a combination thereof: 1) by building or rebuilding telecommunications facilities of their own, 2) by leasing capacity from another local telephone company (typically an ILEC) and reselling it, and 3) by leasing discrete parts of the ILEC network referred to as UNEs.
CO – Central Office	A circuit switch where the phone lines in a geographical area come together, usually housed in a small building.

Coaxial Cable	A type of cable that can carry large amounts of bandwidth over long distances. Cable TV and cable modem service both utilize this technology.
Conduit	A pipe or tube for protecting electric cables or wires, including fiber-optic cable.
CPE – Customer Premise Equipment	Any terminal and associated equipment located at a subscriber's premises and connected with a carrier's telecommunication channel at the demarcation point ("demarc").
CWDM – Coarse Wavelength Division Multiplexing	A technology similar to DWDM only utilizing less wavelengths in a more customer-facing application whereby less bandwidth is required per fiber.
Dark/Wholesale Fiber	Unlit fiber leased to a third party who will "light" it by connecting their own equipment. Dark fiber is leased at a lower cost than lit fiber because the user is responsible for its operation.
Demarcation Point ("demarc")	The point at which the public switched telephone network ends and connects with the customer's on-premises wiring.
Dial-Up	A technology that provides customers with access to the Internet over an existing telephone line.
DLEC – Data Local Exchange Carrier	DLECs deliver high-speed access to the Internet, not voice. Examples of DLECs include Covad, Northpoint and Rhythms.
Downstream	Data flowing from the Internet to a computer (Surfing the net, getting E-mail, downloading a file).
DSL – Digital Subscriber Line	The use of a copper telephone line to deliver "always on" broadband Internet service.
DSLAM – Digital Subscriber Line Access Multiplier	A piece of technology installed at a telephone company's Central Office (CO) and connects the carrier to the subscriber loop (and ultimately the customer's PC).
DWDM – Dense Wavelength Division Multiplexing	An optical technology used to increase bandwidth over existing fiber-optic networks. DWDM works by combining and transmitting multiple signals simultaneously at different wavelengths on the same fiber. In effect, one fiber is transformed into multiple virtual fibers.
E-Rate	A Federal program that provides subsidy for voice and data circuits as well as internal network connections to qualified schools and libraries. The subsidy is based on a percentage designated by the FCC.
EON – Ethernet Optical Network	The use of Ethernet LAN packets running over a fiber network.

Ethernet	A system that connects devices in a wired network via a protocol, which uses a common network language to transmit data.
EvDO – Evolution Data Only	EvDO is a wireless technology that provides data connections that are 10 times as fast as a traditional modem. This has been overtaken by 4G LTE.
FCC – Federal Communications Commission	A Federal regulatory agency that is responsible for regulating interstate and international communications by radio, television, wire, satellite and cable in all 50 states, the District of Rock Falls, and U.S. territories.
FDH – Fiber Distribution Hub	A connection and distribution point for optical fiber cables.
Fiber	Fiber-optic cable, a technology used to transmit data using pulses of light over strands of glass over long distances.
FTTN – Fiber to the Neighborhood	A hybrid network architecture involving optical fiber from the carrier network, terminating in a neighborhood cabinet which converts the signal from optical to electrical.
FTTP – Fiber to the premise (or FTTB – Fiber to the building)	A fiber-optic system that connects directly from the carrier network to the user premises.
FTTx – Fiber to the X	All fiber optic topologies from a provider to its customers, based on the location of the fiber's termination point
GIS – Geographic Information Systems	A system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data.
GPON- Gigabit-Capable Passive Optical Network	Similar to BPON, GPON allows for greater bandwidth through the use of a faster approach (up to 2.5 Gbps in current products) than BPON.
GPS – Global Positioning System	a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.
GSM – Global System for Mobile Communications	This is the current radio/telephone standard developed in Europe and implemented globally except in Japan and South Korea.
HD – High Definition (Video)	Video of substantially higher resolution than standard definition.
HFC – Hybrid Fiber Coaxial	An outside plant distribution cabling concept employing both fiber-optic and coaxial cable.

ICT – Information and Communications Technology	Often used as an extended synonym for information technology (IT), but it is more specific term that stresses the role of unified communications and the integration of telecommunications, computers as well as necessary enterprise software, middleware, storage, and audio-visual systems, which enable users to access, store, transmit, and manipulate information.
IEEE – Institute of Electrical Engineers	A professional association headquartered in New York City that is dedicated to advancing technological innovation and excellence.
ILEC – Incumbent Local Exchange Carrier	The traditional wireline telephone service providers within defined geographic areas. Prior to 1996, ILECs operated as monopolies having exclusive right and responsibility for providing local and local toll telephone service within LATAs.
IOT – Internet of Things	The interconnection via the internet of computing devices embedded in everyday objects, enabling them to send and receive data.
IP-VPN – Internet Protocol-Virtual Private Network	A software-defined network offering the appearance, functionality, and usefulness of a dedicated private network.
ISDN – Integrated Services Digital Network	An alternative method to simultaneously carry voice, data, and other traffic, using the switched telephone network.
ISP – Internet Service Provider	A company providing Internet access to consumers and businesses, acting as a bridge between customer (end-user) and infrastructure owners for dial-up, cable modem and DSL services.
ITS – Intelligent Traffic System	Advanced applications which, without embodying intelligence as such, aim to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated, and 'smarter' use of transport networks.
Kbps – Kilobits per second	1,000 bits per second. A measure of how fast data can be transmitted.
LAN – Local Area Network	A geographically localized network consisting of both hardware and software. The network can link workstations within a building or multiple computers with a single wireless Internet connection.

LATA – Local Access and Transport Areas	A geographic area within a divested Regional Bell Operating Company is permitted to offer exchange telecommunications and exchange access service. Calls between LATAs are often thought of as long distance service. Calls within a LATA (IntraLATA) typically include local and local toll services.
Last Mile	The final connection between a premise, such as a house or business, and a wider communication network
Latency	The delay before a transfer of data begins following an instruction for its transfer.
Lit/Enterprise Fiber	Fiber-optic cable that is operational and connected to equipment for data transmission to occur.
Local Loop	A generic term for the connection between the customer's premises (home, office, etc.) and the provider's serving central office. Historically, this has been a copper wire connection; but in many areas it has transitioned to fiber optic. Also, wireless options are increasingly available for local loop capacity.
MAN – Metropolitan Area Network	A high-speed intra-city network that links multiple locations with a campus, city or LATA. A MAN typically extends as far as 30 miles.
Mbps – Megabits per second	1,000,000 bits per second. A measure of how fast data can be transmitted.
Middle Mile Network	Middle mile is a term most often referring to the network connection between the last mile and greater Internet. For instance, in a rural area, the middle mile would likely connect the town's network to a larger metropolitan area where it interconnects with major carriers.
MPLS – Multiprotocol Label Switching	A mechanism in high-performance telecommunications networks that directs data from one network node to the next based on short path labels rather than long network addresses, avoiding complex lookups in a routing table.
ONT – Optical Network Terminal	Used to terminate the fiber-optic line, demultiplex the signal into its component parts (voice telephone, television, and Internet), and provide power to customer telephones.
Overbuilding	The practice of building excess capacity. In this context, it involves investment in additional infrastructure projects to provide competition.

OVS – Open Video Systems	OVS is a new option for those looking to offer cable television service outside the current framework of traditional regulation. It would allow more flexibility in providing service by reducing the build out requirements of new carriers.
PON – Passive Optical Network	A Passive Optical Network consists of an optical line terminator located at the Central Office and a set of associated optical network terminals located at the customer's premise. Between them lies the optical distribution network comprised of fibers and passive splitters or couplers. In a PON network, a single piece of fiber can be run from the serving exchange out to a subdivision or office park, and then individual fiber strands to each building or serving equipment can be split from the main fiber using passive splitters / couplers. This allows for an expensive piece of fiber cable from the exchange to the customer to be shared among many customers, thereby dramatically lowering the overall costs of deployment for fiber to the business (FTTB) or fiber to the home (FTTH) applications.
PPP – Public-Private Partnership	A Public–Private Partnership (PPP) is a government service or private business venture that is funded and operated through a collaborative partnership between a government and one or more private sector organizations. In addition to being referred to as a PPP, they are sometimes called a P3, or P^3.
QOS – Quality of Service	QoS (Quality of Service) refers to a broad collection of networking technologies and techniques. The goal of QoS is to provide guarantees on the ability of a network to deliver predictable results, which are reflected in Service Level Agreements or SLAs. Elements of network performance within the scope of QoS often include availability (uptime), bandwidth (throughput), latency (delay), and error rate. QoS involves prioritization of network traffic.
RF – Radio Frequency	a rate of oscillation in the range of about 3 kHz to 300 GHz, which corresponds to the frequency of radio waves, and the alternating currents which carry radio signals.
Right-of-Way	A legal right of passage over land owned by another. Carriers and service providers must obtain right-of-way to dig trenches or plant poles for cable systems, and to place wireless antennas.

RMS – Resource Management System	A system used to track telecommunications assets.
RPR – Resilient Packet Ring	Also known as IEEE 802.17, is a protocol standard designed for the optimized transport of data traffic over optical fiber ring networks.
RUS – Rural Utility Service	A division of the United States Department of Agriculture, it promotes universal service in unserved and underserved areas of the country with grants, loans, and financing. Formerly known as "REA" or the Rural Electrification Administration.
SCADA – Supervisory Control and Data Acquisition	A type of industrial control system (ICS). Industrial control systems are computer controlled systems that monitor and control industrial processes that exist in the physical world.
Smart City	A community where data collection, automation, and other technology-based applications are used to improve operations and quality of life for citizens.
SNMP – Simple Network Management Protocol	An Internet-standard protocol for managing devices on IP networks.
SONET – Synchronous Optical Network	A family of fiber-optic transmission rates.
Streaming	Streamed data is any information/data delivered from a server to a host where the data represents information that must be delivered in real time. This could be video, audio, graphics, slide shows, web tours, combinations of these, or any other real time application.
Subscribership	Subscribership is how many customers have subscribed for a particular telecommunications service.
Submarine Network	Submarine networking is the process by which data is carried on subsea cables to connect continents. Submarine networks carry 95 percent of the world's intercontinental electronic communications traffic.
Switched Network	A domestic telecommunications network usually accessed by telephone, key telephone systems, private branch exchange trunks, and data arrangements.
T-1 – Trunk Level 1	A digital transmission link with a total signaling speed of 1.544 Mbps. It is a standard for digital transmission in North America.
T-3 – Trunk Level 3	28 T1 lines or 44.736 Mbps.

UNE – Unbundled Network Element	Leased portions of a carrier's (typically an ILEC's) network used by another carrier to provide service to customers. Over time, the obligation to provide UNEs has been greatly narrowed, such that the most common UNE now is the UNE-Loop.
Universal Service	The idea of providing every home in the United States with basic telephone service.
Upstream	Data flowing from your computer to the Internet (sending E-mail, uploading a file).
UPS – Uninterruptable Power Supply	An electrical apparatus that provides emergency power to a load when the input power source, typically main power, fails.
USAC – Universal Service Administrative Company	An independent American nonprofit corporation designated as the administrator of the Federal Universal Service Fund (USF) by the Federal Communications Commission.
VDSL – Very High Data Rate Digital Subscriber Line	A developing digital subscriber line (DSL) technology providing data transmission faster than ADSL over a single flat untwisted or twisted pair of copper wires (up to 52 Mbit/s downstream and 16 Mbit/s upstream), and on coaxial cable (up to 85 Mbit/s down and upstream); using the frequency band from 25 kHz to 12 MHz.
Video on Demand	A service that allows users to remotely choose a movie from a digital library whenever they like and be able to pause, fast-forward, and rewind their selection.
VLAN – Virtual Local Area Network	In computer networking, a single layer-2 network may be partitioned to create multiple distinct broadcast domains, which are mutually isolated so that packets can only pass between them via one or more routers; such a domain is referred to as a Virtual Local Area Network, Virtual LAN or VLAN.
VoIP – Voice over Internet Protocol	An application that employs a data network (using a broadband connection) to transmit voice conversations using Internet Protocol.

VPN – Virtual Private Network	A virtual private network (VPN) extends a private network across a public network, such as the Internet. It enables a computer to send and receive data across shared or public networks as if it were directly connected to the private network, while benefitting from the functionality, security and management policies of the private network. This is done by establishing a virtual point-to-point connection through the use of dedicated connections, encryption, or a combination of the two.
WAN – Wide Area Network	A network that covers a broad area (i.e., any telecommunications network that links across metropolitan, regional, or national boundaries) using private or public network transports.
WiFi	WiFi is a popular technology that allows an electronic device to exchange data or connect to the Internet wirelessly using radio waves. The WiFi Alliance defines WiFi as any "wireless local area network (WLAN) products that are based on the Institute of Electrical and Electronics Engineers' (IEEE) 802.11 standards".
WiMAX	WiMAX is a wireless technology that provides high-throughput broadband connections over long distances. WiMAX can be used for a number of applications, including “last mile” broadband connections, hotspot and cellular backhaul, and high speed enterprise connectivity for businesses.
Wireless	Telephone service transmitted via cellular, PCS, satellite, or other technologies that do not require the telephone to be connected to a land-based line.
Wireless Internet	1) Internet applications and access using mobile devices such as cell phones and palm devices. 2) Broadband Internet service provided via wireless connection, such as satellite or tower transmitters.
Wireline	Service based on infrastructure on or near the ground, such as copper telephone wires or coaxial cable underground or on telephone poles.