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Fiber Business and Financial Model

Prepared for the City of Virginia Beach
May 2017

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1 Executive Summary

1.1 Background and Objectives

The material in this section was provided to CTC by the City of Virginia Beach; we include this background information, some of it verbatim from City sources, at the City's request.

1.1.1 Master Technology Plan

In 2013, the City of Virginia Beach developed its Master Technology Plan—a roadmap for how the IT Department will partner with other City departments to implement the right technologies needed for long-term business success. The plan contains four major pillars that strive for customer service excellence and that help align the City's technology investments with business priorities:

1. Transforming service delivery
2. Building better business solutions
3. Strengthening IT governance
4. Improving infrastructure and operations

The plan also identifies specific initiatives that support these pillars, many of which the City has begun or completed. For example, the fourth pillar, "Improving Infrastructure and Operations," includes a recommendation to explore ways to create a next-generation network (NGN) to "increase network bandwidth, reduce the cost of operations, and ensure critical systems are operational and accessible when needed the most."

This report documents the City's progress in creating the NGN, assesses the City's need and market for future NGN capabilities, and provides strategic and technical recommendations for achieving the City's goals related to broadband infrastructure and operations.

In creating the NGN, the Virginia Beach IT department has done an exemplary job in aggregating fiber and conduit assets from City departments and other resources; together, this infrastructure enables the City to meet many of its overall broadband goals. We recommend that the IT department continue to lead the NGN and management of the City's fiber resources. In addition we also recommend that the IT department work closely with the Economic Development staff to develop strategies to leverage fiber and conduit assets for business growth and support.

1.1.2 Next Generation Network

In the City's Master Technology Plan, the recommendations related to implementing a next-generation network (NGN) focus on both expanding the City's network fiber to connect the City's off-campus locations (including libraries, parks, recreation centers, and fire and police stations) to the municipal campus and implementing network redundancy. This report makes

recommendations to achieve this goal—a set of initiatives that collectively will enable City staff and citizens to benefit from superior network performance, expanded bandwidth, faster applications, and upgrades to modern communications technologies such as Voice over IP (VoIP) and video conferencing. As the City continues to make technology investments to transform services, expanding bandwidth through NGN will serve as a critical enabler.

1.1.3 City Council Resolution

In March 2015, the Virginia Beach City Council adopted a Broadband Resolution, which charged the staff to explore and create opportunities to leverage NGN investments made by the City and Virginia Beach City Public Schools (VBCPS) to advance high-speed broadband across the region.[1] As a result of the resolution, the City created a Broadband Task Force composed of policy makers, educators, economic development leaders, information technology leaders, and legal representatives to explore available options for leveraging NGN and expanding broadband.

1.1.4 Broadband Task Force Goals

The Broadband Task Force studied what other cities were doing and analyzed existing availability, demand, and satisfaction of broadband services in the City. After collecting and analyzing this information, the task force was able to develop goals that met the needs of the various stakeholders.

The first goal was to provide a level of excellence in City services. This goal was already in progress with the current expansion of the City's NGN. However, **not only did NGN provide the means to deliver excellent government services, it also provided the backbone network that could be leveraged to support the other goals of the task force.** These other goals included leveraging NGN for educational opportunities, exploring opportunities to create a unified government network (between the City and VBCPS fiber networks), leveraging NGN for economic development opportunities, and leveraging NGN for regional opportunities such as information sharing and collaboration with other cities.

The Broadband Task Force believed that if these goals could be accomplished, the end result would be a unified government network that enables four of the six elements in the City's strategic document, "Envision 2040": Connected Community, Learning Community, Diverse Community, and Thriving Community.

[1] One of the specific ways that the City Council sought to jump-start broadband advancement was by exploring the development of a regional broadband authority. According to the City, broadband authorities in Virginia are governed by the Virginia Wireless Services Authorities Act, which allows municipalities to form their own authorities to provide certain communications services, including high-speed data and internet access services. CTC does not provide legal services and did not independently verify this information.

1.1.5 Cable Franchise Agreement Renewals

As part of the City's franchise renewals with Cox Communications, the City developed a cable television residential survey and a business survey. Because residents receive broadband services from these two companies, the City took the opportunity to add questions on broadband to better assess the current environment regarding the digital divide and broadband demand. On the business survey, questions were asked pertaining to demand, satisfaction, and future needs of broadband services for businesses. The results of these two surveys helped validate the capacity and coverage of current broadband services in the City.

1.1.6 Biomedical Research Park

In April 2016, the Virginia Beach City Council voted to set aside 155 acres in Princess Anne Commons for a biomedical park. Developing biomedical opportunities—which the City believes can be supported by broadband services and fiber access—can create a continuous source of talent in order to attract new businesses, retain talented professionals, and complement the goals and needs of the City and VBCPS.

1.1.7 Mayor's State of the City Address

In his 2016 State of the City Address, Virginia Beach Mayor William Sessoms, Jr. emphasized the importance of connectivity. He spoke of the importance of broadband capacity in helping businesses grow and compete, in facilitating the growth of the biomedical research industry, and in establishing greater connectivity between the City and higher education.

1.2 Opportunity and Needs Assessment

In its assessment of the current broadband opportunities and needs in the City, CTC conducted residential and business broadband surveys, as well as held meetings with central information officers (CIOs) from cities and higher education institutions in the region.

1.2.1 Residential and Business Broadband Surveys

To gauge the community's need for broadband services, the City commissioned both residential and business broadband surveys. The survey questions were written by the City's contractors, CBG Communications and Dr. Book, with the consultation, assistance, and approval of the City's IT department. CBG then administered the surveys—conducting telephone interviews of 900 residential respondents and 400 business respondents—and analyzed the results.

Overall, the survey results show that the City appears to be relatively well-served, and that there are no significant issues with internet access for the majority of residents and businesses. The issues identified—including isolated locations where service is not available (i.e., lack of ubiquity) and some business locations where DSL is the only available service (i.e., lack of sufficient performance and reliability for business users) are not unique to Virginia Beach.

Among business respondents, 90 percent indicated they have internet access; of the respondents who do not have internet access, 60 percent indicated that they have no need for the service and 8 percent stated that they are not comfortable using the internet. No business respondents indicated that internet service was not available at their location, nor was price identified as a reason for not having a connection.

Among residential respondents, the survey results indicate that 92 percent of residents have internet access. As CBG noted in its analysis of the residents' responses to the survey's more qualitative questions, "[t]he findings suggest that overall Virginia Beach residents rate the characteristics of internet service positively, however there is reported dissatisfaction with the cost of that service. In households that subscribe to Verizon and as a result of overbuilding have a more apples to apples choice in Internet service, higher levels of satisfaction are reported with in all areas except 'cost.' In other words, direct broadband competition has resulted in a more satisfactory environment in reported choice, speed and reliability of Internet service; but not in cost."

Complete results for the residential and business broadband surveys are included in Appendix I.

1.2.2 Regional CIO Meetings

During the course of the project, CTC and City staff met with several chief information officers (CIOs) from cities and higher educational institutions in the region, including representatives of the 16 local governments in the Hampton Roads Planning District Commission (HRPDC). Most CIOs expressed a desire to have a coordinated effort in advancing the availability and affordability of connectivity services in the region. Further, the CIOs generally concurred on the need to aggregate resources and look at cooperative efforts to expand.

Insights from the discussions included:

- Existing services do not meet the cities' current needs. Services are expensive and lack the scalability the cities need as their requirements for greater speed and reliability continue to increase.
- The cost of extending to new facilities (i.e., construction of a new fiber connection) is often prohibitive, especially when considered in light of the monthly recurring costs for that service.
- CIOs at higher education institutions would like to create opportunities for graduates through innovation centers rather than (or to complement) traditional job-seeking efforts; innovation centers require access to reliable, high-speed broadband.

- World-class broadband is required to attract and retain faculty at higher education institutions.
- Leveraging public resources might provide incentives to alternative carriers to address any service gaps for residences and small businesses.

It was clear during the interviews that the City's efforts to collect data to better understand collective public assets and aggregate needs has facilitated discussions between private entities and existing service providers.

1.2.3 Service Provider Meetings and Discussions

To better understand potential demand for dark fiber, CTC and City staff met with representatives of the City's incumbent service providers, Verizon and Cox Communications, and other regional service providers. Based on these discussions, it seems **that the incumbent providers' perceptions of the availability and reliability of services in Virginia Beach varied greatly from the perceptions of the CIOs interviewed**. Unlike the CIOs, the representatives of the incumbent providers indicated that they do not see gaps in terms of the availability of services, or any significant issues with the reliability or pricing of services in Virginia Beach.

Since the public announcement of the trans-Atlantic cable coming into Virginia Beach, specialty and regional fiber providers have expressed significant interest in building fiber in the City. Their interest is not in connecting facilities in the City, however—it is to connect Corporate Landing to interconnection facilities in Ashburn, Virginia; Raleigh, North Carolina; and other locations outside of the City. To make these long-distance connections, the companies are looking at installing 432- to 864-strand low-loss express fiber cable. While these service providers are not interested in leasing low-strand-count segments to users in Virginia Beach, they did indicate a desire to lease conduit. They also indicated that when they lease fiber, they prefer Indefeasible Rights of Use Agreements (IRUs) rather than short-term leases.

During the interviews, we did find some potential interest among the service providers in leasing fiber along selected strategic routes for a three- to five-year term.

Some providers raised concern with the permitting process and procedures required to construct fiber infrastructure in Virginia Beach.

1.3 Market Assessment

CTC also conducted a comprehensive market assessment, comparing dark fiber and conduit pricing in the Virginia Beach area with other markets nationwide. This section briefly summarizes our findings.

1.3.1 Service Overview

Based on CTC's research, three service providers in the Virginia Beach region offer dark fiber services: FTS Fiber, Lumos, and Level 3. We have seen dark fiber monthly lease pricing in the mid-Atlantic region ranging from $30 per strand per mile per month in Carroll County, Maryland, to $600 per strand per mile per month in Arlington County, Virginia. The variation in pricing is consistent with the urbanity of the location. Also, lease terms vary from one to 10 years; longer lease terms usually have lower rates.

The carriers that provide Ethernet and DIA services in the Virginia Beach region are AT&T, Level3, Cogent Communications, Comcast, Cox Communications, Lumos, Verizon, Windstream Communications and XO Communications. Prices depend on the bandwidth, location, and network configuration, whether the service is protected or unprotected, and whether the service has a switched or mesh structure. 1 Gbps DIA service prices range from $1,200 to $5,000 per month in the City, while 1 Gbps point-to-point Ethernet circuit prices range from $2,000 to $3,060 per month in the City. Additional non-recurring charges will be present. We have provided an assessment of the competitive provides in the Virginia Beach vicinity in Appendix D.

1.3.2 Conduit Lease

We found that, nationwide, conduit lease costs range from 25 cents to $6 per foot per year—with a special crossing across the Delaware Memorial Bridge in Delaware, priced at $7 per foot per year in 2012. This large variation reflects the importance of local factors in setting conduit lease rates.

Typically, a city will price conduit leases to cover the costs related to the operation and maintenance of the conduit system. The rate is often based on a percentage of the total cost of construction of the infrastructure. Other factors such as depreciation, expenses, and return-on-investment (ROI) also affect the city's conduit leasing strategy. City governments usually also charge additional fees as part of the conduit leasing process, including application fees for the use of the conduit, permitting fees, inspection fees for ensuring compliance with any standards, and other administrative fees.

In the vicinity of Virginia Beach, we found that conduit leases range from 42 cents per foot per year in more rural areas to $5 per foot per year in urban areas.

We have provided a summary of examples of the conduit lease pricing in Appendix B.

1.3.3 Dark Fiber

During CTC's research, we found examples of Indefeasible Rights of Use (IRU) pricing (i.e., up-front payment) offered by the Mid-Atlantic Broadband Communities Corporation (MBC), MCNC (which operates the North Carolina Research and Education Network), and a rural county in

South Carolina. Prices ranged from $325 to $2,000 per strand mile for a 20-year term with an annual maintenance fee of around $250 per mile.

We note that dark fiber lease pricing in the mid-Atlantic region ranged from $30 per strand per mile per month in Carroll County, Maryland, to $600 per strand per mile per month in Arlington County, Virginia. The variation in pricing is consistent with the urbanity of the location; the more urban the location, the higher the price. Lease terms vary from one to 10 years. Longer lease terms usually have lower rates.

We have provided a summary of examples of the dark fiber lease pricing in Appendix A.

1.4 Assessment of Existing Fiber Assets

The City has deployed an extensive conduit system that was primarily used to support connectivity between traffic signal enclosures and other Intelligent Transportation Systems (ITS). As technology evolved, the City replaced the original copper wiring in much of the conduit with fiber.

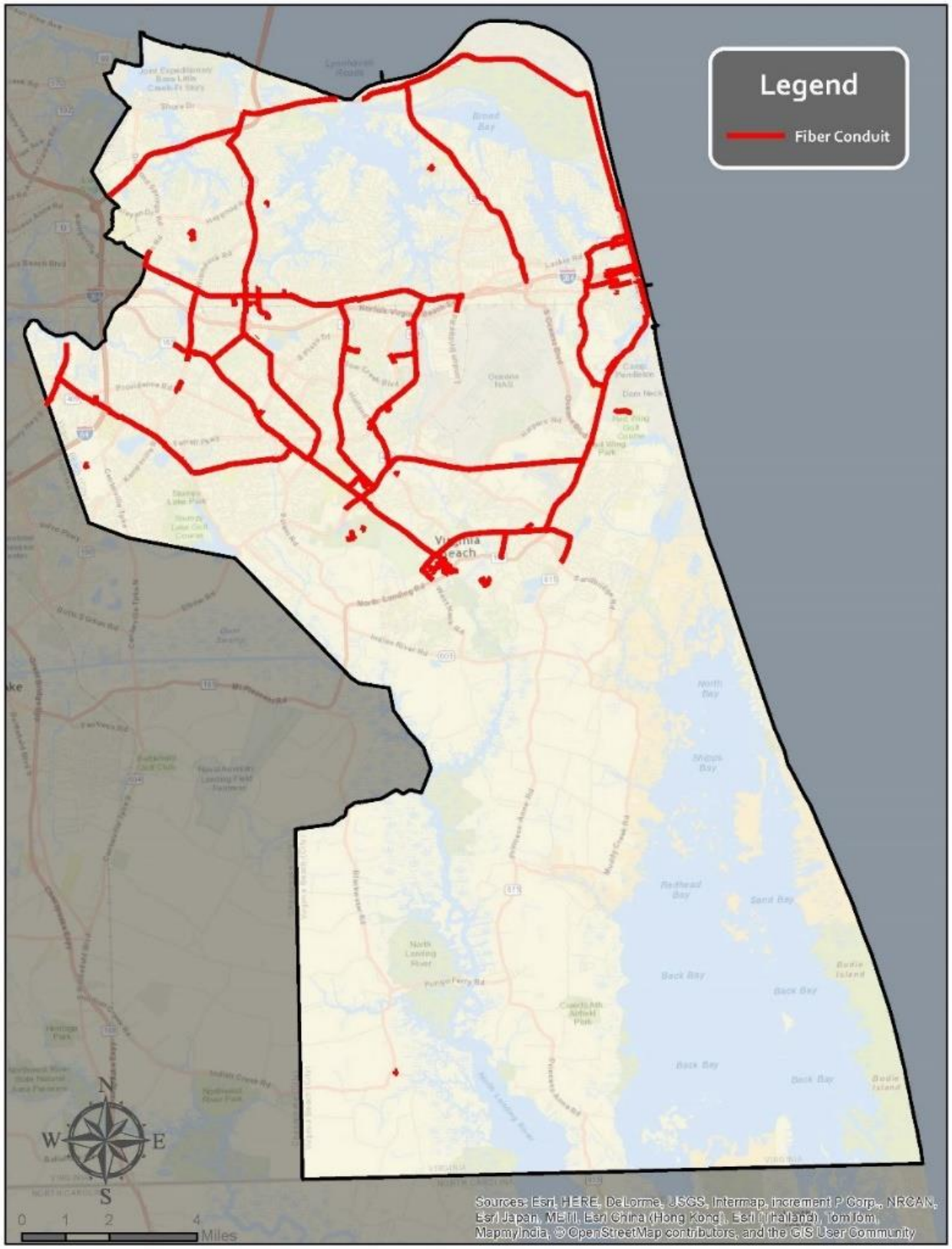
The following sections summarize the location and condition of those conduit and fiber assets, which the City expects to leverage to deploy the NGN.

1.4.1 Conduit with Fiber Optics

The City has 106.7 miles of conduit with fiber optics with an average of 209 feet between handholes. The conduit consists of varying dimensions of HDPE and PVC including 2.6 miles of two-inch, 102 miles of three-inch, and 2.1 miles of four-inch conduit. The City standard for new construction with directional boring is three-inch HDPE conduit.

The conduit is located primarily in the northern part of the City along major roadways where it supports connectivity to traffic intersections and other ITS devices. Figure 1 illustrates these routes.

Figure 1: Map of Existing Conduit with Fiber Optics



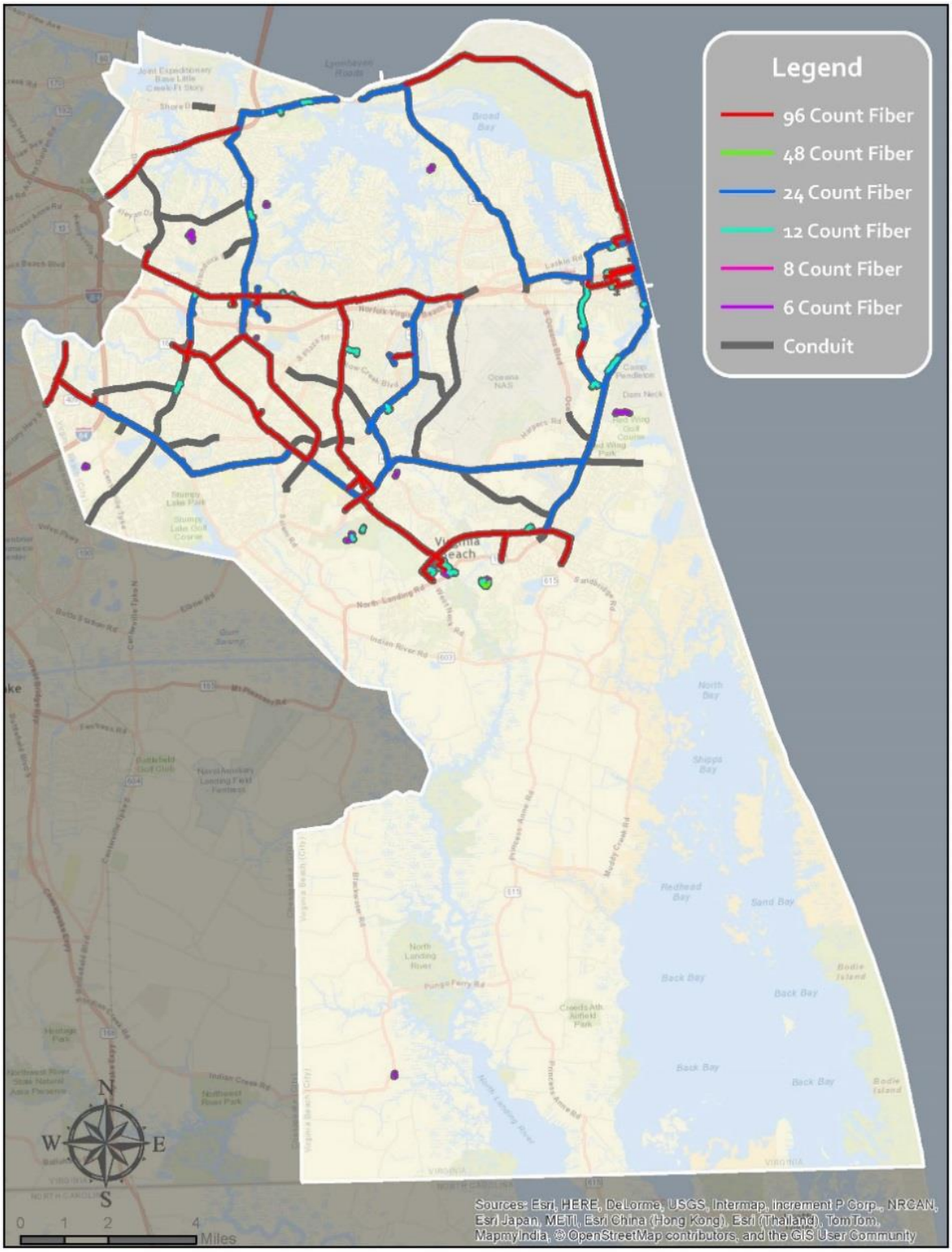
1.4.2 Existing Fiber Optics

The City of Virginia Beach has 160.3 miles of fiber within its existing conduit, consisting of various fiber counts. In ascending order of total mileage, the fiber comprises six-count, 12-count, 96-count, and 24-count. The City also has one 48-count fiber and one eight-count fiber that interconnect facilities at the Leroy Drive City campus.

These fiber counts are relatively small by modern backbone cable sizes. The City originally deployed 24-count cables to support the traffic systems; with the need for additional fiber strands, it has deployed 96-count cables in the past few years.

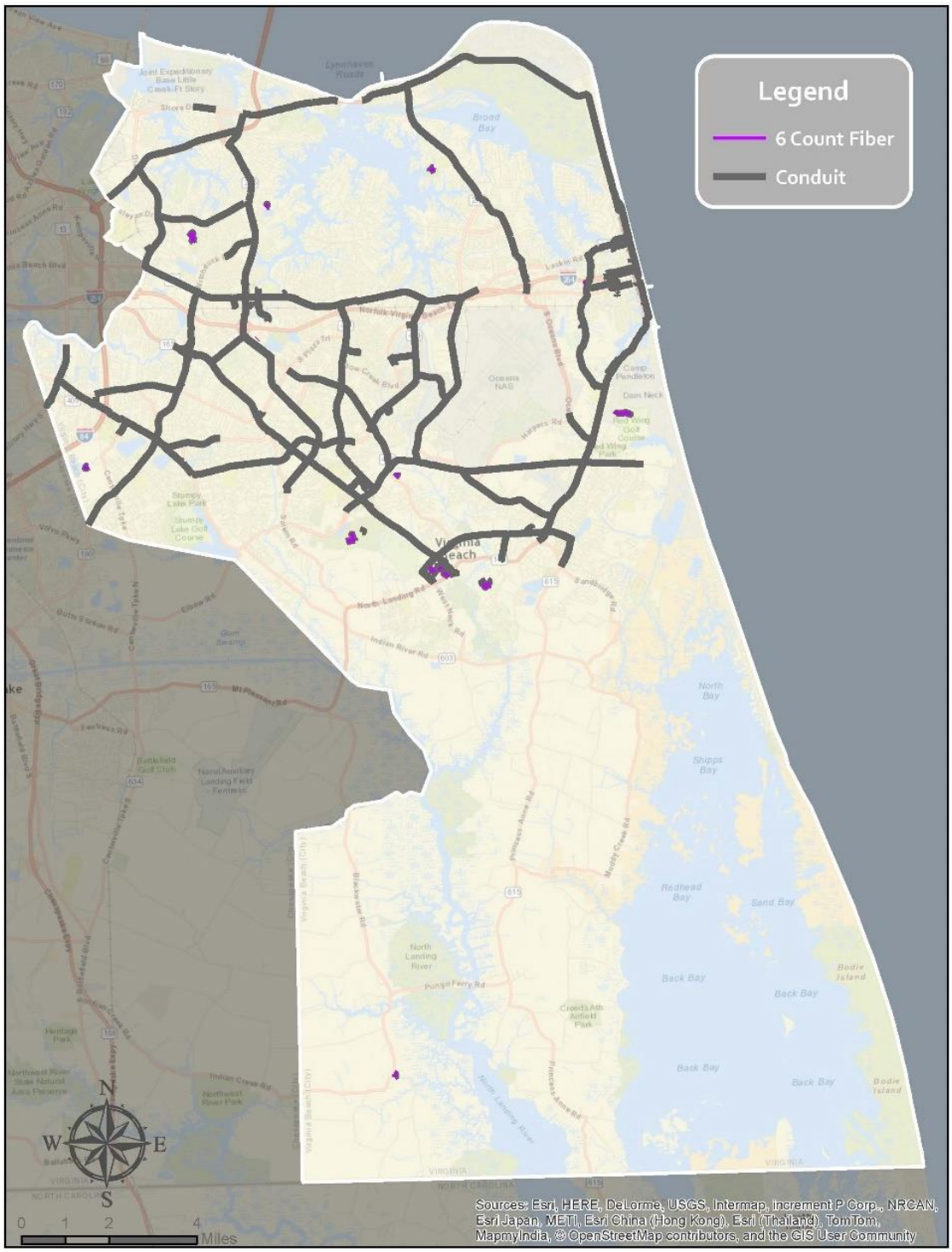
Figure 2 shows the location of the City's fiber cables, while Figure 3 through Figure 6 show locations by fiber count.

Figure 2: Map of Fiber by Fiber Count



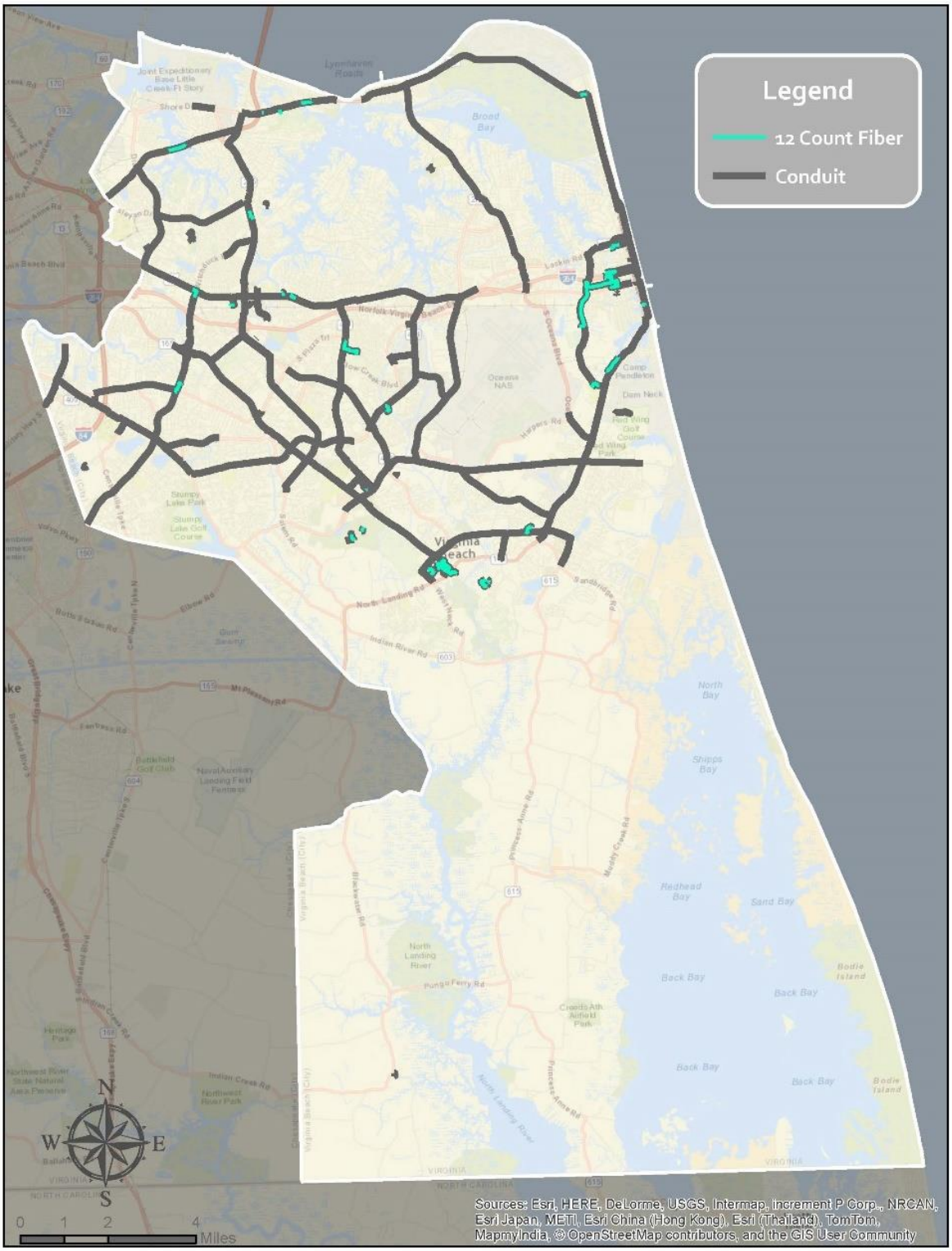
The City of Virginia Beach has 2.6 miles of six-count fiber, illustrated in Figure 3. This fiber mainly interconnects City facilities in the same campus or serves as lateral installations to City facilities.

Figure 3: Map of Six-Count Fiber



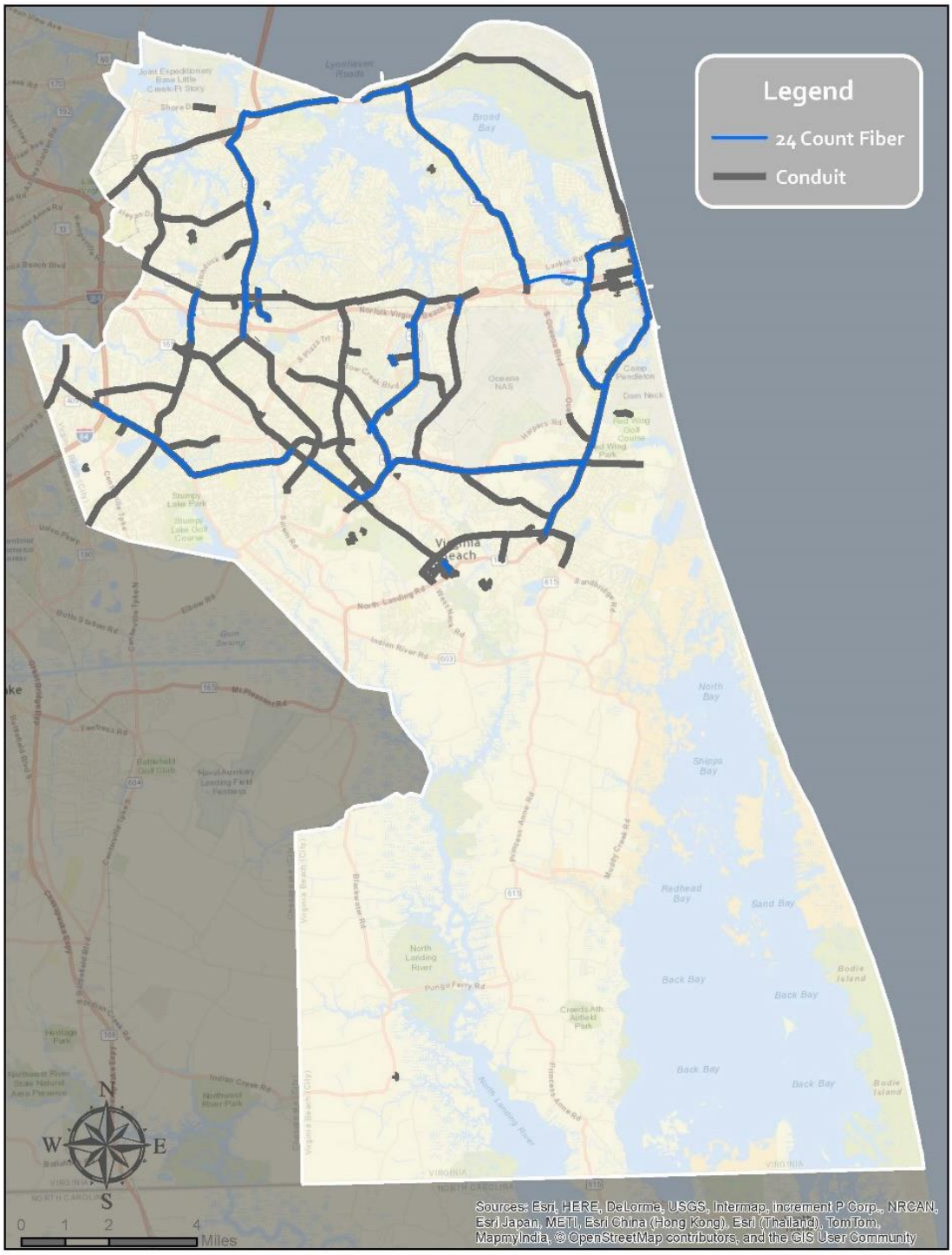
The City has 14.4 miles of 12-count fiber, illustrated in Figure 4. This fiber mainly interconnects City facilities in the same campus or serves as lateral installations to City facilities.

Figure 4: Map of 12-Count Fiber



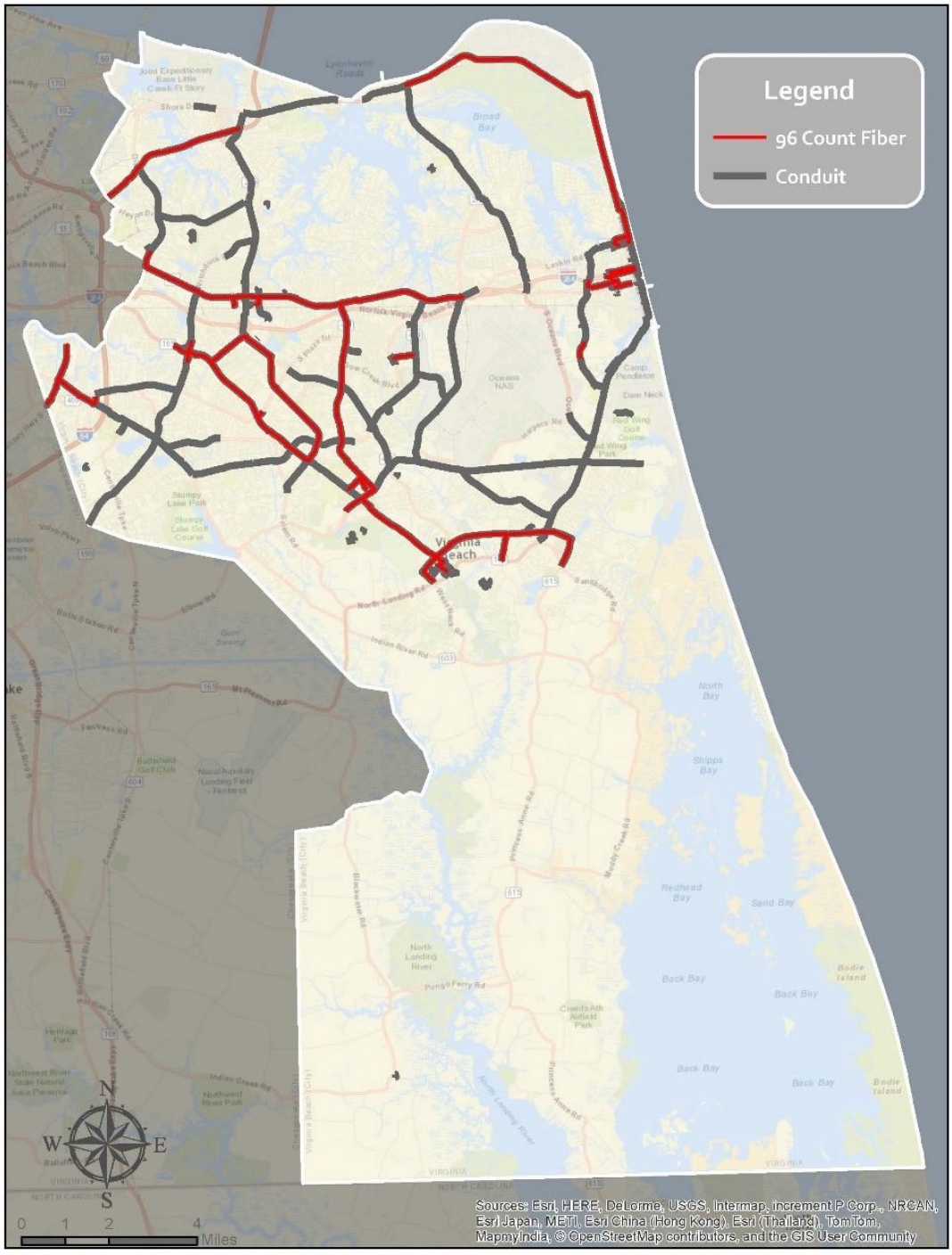
The City has 88.4 miles of 24-count fiber, illustrated in Figure 5. The 24-count fiber is the original backbone fiber deployed to support the traffic systems. In some areas, 24-count fiber has been overbuilt with an additional 24-count cable or a 96-count cable. The overbuilding was performed in order to share conduit routes or as additional fiber strand counts where required.

Figure 5: Map of 24-Count Fiber



The City has 54.5 miles of 96-count fiber, illustrated in Figure 6, which is the primary backbone cable installed in the past several years to expand the traffic system backbone. While 96-count fiber contains four times the capacity of a 24-count fiber, the larger fiber count may still not provide sufficient capacity along congested routes if the City were to pursue aggressive leasing of dark fiber strands.

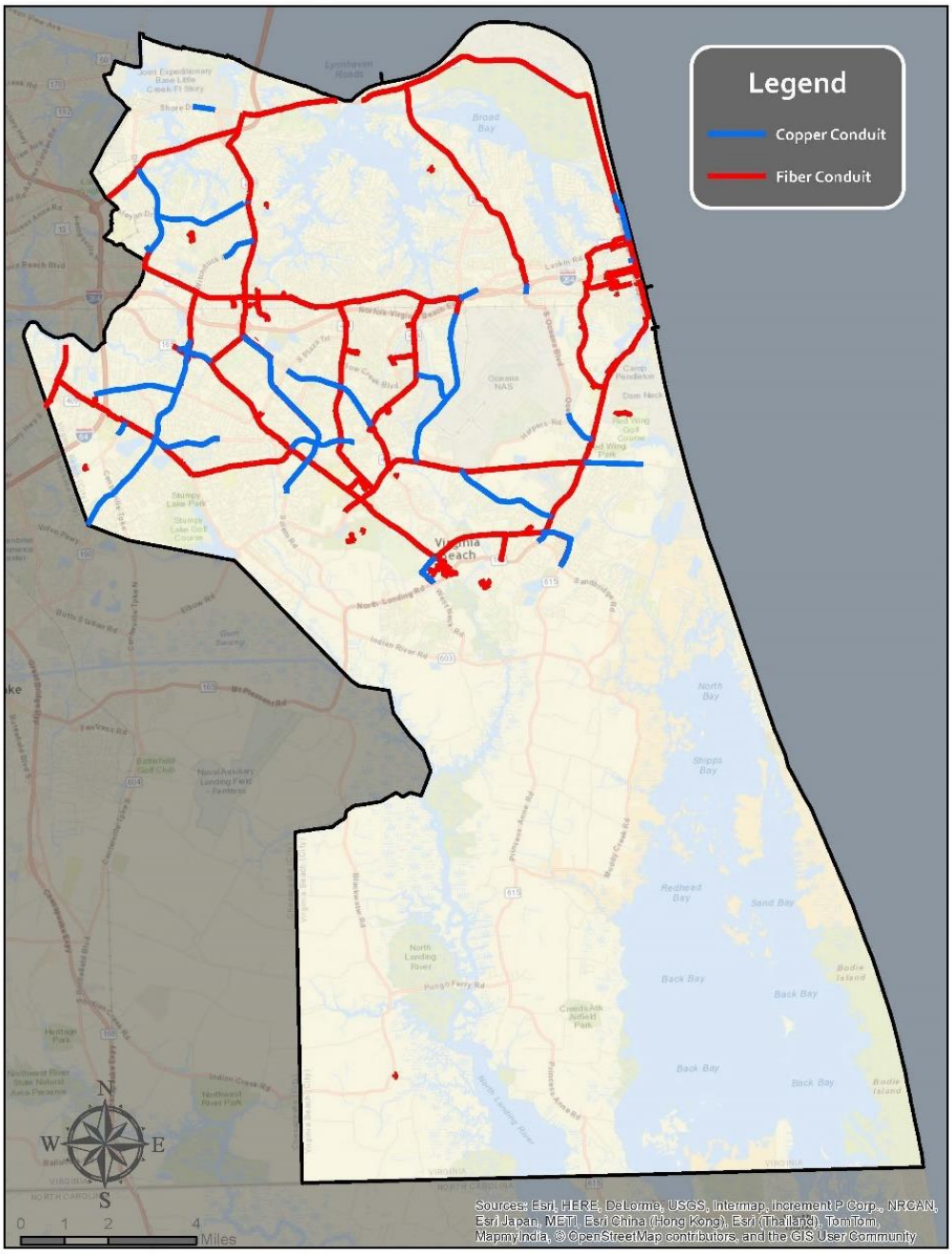
Figure 6: Map of 96-Count Fiber



1.4.3 Conduit with Copper Wiring

The City has an additional 37.9 miles of conduit that contains copper wiring that supports legacy traffic systems. This conduit can be leveraged to pull additional fiber cables to support the NGN and newer ITS initiatives. Depending on the size of the conduit, its condition, and the size of the fiber cable, a new fiber cable could be pulled without removing the copper cabling. In other scenarios, the copper cabling may need to be removed to make room for the fiber optics.

Figure 7: Map of Copper and Fiber Conduit



1.5 Service Framework and Pricing Recommendations

The Virginia Beach IT department has done an exemplary job in aggregating fiber and conduit assets from City departments and other resources; together, this infrastructure enables the City to meet many of its overall broadband goals—but **given the limited availability of fiber and conduit, and the cost of expansion, the City must treat its infrastructure as scare resources and be strategic in managing their future use.** Specifically, we note that dark fiber and conduit leasing could quickly use up the City's fiber and conduit assets.

Given this, we recommend that the City *not* consider leasing its conduit (see Section 1.5.3.2). Virginia Beach has a single three-inch conduit; in contrast, cities that have successfully leased their conduit to private entities typically have multiple spare conduits. For example, Arlington County, Virginia, has installed multiple spare conduit banks to enable its conduit leasing strategy.

To meet current and future City needs, an additional cable may need to be run in the conduit where the existing fiber cable does not have sufficient strand counts. Any cable routed by another entity in City conduit would need to accommodate the City's needs as well, because there is insufficient space for future fiber growth once a new cable is pulled.

Pulling out the existing fiber and installing innerduct with higher-count cables is a potentially viable solution, but may limit the City's ability to access the fiber and resell excess strands depending on the fiber sharing agreement with the other entity. Very high-count cables (greater than 288) may be difficult to pull through the existing conduit due to the lack of innerduct (which can cause twisting with existing cables), and because the existing handholes may not be large enough to support the required bend radius for storing slack and larger splice enclosures.

1.5.1 Proposed Fiber Strategy

The City is in the process of leveraging its existing fiber and expanding the network to connect 79 City facilities that are not located on one of the City's main campuses. The expanded Next Generation Network (NGN) will provide the City with a state-of-the-art fiber and network electronics platform that will greatly improve the City's ability to provide IT services to its departments.

The City has already used the existing fiber optic network to construct the backbone of the network, called Phase 0. The City is currently connecting City facilities to the NGN using existing fiber and by constructing additional fiber segments, which create subrings of the Phase 0 backbone. This expansion is called Phase 1 of the NGN. The current construction strategy is to construct 144-count fiber optic cables where new construction is needed—leveraging the City's existing conduit containing copper wiring ("copper conduit") to the greatest extent possible (see Section 3.2.1).

The segments where there are 96 or 144 strands would allow the City to undertake dark fiber leasing (on a strategic basis, such as to meet carriers' requests, to support small cell deployments, and to meet some economic development opportunities).

In parallel to this strategy of expanding the City's physical fiber assets, we also recommend that the City develop a capacity as a data repository for tracking public fiber assets not just within Virginia Beach, but in the region as a whole.

Items to consider tracking and documenting include:

- Fiber routes – indicate whether overhead or underground
- Fiber count by segment – total, used, maintenance spares, allocated, and available
- Fiber type by segment
- Conduit routes – size, use of innerduct (type and size), cables in each duct

Strand mapping and other documentation needed for maintenance, customer connections, and other operations must be maintained by each entity, and keeping these records both accurate and current is critical for each entity and activities in the greater region.

1.5.2 Operating and Maintenance Model

The City's NGN "Responsible-Accountable-Consulted-Informed" (RACI) matrix, which we include in Appendix J, outlines a wide range of operating and maintenance tasks—and assigns a level of accountability and involvement to the appropriate City staff, department, or contractor entity.

At a high level, the City's RACI matrix presents a model in which the City's Information Technology department administers all fiber assets. We have reviewed the assignments in the matrix and concur with the assignments. We recommend that the City continue to hire contractors to perform maintenance tasks. While this is a cost-effective approach, given the City's limited in-house resources for such tasks, the IT department should monitor the contractor's performance and costs on a regular basis. Similarly, we recommend that the City consider hiring contractors to perform fiber locates and ticket processing. **We believe the City should keep all fiber documentation, mapping, and record-keeping in-house; as these tasks are critical for both ongoing operations and future strategic planning.**

1.5.3 Policy Considerations/Recommendations

The following sections entail our recommendations for the City, including policy considerations for dark fiber and conduit leases, and pricing thereof.

1.5.3.1 Dark Fiber Lease

Dark fiber leasing is a key component in the City's strategy to monetize its broadband network infrastructure. On the customer side, it provides an easy path of entry to new routes, especially

when time to market is a key concern. The revenue obtained through leasing can be directly invested into the both City's operation and expansion of the network.

We have provided recommendations related to technical and policy matters raised by dark fiber leasing in Section 4.2.1. Other considerations the City should examine include the potential sub-leasing of leased fiber and using published rates for leasing versus a case-by-case basis for negotiating leases.

We also note that, while we have used the term "lease" throughout the document (to match the City's nomenclature, and the common usage in the industry), we recommend that the City get advice from its qualified legal counsel on the use of the term "license" instead of "lease" for short-term dark fiber contracts.

As we understand the evolving use of these terms, a "license" would allow the City to provide a connection between two end points via any path—while a "lease" requires the City to provide specific fibers along a specific route. A lease might be appropriate for long-term IRUs (and for conduit), but a license might be a better strategic approach to short-term dark fiber agreements.

1.5.3.2 Conduit Lease

Telecommunications conduit is a relatively scarce commodity, but compared to more urban markets with overly crowded rights-of-way and high labor rates, new conduit construction in Virginia Beach is relatively affordable. Thus, while the City can reasonably expect to recover some of its construction costs when leasing conduit, higher conduit lease prices will drive potential customers toward constructing their own. Conduit leasing is also a relatively low-volume business with smaller margins compared to dark fiber leasing. Techniques to increase the usability of the City's existing conduit include the placing of innerduct and avoiding the isolation of conduit segments, as outlined in Section 4.2.2.

1.5.4 Pricing Recommendations

Pricing for existing dark fiber and conduit varies based on a number of factors such as the location and urbanity of a region and the avoided construction costs along the desired routes.

Reasonable pricing models are wide-ranging and influenced by numerous factors. While cost recovery is a fundamental objective of lease pricing, ultimately it is what the market is willing to pay that determines pricing. The City must also balance its interest in encouraging economic development and encouraging competition within the local broadband market. As such, it may be prudent to keep prices at a reasonable "market rate" to sufficiently reduce barriers of entry for competitive commercial providers.

Our pricing recommendations reflect the rates that we have seen across the country and are skewed towards the examples that we have seen in the Virginia Beach vicinity as outlined in Appendices A and B.

1.6 Investment Strategy

With the Phase 0 design and the Phase 1 expansion (which will cost an estimated $3.5 million including service drops), the City will be able to meet its core connectivity goals, but will have limited remaining fiber available for lease. Many segments will have only 24 strands total—and the majority of those strands will need to be reserved for either current City use or future City/public growth.

The City's ability to lease conduit is even more restrained, because the City has a single three-inch conduit, with no inner-duct. Once an additional cable is pulled, no further cables are likely to fit unless a given segment is completely replaced. **We do not recommend that the City consider leasing conduit except maybe on a case-by-case basis**.

Our investment recommendations include:

1. Enhance the proposed expansion plan, and run new subring fiber back to the hubs. **This approach would increase the project cost by $1.7 million (to $5.2 million), but would expand many segments to 96 or 144 strands and ensure that every new strand of fiber built can be used for City/public needs or leasing excess strands.** This will help facilitate some strategic fiber leases, though we note that the City's capacity for leasing will still be limited when compared to some greenfield builds; Arlington County, Virginia, for example, has 864-strand fiber dedicated for leasing plus extra conduits on each route.

2. Extend fiber to selected higher-education sites, which would increase the project cost by $800,000.

3. Construct two diverse routes to the edge of the City (Woodstock Elementary and Renaissance Academy from corporate landing) for an additional $400,000.

4. Upgrade the remaining 24-strand segments (pull cable) to either 96- or 144-strand count, which would add an additional $314,000 to the project. This upgrade is required to support expanding City needs for the NGN. Even with these upgrades, we recommend leasing excess strands on a case-by-case basis. The City may be able to look at some dark fiber leases of excess strands for business customers, but leasing to a carrier (e.g., the recent request for 20 strands) might be difficult both because of the limits on the City's overall fiber capacity and its overall public goals. We discuss proposed strand allocations in Section 4.5.

5. Evaluate and price segments to K-12 schools and economic development sites on a case-by-case basis.

When considering the above investments and ongoing maintenance costs, it is critical to recognize the substantial avoided costs of acquiring connectivity services from providers and their ongoing monthly fees.

2 The Impact of Fiber on the Entrepreneurial Ecosystem

The availability of abundant bandwidth is critical for businesses of all shapes and sizes, but access to affordable, symmetrical gigabit-per-second (1 Gbps) connections is especially important for startups and innovative, early-stage companies. The first few cities to offer Gbps connections have managed to attract a flock of entrepreneurial spirits, eager to harness the ability to quickly send and receive huge data sets, develop new business processes, and disrupt the status quo.

Even though only a small minority of Americans currently enjoy a symmetrical Gbps connection, the companies of tomorrow have already begun to figure out how to leverage abundant bandwidth to improve the delivery of all kinds of goods and services, from medical care to the food we eat. Having fiber to business districts and office parks is critical for economic development, because the next generation of successful startups will need a fiber connection to enable the types of high-speed data transfer and real-time collaboration with remote team members that will be fundamental for the businesses of the future.

2.1 Lessons from the First Communities to Get Gbps Service

The widespread availability of an affordable, symmetrical Gbps connection is still limited to a handful of markets, and, as a result, there is a lack of causation analysis on the impact these services have on different sectors of the economy. However, anecdotal observation suggests that the availability of Gbps connections provide an economic boost that is especially pronounced among early-growth startups.

While the U.S. economy as a whole has bounced back since the crash of 2008, few places have seen as pronounced a recovery as Chattanooga, where the public utility has offered Gbps service to every residence and business since 2010. The unemployment rate has dropped from over 10 percent at the peak of the recession to just less than 5 percent as of the end of 2016.[2]

The proliferation of startups during this period has been a major contributor to the recovery. An independent study from the University of Tennessee estimated that, of the 2,832 to 5,228 jobs that the fiber-network added to the Chattanooga area between 2009 and 2014, at least 1,024 of those new jobs were part of the city's thriving technology startup scene.[3]

Although the city has taken a number of additional steps to make itself an attractive place for early-stage businesses, the fiber infrastructure has been an important lure to attract those

[2] Jason Koebler, "The City that was Saved by the Internet," *Motherboard,* October 27, 2016, https://motherboard.vice.com/en_us/article/chattanooga-gigabit-fiber-network

[3] Dr. Bento Lobo, "The Realized Value of Fiber Infrastructure in Hamilton County, TN," *The University of Tennessee at Chattanooga,* 18 June, 2015, http://ftpcontent2.worldnow.com/wrcb/pdf/091515EPBFiberStudy.pdf

entrepreneurial spirits that crave a less cutthroat and more affordable alternative to set up shop than Silicon Valley or New York City.

Similarly, Kansas City, the first place to enjoy Google Fiber service, saw a rapid proliferation of startups in the wake of the Gbps services becoming available in late 2012. Since then, the city's 'Startup Village' alone has served as a home to 48 new startups, 10 of which have outgrown the Village (and five of which have failed).[4] Even though Google markets the service to residential users, the 1 Gbps symmetrical connection is more than sufficient for many business processes. In some cases, the employees of multiple small startups were able to share a single connection without making a dent in the full capacity of the connection. While many of the startups do not necessarily need the ultra-high speed connection for the products and services they are developing, Google's service and the competition it has sparked amongst competitors in the area ensure that there is no shortage of affordable workspaces with low-cost, abundant bandwidth.[5]

2.2 Big Data Creates Opportunities for Innovation

At least some of the enthusiasm that fueled the startup boom in two previous examples stemmed from the fact that they were two of the first cities in the country where symmetrical Gbps services were widely available at an affordable price. As comparable services become available in more and more markets, we expect that having a symmetrical Gbps will become less of a lighting-rod to attract entrepreneurs and more of a necessary table-stake that cities will need to appeal to innovative, early-stage businesses.

The ability to quickly transfer huge data sets from place to place creates a huge range of new possibilities, and entrepreneurs in every sector of the economy have begun to take advantage of the opportunities that symmetrical Gbps connections enable. Nowhere is this clearer than in industries that stand to benefit from the rapid analysis of genetic data. The human genome, as it comes off of the sequencer, is roughly 200GB of data.[6] The new businesses that emerge to analyze this data will cluster around areas with abundant bandwidth. For example, Tute Genomics, a company that provides rapid and accurate analysis of human genomic data to assist with genetic diagnosis, launched in Provo, Utah, another one of the earliest cities to have Google

[4] Bobby Burch, "How Kansas City Startup Village Grew from the Arrival of Google Fiber to Thriving innovation District," *EQ*, December 12, 2016, http://eqstl.com/kansas-city-startup-village-grew-arrival-google-fiber-thriving-innovation-district/

[5] Marguerite Reardon, "Google Fiber spawns startup renaissance in Kansas City," *CNET*, June 19, 2013, https://www.cnet.com/news/google-fiber-spawns-startup-renaissance-in-kansas-city/

[6] Dr. Reid Robinson, "How big is the human genome?" *Medium*, January 6, 2014, https://medium.com/precision-medicine/how-big-is-the-human-genome-e90caa3409b0

Fiber service. For a time, Google Fiber was not available in their office location, so employees would use their home connections to transfer big files before returning to the office.[7]

Analyzing genetic information is quickly becoming part of standard researching procedures for a wide range of business endeavors, from developing more personalized pharmaceutical solutions,[8] to breeding more resilient varieties of food crops and domesticated animals.[9] While some of this innovation will take place within large companies, there is ample opportunity for entrepreneurs to use cutting edge technologies to create disruptive new business models. However, given the size of genetic data sets, innovations in these fields will tend to emerge from areas with an abundance of bandwidth.

Genetic information is just one of numerous large data sets that businesses are in the early stages of learning how to analyze in order to improve decision making and boost performance. From retailing and manufacturing to finance and insurance, businesses are collecting more data than ever before. Now they are faced with the challenge of how to use these enormous data stores to improve efficiency and productivity.[10] The amount that companies spend on data analytics is set to surge in the coming years,[11] creating new opportunities for individuals with the skills and robust, reliable broadband connections necessary to make sense of huge data sets.

2.3 Fiber's Role in Supporting the Entrepreneurial Ecosystem

Individuals are already discovering new ways to harness symmetrical Gbps connections to improve businesses and society. The underlying fiber network makes these advances possible, and determines where innovation can happen. If the only place to enjoy abundant bandwidth in a region is in huge office parks and major research universities, then innovation will likely be concentrated in these large, established institutions.

Having a fiber connection to every home and coffee shop gives people the freedom to tinker and push the limits of technology outside the confines of existing bureaucracies. Many employees of large businesses have passions and expertise that extend beyond their current job description. With a home broadband connection that parallels their connection at work, they can research

[7] Jamie McGee, "In Kansas City, Google Fiber has changed workers lives," *The Tennessean,* http://www.tennessean.com/story/money/tech/2015/02/01/kansas-city-google-fiber-changed-workers-lives/22601915/

[8] Andrew Ward, "Drug Companies Unite to Mine Genetic Data," *Financial Times,* March 25, 2015, https://www.ft.com/content/4d1792fe-d2f1-11e4-b7a8-00144feab7de

[9] Dyllan Furness, "From corn to cattle, gene editing is about to supercharge agriculture," *Digital Trends, April 17, 2017,* http://www.digitaltrends.com/cool-tech/crispr-gene-editing-and-the-dna-of-future-food/

[10] Nicolaus Henke, et al. "The age of analytics: Competing in a data-driven world," *McKinsey & Company,* December 2016, http://www.mckinsey.com/business-functions/mckinsey-analytics/our-insights/the-age-of-analytics-competing-in-a-data-driven-world

[11] "Big Data Spending Set to Surge," *IT Online,* March 31, 2017, https://it-online.co.za/2017/03/31/big-data-spending-set-to-surge/

and test hypothesis in their time off, and develop their passions into creative new business models.

Startups tend to be nimble, often operating on a shoe-string budget for their first few years. Having ubiquitous fiber in an area ensures that there is no shortage of satisfactory workplaces with sufficient bandwidth for data-intensive application. Whether team members work from home, a co-working space or a coffee shop, fiber connections ensure that time is spent getting work done instead of waiting for files to load. Fiber connections are especially important for enabling real-time collaboration with remote team members. Often startups lack the in-house expertise to complete every task themselves. If a team member needs to direct a team of software developers operating all over the world, it is critical that the team not lose time to dropped calls and lagging video conferences.

Ensuring widespread access to affordable, symmetrical, Gbps connections on its own will not transform an area into a hotbed of startups. However, coupled with other policies that encourage entrepreneurship and give early-stage companies access to growth capital, ubiquitous fiber may enable individuals to tinker with new technologies and allow entrepreneurs to develop innovative ideas into sustainable business models.

3 Proposed Fiber Strategy

3.1 Overview of Strategy[12]

The broadband vision for Virginia Beach is summed up in the Envision Virginia Beach 2040 Committee Report, which envisions that "Citizens, businesses and visitors have access to advanced broadband technologies that efficiently and effectively supports regional interconnectivity as well as global commerce."[13] In addition, the Virginia Beach City Council Resolution to establish a broadband authority addresses the importance to business and new industries.

According to the City's press release, "Expanding access to ultra-high-speed internet service in Virginia Beach would be a powerful incentive for new businesses here, especially in the expanding biomedical field."[14] The press release goes on to say that this initiative also will help lay the "groundwork for leveraging that network to create a citywide system, which would help local businesses and underserved areas in Virginia Beach."

The City's broadband strategy consists of two phases. The first phase to expand the network during 2016 to 2018 consists of the following milestones:

- Connect City facilities
- Expand Strategic Growth, Special Economic Growth, and Technology Business Target Areas (Middle Mile)
- Adhere to the "Dig Once" strategy for all horizontal projects
- Develop a business and financial model in support of the strategy
- Develop business relationships with neighboring authorities and providers
- Assist with trans-oceanic landings and mini-data center initiative
- Create a plan to address digital divide
- Engage neighboring cities to explore ways to expand connectivity in region
- Explore opportunities to connect with GO Virginia initiative

The second phase consists of the following milestones:

- Explore the opportunity to establish a common architecture between the City and VBCPS
- Reinvest budgetary savings back into technology
- Develop a regional strategy
- Explore other opportunities for technology collaboration for regional strategy

[12] The material in this section was provided to CTC by the City of Virginia Beach; we include this background information, some of it verbatim from City sources, at the City's request.
[13] Envision Virginia Beach 2040 Committee Report, May 15, 2012.
[14] "City Council to Explore Creating Broadband Internet Authority," Virginia Beach Press Release, March 18, 2015.

- Expand opportunities with service providers

3.1.1 Excellence in City Services

The City can foster excellence in its service by expanding the current fiber network, and leveraging it for additional benefits.

3.1.1.1 Expansion of Fiber Network

The City is in the process of leveraging its existing fiber and expanding the network to connect 79 City facilities that are not located on one of the City's main campuses. The expanded Next Generation Network (NGN) will provide the City with a state-of-the-art fiber and network electronics platform that will greatly improve the City's ability to provide IT services to its departments. The City has already used the existing fiber optic network to construct the backbone of the network, called Phase 0 (see Section 3.2.1).

3.1.1.2 Leveraging Network for Additional Benefits

Potential customers who would benefit from the use of high-speed service include the following:

- Private companies (e.g., Valkyrie Enterprises, LifeNet Health, etc.)
- Business Incubators
- Research universities
- Federal labs and research institutes
- Healthcare providers
- Community anchor institutions

3.1.2 Educational Needs and Opportunities

The City can capitalize on educational opportunities by strategically connecting its network to higher education locations throughout the region. This model has proven effective in Fairfax County, as discussed below.

3.1.2.1 Connectivity to Higher Education

NGN can support a regional strategy for education, including through connectivity to the City's identified Educational Impact Zones and collaboration with higher education institutions in support of business incubators.

Connecting VBCPS schools to higher education locations would facilitate educational pathways in high-demand occupational career areas such as cyber security and entrepreneurship. These connections would allow for greater public/private partnerships for research and technology transfer from high schools through college, thereby creating a pipeline for the biomedical research initiative of the City and the greater region.

In addition, by reducing annual operating expenses, dollars could be redirected to student support and/or the development of educational pathways and training opportunities.

The region's many transitioning military members would benefit from these NGN-based education and training opportunities and could potentially move into private sector occupations in the region.

3.1.2.2 Case Study: Fairfax County, Virginia

Fairfax County is a County in Northern Virginia that is close to the Washington, D.C. metropolitan area. The County has a franchise agreement with Cox across most of the County. The County also has a parallel business agreement with Comcast under which it builds to schools in an area (Reston region) where Cox has a weak footprint. The County's fiber infrastructure tends to be via Cox's hubs, creating a heavy dependency on its physical infrastructure and difficulty in interconnecting with other providers.

Six Cox hubs are interconnected with fiber rings; the County has electronics in each hub. The individual schools connect back to the hubs on dedicated runs. Some have route diversity and some do not. There are six strands to each school. Until most recently, the schools ran their own electronics on separate fibers.

Cable franchise agreements, including the agreement with Cox, allow Fairfax County to classify the fiber as primary priority—which are eligible for better service-level agreements (SLA). However, because cable franchise arrangements impose restrictions on the use of fiber and prevent conveyance to third parties for resource sharing, the County is limited in its ability to interconnect, access commercial services, or allow third-party traffic. In the future, the County may have to depend on using costly one-off point-to-point IRUs to avoid using any Cox infrastructure.

3.1.3 Unified Government Network

A unified government network might allow the City and VBCPS to share assets and services in order to create efficiencies, lower investment costs, and reduce total cost of ownership. A unified network in Virginia Beach could also potentially be a building block for a unified regional government network, given the interest among the region's CIOs in collaboration for collective benefit (see Section 1.2.2).

3.1.4 Economic Development Opportunities

Expansion of the City's fiber network offers multiple economic development opportunities, which can be strategically leveraged for middle mile, radio tower, and distributed antenna systems (DAS) opportunities.

3.1.4.1 Middle Mile Strategy

The middle mile strategy addresses a fundamental question: "What if a company considers locating to a target area within Virginia Beach?" By being "fiber-ready" and having predefined areas, an opportunity exists to attract and retain businesses, provide additional job opportunities within the City, and potentially lower connectivity and internet costs for the businesses.

3.1.4.1.1 Fiber-Ready Approach

The City aims to provide business entities that locate within Strategic Growth Areas (SGAs), Special Economic Growth Areas (SEGAs), and Technology Business Target Areas the opportunity to obtain fiber connectivity.

This would include ensuring direct access to dark fiber, establishing connection points close to borders of neighboring jurisdictions, and developing a business plan and financial model for middle mile services.

3.1.4.1.2 Dark Fiber Leasing

In addition to being fiber-ready, the City would plan to lease conduit and dark fiber to business entities locating within the target areas.

3.1.4.1.3 Transatlantic Fiber

To further strengthen the City's ability to be fiber-ready and to lease dark fiber, the City would develop a trans-oceanic onboarding service delivery plan and long-term lease agreement with Camp Pendleton. It would partner to provide middle mile services—including for the benefit of local service providers, which could leverage the middle mile to serve new customers.

3.1.4.1.4 Business Incubators

One potential business driver for broadband expansion is to transform the region's economy by developing high-growth industries. In recent years, the cyber security industry has grown substantially due to countless cyberattacks. In discussions with the Virginia Beach Economic Development Department, the City is interested in exploring ways to attract companies that specialize in this field and in making Virginia Beach a hub for cyber security. The City is exploring how this could be a possible new business sector and what the region's niche would be. Broadband technologies would play a vital role in achieving these goals.

3.1.4.1.5 Service Providers

The business drivers that are often cited for establishment of broadband authorities and municipal broadband networks include providing competition among service providers to help reduce the cost of broadband expansion, creating jobs to offset job losses, providing incentives to homegrown companies to remain in the area, and enhancing innovation and entrepreneurism to reduce the dependency on less stable industries. All of these drivers easily apply to the Virginia

Beach region as well, especially in consideration of the area's dependence on the military, government, and tourism and the possible effects of sequestration.

3.1.4.2 Radio Tower Strategy

Opportunities might exist for the City to lease fiber to tower owners to support backhaul of wireless communications. To establish the potential market, the City could conduct an audit of existing towers to identify their owners, the space available, and the leases already in place. Regional providers such as Mid-Atlantic Broadband, FTS, Lumos, other might have contracts or contacts with providers—which might represent opportunities to partner with regional providers.

3.1.4.3 Distributed Antenna Systems and Small Cell Strategy

Across the country, cellular carriers are installing or seeking to construct new distributed antenna system (DAS) networks and small cells to meet users' demand for mobile broadband data. The City should consider creation of a policy regarding small cell deployments. Among the considerations for this type of policy are:

- Ensuring consistency of pole attachments and installations in the rights-of-way
- Establishing aesthetic requirements
- Ruling on whether street lights or other structures can be used for attachments
- Establishing ownership of installed equipment at the expiration of a given lease
- Documenting height restrictions for poles that are approved to be installed
- Documenting minimum distance requirements
- Establishing co-location requirements
- Establishing requirements (if desired/feasible) for the City to acquire strands or access to conduit when a private entity installs fiber or conduit

We also recommend that the City consider issuing a request for information (RFI) or request for proposals (RFP) for a carrier-neutral DAS or small cell implementation for the downtown beachfront. This is discussed further in Section 4.4.2.2

3.2 Fiber Optic Expansion Initiatives

The City has a plan to leverage its existing fiber and conduit system to provide connectivity to City facilities and its regional partners. The expansion of the network to meet these goals will

extend the footprint of the City's network and make the City better capable of supporting broadband development in the community. The City goals are as follows:

- Leverage the existing infrastructure and expand on it to provide connectivity to City facilities;
- Expand the network to support higher educational users within the City;
- Use the network to create and its potential for interconnectivity and cost savings to create a unified network between VBCPS and the City;
- Explore using the network to aid economic development specifically in City identified growth areas;
- Expand the fiber optic network to the City borders from major internet interconnection point to provide connectivity with neighboring government entities and internet service providers;
- Enhance the City's fiber optic network along key routes to improve redundancy, increase the number of fiber optic strands available, and better opportunities for serving providing dark fiber services to City businesses.

3.2.1 Provide Connectivity to City Facilities

The City is in the process of leveraging its existing fiber and expanding the network to connect 79 City facilities that are not located on one of the City's main campuses. The Next Generation Network (NGN) will provide the City with a state-of-the-art fiber and network electronics platform that will greatly improve the City's ability to provide IT services to its departments. The City has already used the existing fiber optic network to construct the backbone of the network, called Phase 0, as shown in Figure 8 (below).

The Phase 0 backbone uses 50 miles of existing fiber and connects six hub locations. The hub locations contain electronics that will connect the other City facilities.

The City is currently connecting City facilities to the NGN using existing fiber and by constructing additional fiber segments, which create subrings of the Phase 0 backbone. This expansion is called Phase 1 of the NGN. The current construction strategy is to construct 144-count fiber optic cables where new construction is needed—leveraging the City's existing conduit containing copper wiring ("copper conduit") to the greatest extent possible. Figure 9 (below) depicts Phase 1 of the fiber construction.

As currently designed, Phase 1 uses existing fiber optics to the greatest extent possible to minimize construction costs. Of the 91.8 miles of fiber optics in Phase 1, approximately 70 miles

is using existing fiber, six miles is pulling through existing copper conduit, and 16 miles in new conduit and fiber construction.

Compared to the 50 miles of fiber from Phase 0, Phase 1 adds 91.8 miles of fiber with 32 completed sites and an additional 47 proposed sites. There are 141.8 total miles of fiber and 85 total sites when Phase 0 and Phase 1 are combined.

Beyond Phase 1 there are 82 remaining City facilities that will not be connected to the NGN. Many of these sites may not require fiber optic connectivity or are too cost-prohibitive to justify connecting them to the network. It is important to note, however, that as City needs change and the fiber optic network continues to expand, some of these sites may be added to the network in the future. Figure 10 (below) shows the non-connected City facilities.

Figure 8: Map of Phase 0 Backbone Fiber

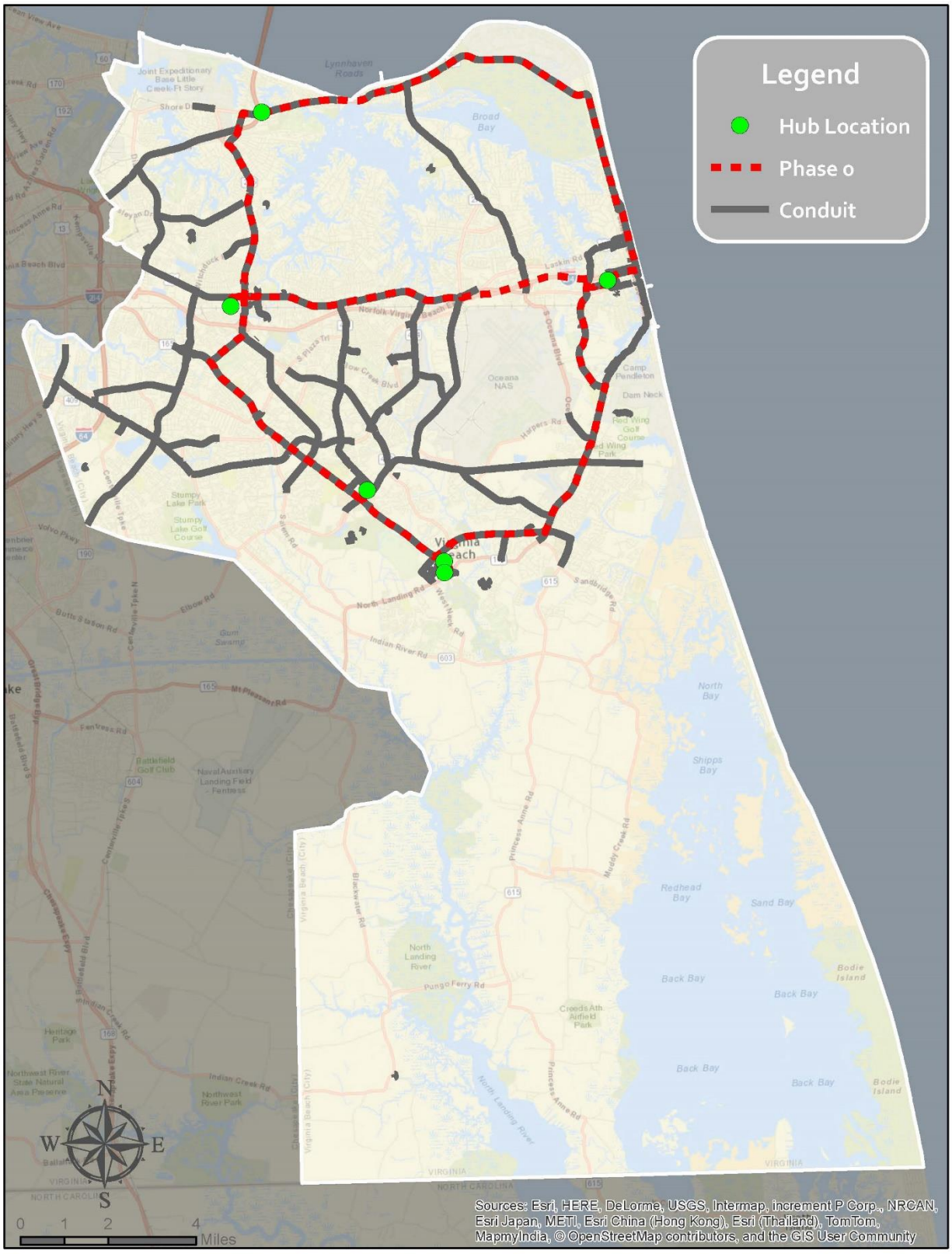


Figure 9: Map of Phase 0 and Phase 1 Fiber

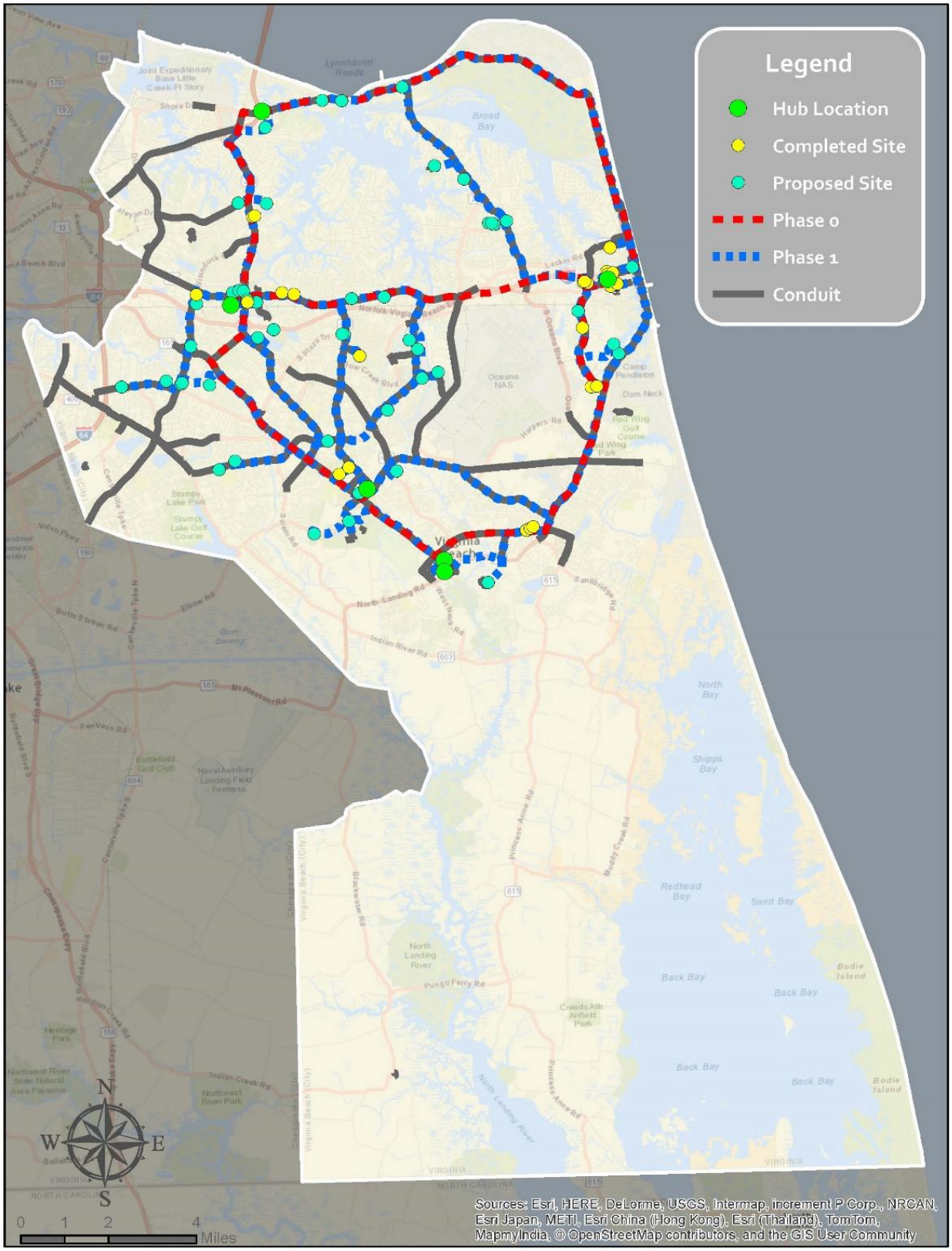
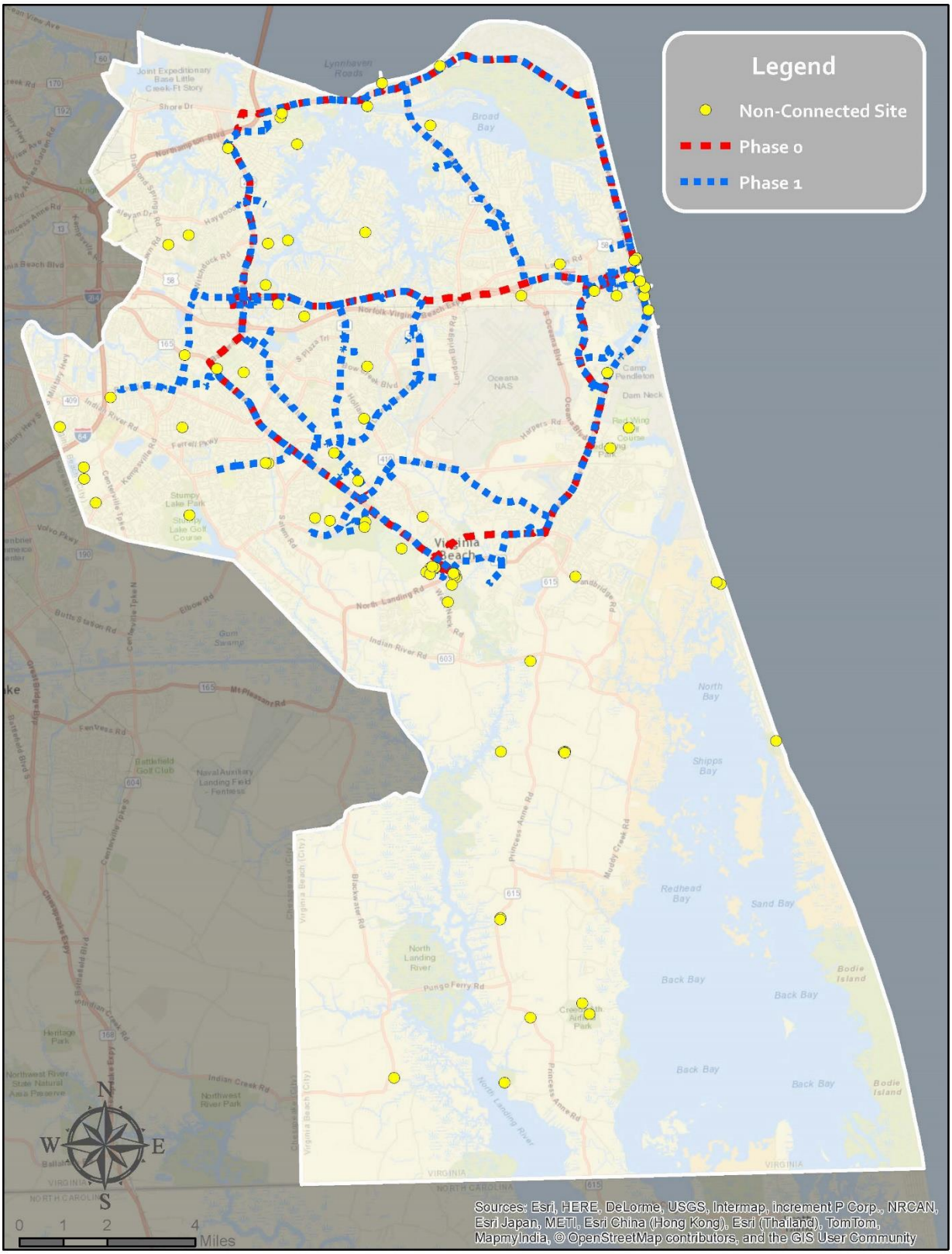


Figure 10: Map of Non-Connected Sites

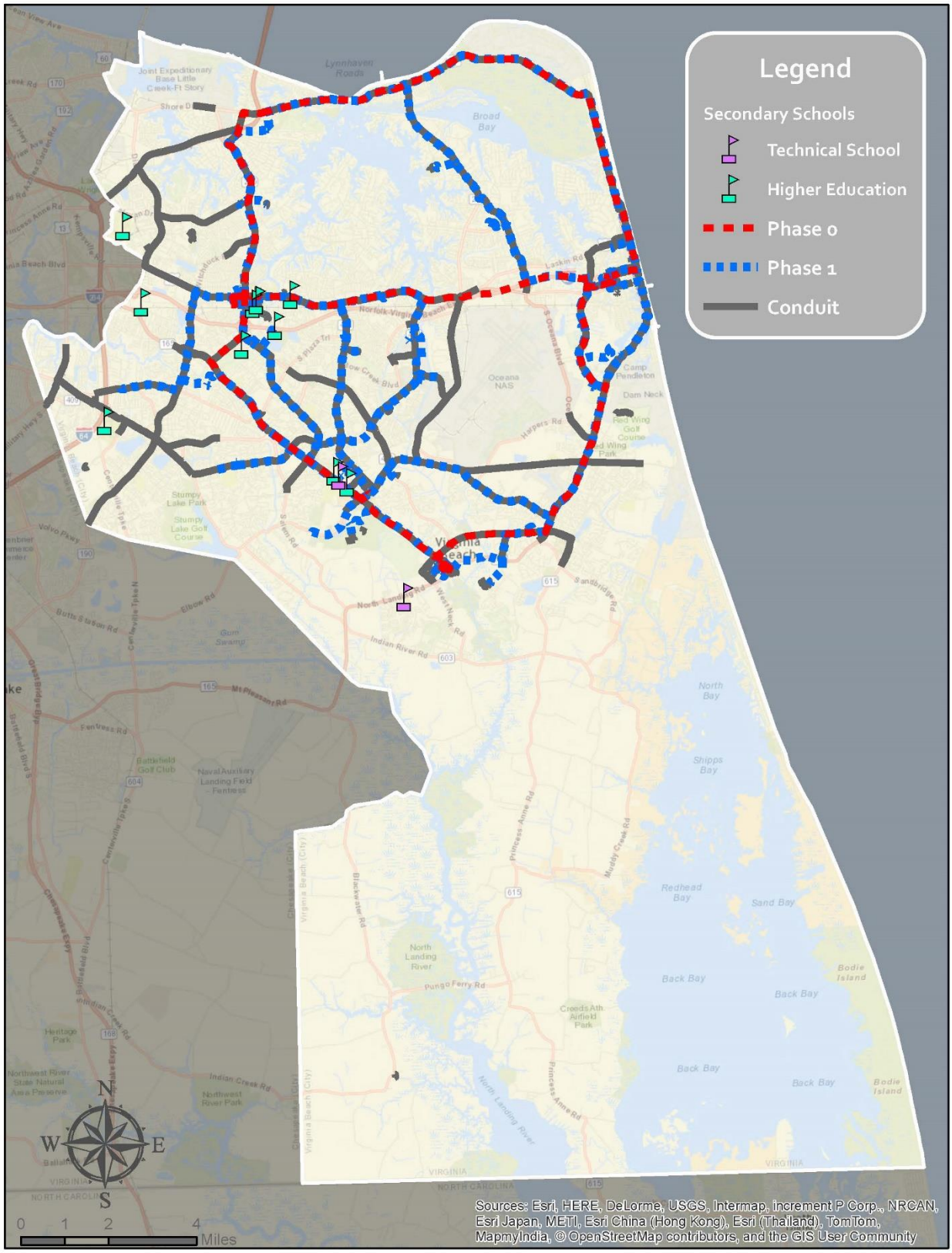


3.2.2 Support Higher Education Users

Higher education users tend to require extensive internet access as well as to be on the forefront of technology. Connectivity would also allow for greater opportunities for research and collaboration between users, as well as opportunities to expand educational offerings and training through tele-learning and other educational initiatives. There are 12 higher education centers in the City, as shown in Figure 11 (below).

Connecting these facilities would not require extensive fiber construction because the existing and Phase 1 construction of the NGN is in close proximity to many of the facilities. Construction to all 12 sites requires approximately 15 miles of existing fiber, one mile of existing copper conduit, and six miles of new fiber optic and conduit construction.

Figure 11: Map of Higher Education Centers



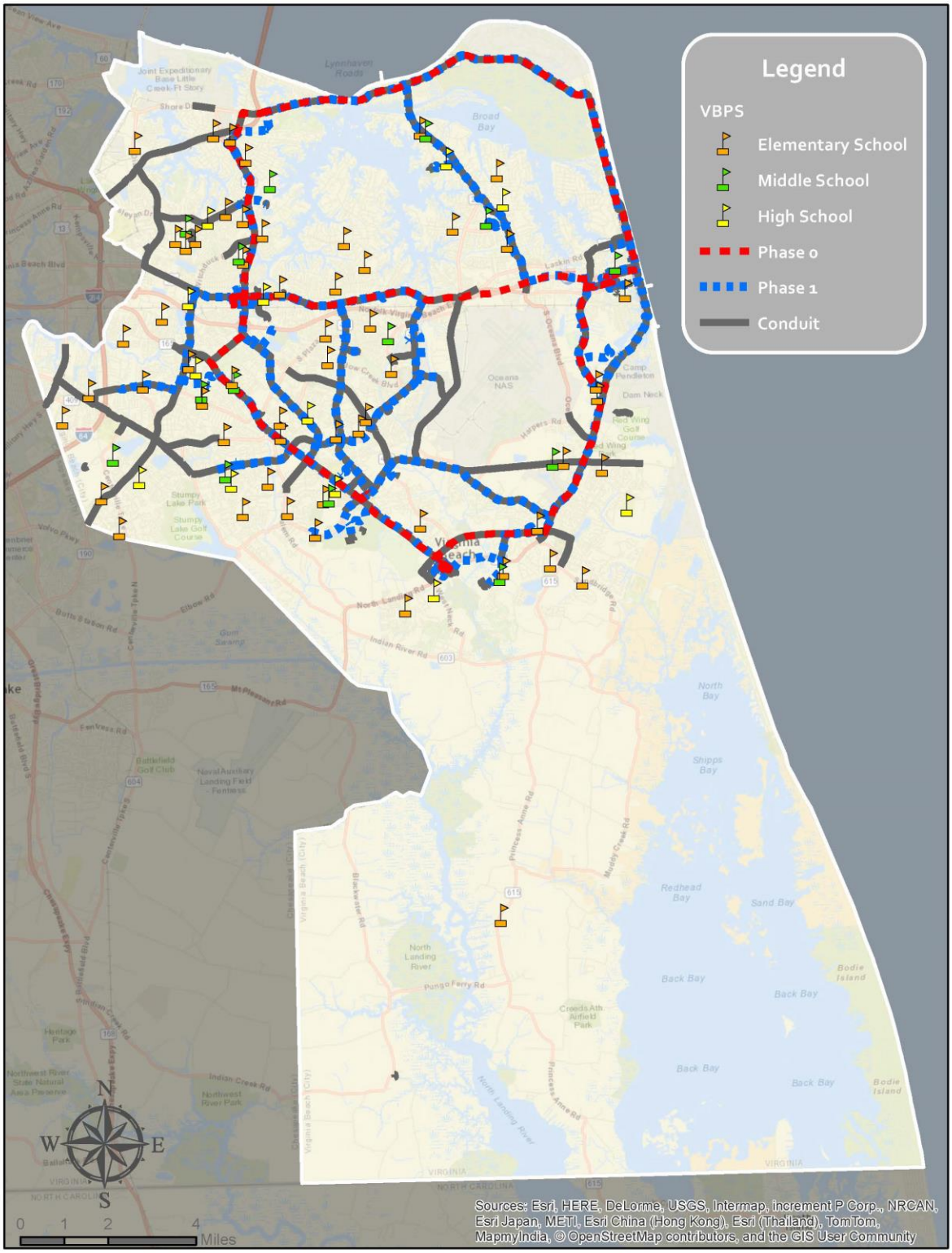
3.2.3 Unified Network with VBCPS

Once the NGN is operational and the City facilities and higher educational users are connected, the City will have the opportunity to work with VBCPS to create a unified network for public agencies. Leveraging one network to support multiple agencies reduces the cost and complexity of network while providing additional opportunities for collaboration and interconnectivity between users. Connecting VBCPS with higher educational users presents a wealth of opportunities for learning and collaboration. Whereas, connectivity between the City's public safety entities and VBCPS can increase situational awareness and response times to incidents of school property.

VBCPS already operates its own fiber optic network and electronics. One approach for creating a unified network would be to analyze the existing VBCPS network architecture to determine the most cost effective way of connecting the School's hub sites into the NGN backbone. Adding the school sites as hub sites to NGN would minimize the amount of network engineering required to incorporate VBCPS into the NGN.

Figure 12 shows the proximity of VBCPS locations to the fiber optic network.

Figure 12: Map of VBCPS Locations and Fiber



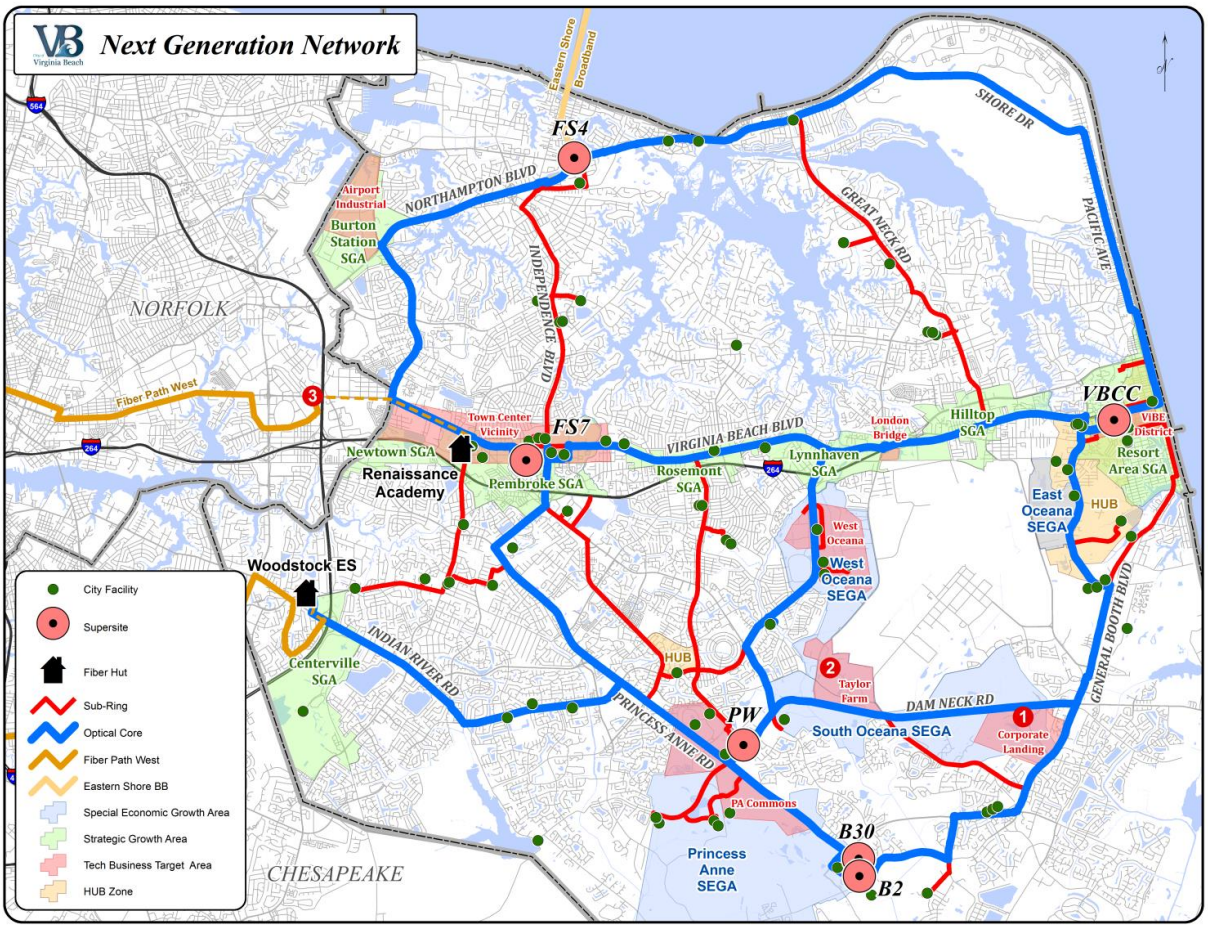
This figure shows that many of the locations are close to the existing network. There may be opportunities to connect VBCPS locations not currently on the School network at reduced construction costs. Fiber resource sharing and joint fiber construction may also allow additional City and VBCPS sites to be added to the network at reduced costs.

3.2.4 Aid Economic Development

Access to affordable high-speed internet can be a great economic development tool to attract businesses to the City and expand economic opportunities in areas where they may be limited. The City has identified these specific areas through its economic development efforts; by expanding the fiber optic network to these communities the City can ensure that they are fiber ready. Ensuring that there is a fiber connection near or adjacent to these areas means that these economic development zones have access to dark fiber which can connect them to internet points of presence for access to middle mile providers.

Figure 13 shows the defined economic areas in relation to the fiber optic network.

Figure 13: Economic Development Areas in Relation to the NGN



The fiber optic network is in close proximity to all of the economic areas after the completion of Phase 1 of the NGN. This will allow the City to quickly meet any economic development needs that arise as the City looks to increase economic opportunities in the City. Coordination with the City's Economic Development can target opportunities where the fiber can be leveraged or modified to support specific needs.

3.2.5 Expand to Internet POPs and Neighboring Cities

Expanding the network to internet points of presence (POPs) and to the borders of the City allows the network to connect with additional governmental partners and middle mile providers, which enhance the value of the network. Connecting to internet POPs will provide the City and its network users access to multiple internet service providers (ISP) and potential middle mile partners. Internet POPs are locations such as datacenters where multiple ISPs collocate their network electronics and fiber backbones in order to interconnect their networks and connect with customers. Access to internet POPs can provide a variety of benefits to network users, including:

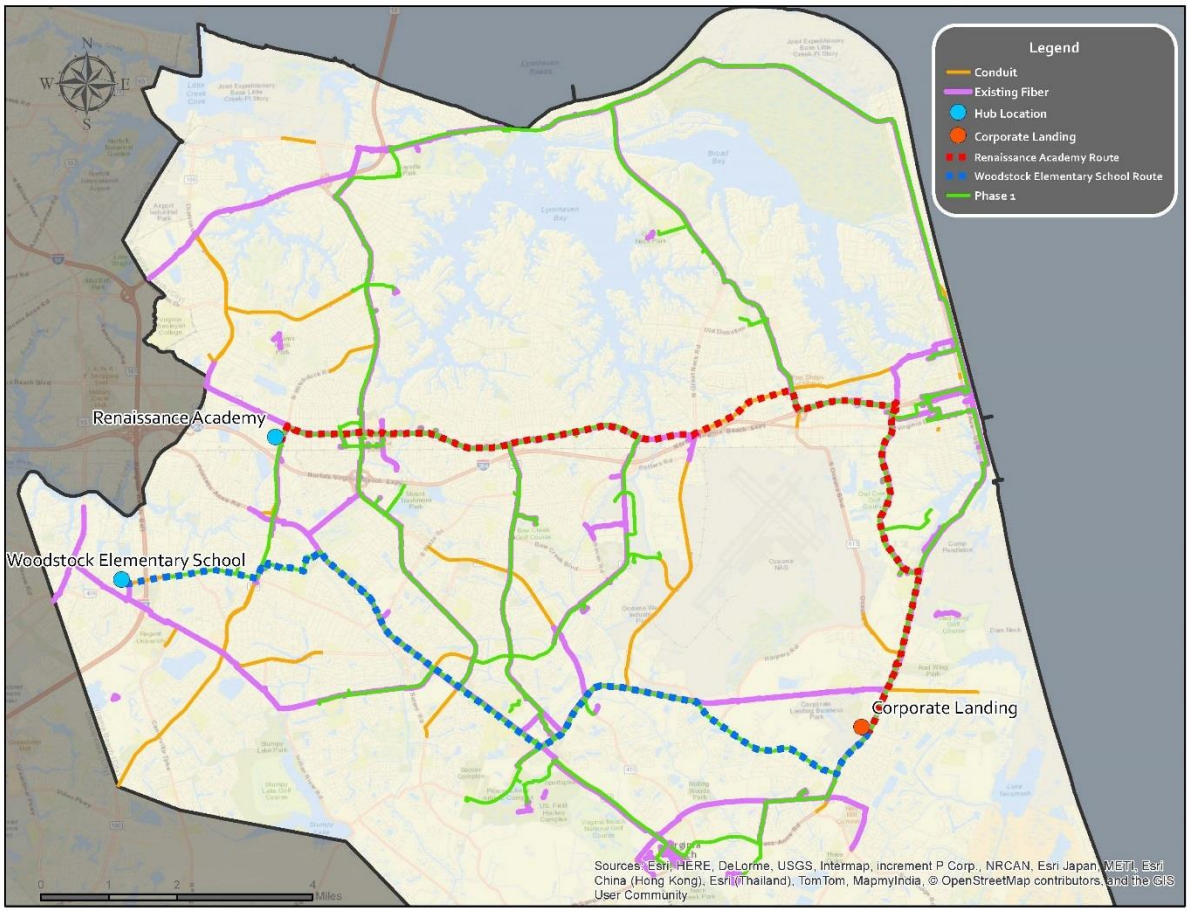
- Cheaper and multiple providers internet connectivity;
- Direct connectivity to application service providers like voice over IP, videoconferencing and collaboration tools;
- High availability hosting space for servers and other critical network applications; and
- Access to middle mile providers looking to provide services using the City's dark fiber.

Expanding to the City borders allows the City to interconnect with other governmental agencies and service providers that may not have a footprint within the City limits. Interconnectivity can benefit all of the governmental partners of the NGN including public safety, VBCPS, and higher education. Regional networks facilitate collaboration between agencies and can reduce costs by developing regional applications rather than applications for each jurisdiction. Regional networks can also provide access to broader governmental networks such as the Commonwealth, Federal agencies, and educational networks like Internet2.

To establish this connectivity, the City will need to construct fiber from the internet POP at Corporate landing to the borders of Chesapeake and Norfolk. The city has identified Renaissance Academy and Woodstock Elementary School as potential locations near the borders where a fiber hut could be located to interconnect with neighboring jurisdictions and potential service providers. The hut will serve as a location to terminate fiber and house electronics needed for an interconnection.

Figure 14 shows the routing for these connections.

Figure 14: Fiber to Corporate Landing and to Chesapeake and Norfolk



3.2.6 Increase the Fiber Optic Network Strand Count

Once the fiber network has met its short-term goals, the City should invest in enhancing the network to increase reliability and capacity. These enhancements include:

- Overbuilding the existing fiber optic network where only 24-count fiber is available;
- Converting important laterals into subrings to increase reliability of the network;
- Identify any single points of failure and remediate by constructing redundant paths;
- Provide diverse redundant paths to key locations; and
- Expand the network along key routes to support additional sites and potential demand for services.

The enhancements will increase fiber count along the routes, which maximizes the number of fiber strands that are available for the City's use as well as for offering dark fiber services to businesses in the City. Where new laterals are spliced into existing fiber, such as a 24-count fiber, it limits the number of fibers that are available on the lateral that can connect to the hub or are available to offer for dark fiber services. The enhancements will also increase the redundancy of the network, which will increase network availability to sites and expand the network's footprint.

4 Financial and Business Plan

4.1 Operating and Maintenance Model

The City's NGN "Responsible-Accountable-Consulted-Informed" (RACI) matrix, which we include in Appendix J, outlines a wide range of operating and maintenance tasks—and assigns a level of accountability and involvement to the appropriate City staff, department, or contractor entity.

At a high level, the City's RACI matrix presents a model in which the City's Information Technology department administers all fiber assets. We have reviewed the assignments in the matrix and concur with the assignments. We recommend that the City continue to hire contractors to perform maintenance tasks; while this is a cost-effective approach, given the City's limited in-house resources for such tasks, the IT department should monitor the contractor's performance and costs on a regular basis. Similarly, we recommend that the City consider hiring contractors to perform fiber locates and ticket processing. We believe the City should keep in-house all fiber documentation, mapping, and record-keeping; those are critical tasks both for ongoing operations and future strategic planning.

4.2 Recommended Policies

We conducted an analysis to assist the City with developing a strategy and associated policies for leasing its fiber and conduit infrastructure.

4.2.1 Dark Fiber Leasing

Technical and policy considerations will influence dark fiber leasing. When managing dark fiber lease agreements, **we recommend that the City implement policies to ensure that the excess fiber strands are used efficiently, and that considerations for potential future expansion are not compromised**. In this regard, the City must balance its interests in creating a competitive, open access environment and ensuring that the network capacity can be expanded if needed to meet demand.

In many respects, these objectives can be in opposition. On one hand, pricing and related policies must be high enough to discourage individual customers from licensing unnecessary capacity, whether simply being wasteful or attempting to control the fiber to block access by competitors; on the other hand, policies and pricing must not discourage would-be customers from building their own fiber, compromising the City's ability to expand its own open access infrastructure and occupying scarce space in the public rights-of-way.

It is critical to remember that 96 strands of fiber may appear abundant—but licensing of dark fiber quickly uses up strands, and fiber rings can easily end up with isolated strand segments.

Meticulous record keeping is an important part of managing dark fiber. Maintaining timely and accurate as-built documentation and strand maps is critical for maintenance, as well as for

understanding what strands are currently in use, what might be available for use, and what strand routing to choose.

We recommend that the City consider the following policies to help ensure long-term protection of the City fiber assets:

- Allocate the number of strands that the City will make available through lease agreements—ensuring that the City retains an appropriate allocation for internal use, for previously committed IRUs, for maintenance (City use and dark fiber lease agreements), and for future expansion
- Require a limit on the fiber strands that one individual entity will be able to lease
- Ensure that the same ribbons are reused for leasing in different segments of the network (allocate based on the number of strands reserved for licensing)
- Restrict access to City handholes and splice enclosures for security purposes. The placement of an adjacent handhole for the lessee will allow them to place and access their splice enclosures and slack loops without compromising City infrastructure. Particularly at junction points of high demand fiber segments, the City may also place a row of smaller handholes that can be used for licensing and each lessee may place their own handholes as well.
- Consider having demarcation at a customer premises.
    - Have a monthly premises entry fee, plus recovery of the cost to extend fiber to premises.
    - Amortize the cost of the fiber extension (laterals and drops) over the term of the lease; to reduce risk, the City can consider not amortizing extensions and requiring 100 percent payment of fiber extensions prior to the start of construction.
    - City retains ownership of any fiber extensions (ensure that a given provider cannot control City fiber by controlling laterals and customer drop cables).
- Ensure that the lessee has the sole responsibility for the activation of the leased fibers and associated facilities
- Establish a clear demarcation of responsibility for the payment of any utilities, connection fees, and service fees that are required for the operation of the fibers.

- Require that the City (or City controlled contractor) conducts splicing and addition of conduit into the handholes; do not allow lessee access to City handhole, even if a common approved contractor is used.
- Ensure that all documents (such as as-builts and strand maps) are updated in fiber management systems—eliminate reliance on staff institutional knowledge
- Require an administrative fee for obtaining a quotation on lease pricing and associated costs.
- Develop a procedure for testing the fiber that has been prepared for leasing that includes:
    - Performing acceptance tests to determine whether the leased fibers meet required technical specifications
    - Provide written results of such tests to the lessee for review and acceptance within a set timeframe.
    - Include in the contract that the City may repair or substitute fibers that do not meet the required tests and specifications, and provide written notice of such repair or substitution.
- Ensure that fiber maintenance agreements are in place with City contractors in order to adhere to Service Level Agreements (SLAs). With regard to maintenance agreements, it is recommended to have policies on periodic maintenance, repairs, and routine monitoring such as:
    - Scheduling and performing periodic maintenance checks on the network, including the leased fibers, interconnection fibers, and Interconnection points, at its sole cost and expense.
    - Monitoring at least one unlicensed fiber in the leased fiber conduit for cable continuity on a 24/7/365 basis, and take timely steps to address the issue before to it affects the operation of licensed fiber.
    - Provide a written notice of any scheduled maintenance and minimize any effect on the licensed fibers
    - Create an action plan to handle emergency repairs (i.e., during an abrupt failure of the City's Network)

The City can expect administration, maintenance, insurance, and other cost increases by licensing fiber infrastructure. Depending on the service level guarantees the City offers, and in particular to what degree the City accepts responsibility for damages that occur to a lessee's cable, fiber licensing may increase operating expenses beyond those already committed to support internal communications. At a minimum, the City must consider the costs associated with invoicing lessees, inspection of fiber to ensure compliance with technical requirements of the license, cost of responding to outages, and oversight of lessee cable installation and repair activities.

Other considerations that would affect the technical policies developed for dark fiber licensing may include:

- Will the City allow sub-leases of its fiber? An arrangement of this type might work as a mechanism to retain the primary lessee as a broker for other leases, potentially as part of an arrangement in which the City's fiber is maintained by the lessee and receives a portion of any sublicense revenues.

- Is the City planning to create a published rate card for leases, or is the City better served by negotiating leases on an individual basis? (A formula-based approach may include a variety of factors, such as total strand miles, terms of agreement, and length of route.) While the transaction costs are higher in the latter, it may provide more flexibility to negotiate license terms that are better aligned with overriding economic development objectives on a case-by-case basis. While certain licenses are more likely to promote higher quality broadband services for the community, others may represent a revenue opportunity for the City that should be maximized.

4.2.2 Conduit Leasing

While leasing conduit has many of the advantages that dark fiber leasing has, conduit should be considered a scarce commodity. Given its high replacement cost, leasing too much conduit at low prices could result in the City incurring significant expense to add capacity to meet future needs. On the other hand, conduit leasing may serve a greater economic development purpose for which relatively low pricing is justified, for promoting competition in retail broadband markets. On the other hand, this must be balanced against setting a precedent for unreasonably low pricing that could impact conduit lease revenues for many years to come. As such, the City can choose to leverage its conduit leasing program to maximize benefit to economic development through low-cost conduit leases that promote private investment, maximize conduit lease revenues, or any balance of these priorities.

There are a number of considerations related to technical and policy matters that will influence particular conduit leases. In particular, we recommend that the City implement lease policies to

ensure conduit and handhole space is used efficiently, and that the integrity of its existing infrastructure is retained. As such, we recommend that the City consider the following:

- Require leases of complete conduit segments between major access points to avoid "orphaned" conduit that has little or no value;
- Require lessees to place their own handholes adjacent to City handholes for their own cable slack loops and splice enclosures, rather than placing these in City handholes;
- Require that lessees use City-approved contractors and/or require City oversight of any access to City conduit or handholes, both during initial cable installation and for repairs or maintenance; and
- Require lessees to pay for the installation of innerduct, or include cost recovery in the lease rate for the City to install innerduct, unless leasing an entire spare conduit. Pricing should be set so as not to discourage leasing spare capacity in shared conduits, taking into account that installation of innerduct makes more efficient use of conduit and increases the value of this City asset.

While not strictly required to facilitate conduit leasing, innerduct placed inside existing conduit helps to ensure the full capacity of the conduit can be maximized. Without innerduct, placing additional cables in a conduit with an existing cable can result in damage to one or both. Also, cables can get intertwined and create an obstruction to any further installations. As such, we recommend the use of innerduct, in particular MaxCell fabric innerduct (or something similar), designed to be placed in conduit with existing cable while occupying very little space itself. When installed simultaneously, multiple cables can be placed in a single conduit or innerduct.

With innerduct installed, a single 2-inch conduit can support a range of additional cable configurations, while still observing a maximum recommended fill ratio of 40-percent, for example: 1) one 288-strand cable and one 96-strand cable; 2) one 432-strand cable and one 12- or 24-strand drop cable; or 3) two 144-strand cables.

4.2.3 Fiber Swaps

In some cases, the City may consider exchanging the use of fiber infrastructure in order to obtain access to fiber routes that would otherwise be very difficult for the City to extend its network into. In our experience, the fiber swaps between two entities are often not, equivalent in value. When a City chooses to swap fiber segments, it is usually with other factors besides a cost comparison that influences its decision. Promoting economic development and creating a hospitable environment to broadband providers are often the basis of a City pursuing fiber exchange agreements.

4.2.4 Public-Private Partnerships

A public–private partnership with an entity that is willing to share some of the risk (and some of the reward) of a fiber deployment.

4.3 Service Framework and Pricing Recommendations

We offer the following considerations to serve as a guide for developing fiber and conduit lease pricing and a policy framework, tailored based on our knowledge of the City's operations and strategic objectives around promoting economic development.

The business case for the existing conduit and fiber infrastructure, both in terms of sunk construction costs and ongoing operating expenses, is substantiated on the basis of avoided leased network service costs that would otherwise be required to meet internal City requirements.

4.3.1 Dark Fiber Leasing

As with other markets having relatively high transaction costs and significant geographic variability, determining market-based pricing for fiber is a challenge. Even when comparative pricing is available in a given locality, it was likely developed on a cost basis for which the particular calculations are not available for review.

Particularly when incumbent providers are responding to competitive pressures associated with the announcement of a new competitor, minimizing time to market can be a significant priority for the new entrant. Timeframes associated with engineering, permitting, and construction can be detrimental to a provider's competitive advantage when introducing an innovative product, affording the incumbents substantial time to respond with customer incentives and product enhancements before the new competitor can establish required take-rates. Dark fiber leasing provides an easy path of entry to new routes.

Leases offer a mechanism to drastically reduce network implementation timeframes, which can increase the value of the lease significantly. Reduced time to market may increase initial take rates for the services offered by the provider, in the absence of a strong competitive response from incumbents.

4.3.1.1 Methods

Reasonable pricing models are wide-ranging and influenced by numerous factors. The "price ceiling" of leases is based on the cost of installing new fiber or conduit. The availability and price of dark fiber and conduit, is the second most significant price influencer. We have the price in the same market vary based on the criticality of route such as passing across a highway or offering connectivity to an internet data center.

The "price floor" corresponds to the incremental cost of maintaining the infrastructure and administering the leases (plus the incremental cost of preparing the fiber or conduit for leasing).

Cost recovery is a fundamental objective of lease pricing, at least in terms of establishing a minimum baseline, for which there are two main components:

- Capital costs – tend to be flat through the lease term, and typically are based on a principal and interest (P&I) calculation with no escalation; and
- Expenses - should be subject to a consumer price index (CPI) for long-term leases, and may warrant the creation of a reserve fund to cover costs of repairing damaged infrastructure, responding to a period of particularly high volume of utility locate ticket activity, and other variable expenses etc.

We caution that cost-based pricing for projects that serve multiple projects, departments, or enterprises is not a "black and white" matter, requiring allocations of capital costs and operating expenses based on assumptions that are subject to dispute. The FCC's formulas for calculating utility pole attachment rates is an example with many analogous attributes. These prescribed lease rates do not offer full recovery of the costs, and those that are not recovered are placed in the rate-base of the pole owner.

In general, with dark fiber lease pricing, instead of a one size fits all approach, it would be beneficial to lease high-demand or high-cost segments at a higher rate than segments, such as across a highway, with lower demand. In order to avoid isolated segments that have very limited value each quote request may need to be analyzed on a case-by case basis.

Ultimately, the City must balance its interest in encouraging economic development, such as through private investment in broadband infrastructure with the risk of setting a precedent for unreasonably high lease prices. Encouraging competition within the local broadband market may represent the most significant, and also the least quantifiable benefit of broadband infrastructure leasing. As such, it may be prudent to keep prices at a reasonable "market rate" to sufficiently reduce barriers of entry for competitive commercial providers.

4.3.1.2 Base Take Rate, Pricing Assumptions, and Scenarios

In the financial model we determined the dark fiber pricing by:

1. Determining the required capital investment required to provide the foundation to meet the City's objectives.

2. Estimating the financing requirements to cover the capital investment and cash flow shortages in the earlier years of the operation; we assumed this amount would be financed over a 20-year period
3. Determining the availability of strands by first removing from consideration the strands required for public use, public use expansion, and maintenance spares
4. Estimating the percentage of strands (strand miles) that will end up isolated as licensing and leases are executed
5. Estimating a range of take rates (percentage of strands leased)
6. Estimating the operating costs, including the debt service for the required capital investment
7. Determining what pricing is required to maintain a positive cash flow
8. Comparing the required pricing to the fees charged by other entities in the region
9. Estimating the percentage of leases required to maintain a positive cash flow that might be obtained with the known opportunities
10. Presenting the dark fiber lease pricing as a base price with an estimated discount. The idea is to use the base price as the initial offer price with the early opportunities. This will allow the City to move the price down as needed during initial negotiations.

The details and various scenarios are outlined in Section 4.5.

4.3.2 Conduit Leasing

We examined key pricing considerations specific to the City that should help to narrow the range of potential pricing models for consideration.

Depending on timeline pressures impacting a particular lessee, we can generally assume that the cost to construct and maintain new conduit bounds the upper limit for pricing of a given conduit lease over the lease term from the perspective of the lessee[15]. Thus, the City can reasonably expect to recover some of its construction costs, but the higher it sets conduit lease prices, the more likely prospective lessees are to resort to new construction of their own. Compared to more urban markets in which there are high costs associated with extensive surface restoration (sidewalk and roadway repair), overly crowded rights-of-way, and high labor rates, new conduit construction in Virginia Beach is relatively affordable.

[15] Comparison of costs is done by examining the net present value (NPV) of each of the options.

Whether or not the City leases conduit, many of the operating expenses related to its conduit are relatively fixed. Utility locate costs, for example, correspond to conduit route distance and are not impacted by the particular usage of the conduit. Depending on fault, repair costs are likely not influenced by whether or not conduit is leased.

The commercial network operators that do have fiber and conduit within the City, are not incentivized to facilitate the entrance of a new competitor into the market. Conduit leasing is a relatively low volume business compared to the retail voice, data, and video services this infrastructure supports, so we would not expect them to widely offer competing conduit leases now or in the future. The City could therefore effectively have a monopoly in the conduit leasing segment.

We now present specific pricing scenarios that we expect represent the full range of what the City may consider reasonable to achieve its objectives in light of the sometimes conflicting factors impacting pricing. These pricing scenarios take into account two primary models for recovery of sunk costs associated with the original conduit construction:

- ***Standalone* Replacement Cost Model** – represents the approximate cost to install a single new conduit, based on actual unit pricing obtained by the City during its original conduit installation, as well as estimated average per foot unit quantities; and

- ***Incremental* Cost Recovery Model –** represents the actual cost incurred by the City for the addition of a single incremental "spare" conduit.

These models differentiate the largest individual factor potentially impacting lease costs, given the wide range represented by the approximate cost to install a new conduit (about $16 per foot) and the comparatively low cost associated with adding an incremental conduit to new construction while in progress (about $1.75 per foot).

There also are variations on the scenarios in which maintenance costs are attributed to the lessee based on either: 1) the Full cost of maintenance along applicable conduit routes, or 2) Prorated maintenance cost based on the percentage of capacity leased along applicable conduit routes. Furthermore, certain models are differentiated based on the whether a full "Dedicated" spare conduit is leased or "Shared" conduit capacity is provided for a single cable of up to 0.85-inches in diameter. All pricing scenarios based on the "Shared" conduit lease model would include cost recovery for the installation of innerduct.

For segments containing only a single existing conduit, lease rates would be higher for applicable scenarios. In these cases, prorated maintenance costs are based on a larger total percentage of

the conduit capacity, with maintenance costs essentially the same regardless of the number of conduits in the path.

We recommend that all pricing scenarios include a onetime contract administration fee to cover legal and engineering consulting fees associated with contract negotiation, on a per lease agreement basis.

4.3.3 Leasing of Towers

In a carrier wireless network, cell towers have typically been connected (backhauled) to the wired telecommunications network through low-bandwidth circuits. As demand for mobile data access has grown, carriers are increasingly seeking fiber for backhaul—a trend that will continue to increase as carriers move toward fifth-generation (5G)[16] wireless technologies. The City may be able to construct relatively small extensions of its fiber routes to connect cellular sites (i.e., construct "fiber-to-the-tower," or FTTT), to provision backhaul from the cell sites to core network locations.

A national survey[17] of cell tower rental rates from 2011 showed that about half or two-thirds of recently signed new leases (not renewals) had rental rates ranging from $1,500 to $2,500 per month. In 2009, several cell site leases with the same carrier in the New York City metropolitan area varied from $1,500 per month to $3,000 per month. The difference in price had a lot to do with wireless ordinances and poor coverage in a critical area.[18] The numbers today will be higher.

Table 1 presents some examples of lease prices. We expect these leasing rates to range from $1,500 to $2,000 per month for the City.

[16] We anticipate that 5G rollouts will begin in the 2020 timeframe. It features greater capacity, smaller cells, and better traffic prioritization.

[17] http://www.varnumlaw.com/blogs/cell-phone-tower/what-is-the-rental-rate-for-a-cell-tower-lease/

[18] https://cellphonetowers.wordpress.com/2010/08/07/cell-tower-lease-rates/

Table 1: Tower Attachment Lease Pricing

Lessor	Lessee	Monthly Rent	Term (Years)	Year of Agreement/ Start Date
City of Port Angeles, WA	Cook Inlet Voice Stream	$750	5	2000
City of Las Vegas, NV	Nextel	$1,200	5	2005
City of Irvine, CA	Verizon	$3,000	25	2011
City of Avondale, AZ	Verizon	$1,500	5	2013
Intellicom Wireless Management	Walton County, FL	$1,850	10	2011
DeKalb County (IL) School District	T- Mobile	$1,400	5	2011
Fauquier County, VA	Blaze Broadband	Year 1: $100 Year 2: $500 Year 3: $750 Year 4: $1,000 Year 5: $1,200	5	2009

4.4 Investment Focus and Strategy

4.4.1 Focus Areas – Broadband Task Force Goals[19]

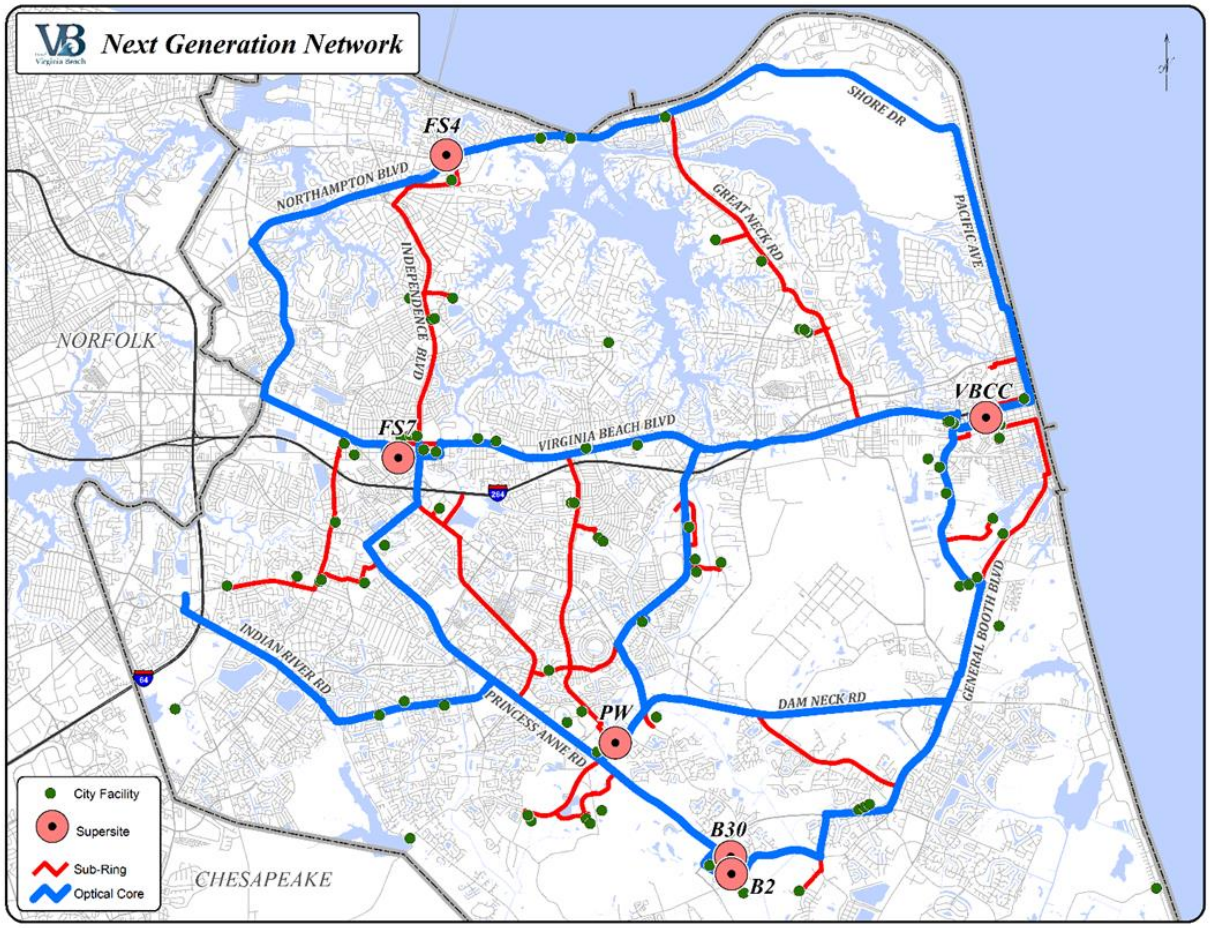
The City's Broadband Task force was developed to promptly explore the creation of a Virginia Beach and/or a Southside Regional Broadband Authority in order to leverage the Next Generation Network investments made by the City of Virginia Beach and the Virginia Beach City Public Schools (VBCPS). The City's Broadband Task Force developed the following five goals. The figures depict the proposed expansion of the City's fiber network to fulfill each goal.

1. **Build a Next Generation Network (NGN) that provided excellent City services**

By expanding the fiber network to connect an additional 75 off-campus locations to the municipal campus and create network redundancy. In addition, to leverage the NGN for additional benefits including economic development, educational and regional opportunities as stated in the other goals. Also, to use a "Dig Once" strategy for road and utility projects to include fiber and conduit.

[19] The material presented in this section was provided to CTC by the City; we include it here at the City's request.

Figure 15: Goal 1: Expanding City Services

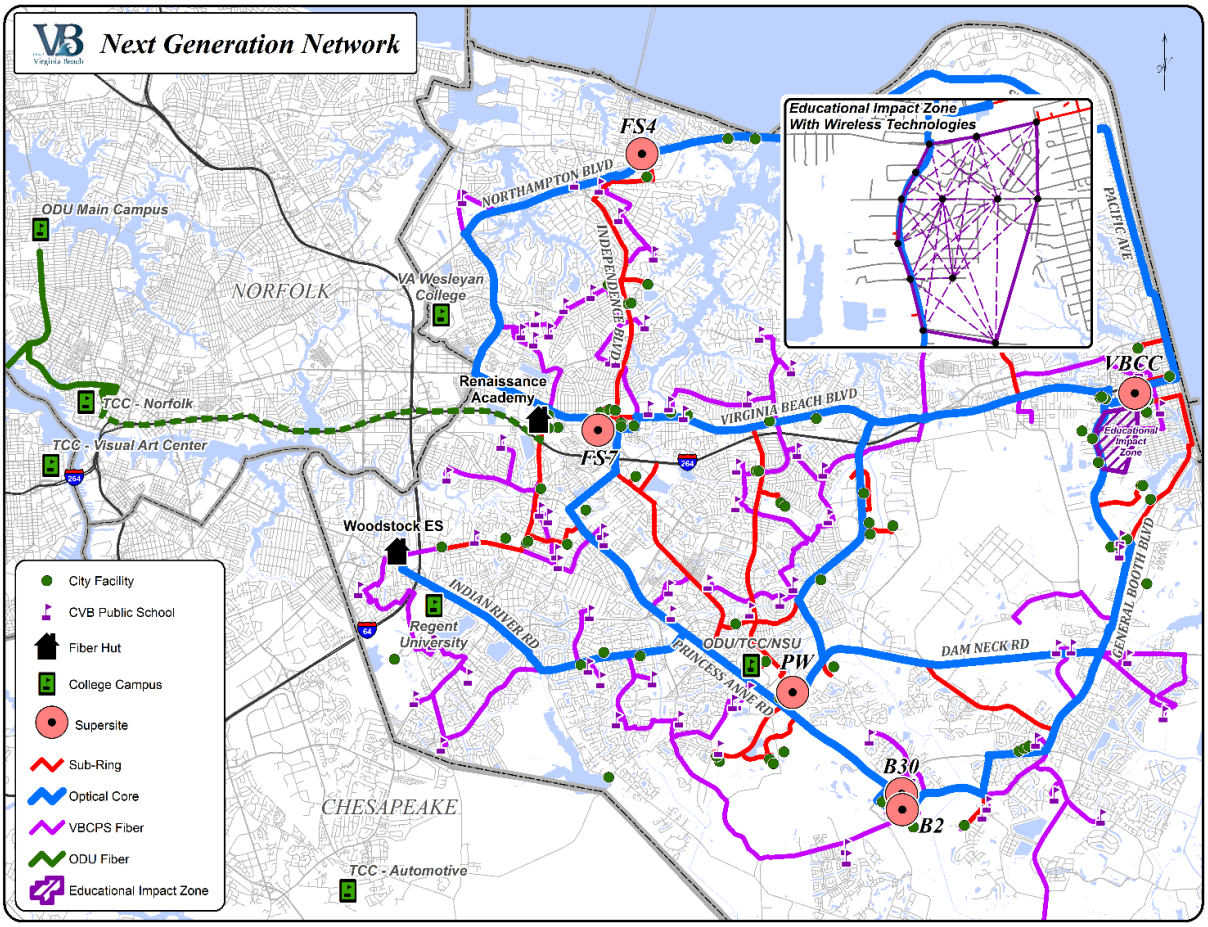


2. Leverage the NGN for educational opportunities and opportunities within the City

The objectives for this goal includes initiatives such as:

- Providing connectivity to higher educational institutions such as ODU, TCC, Norfolk State University, Virginia Wesleyan College, and the Regent University.
- Defining and connect Educational Impact Zones
- Utilizing wireless technologies
- Leveraging devices
- Providing computer training

Figure 16: Goal 2: NGN Educational Opportunities

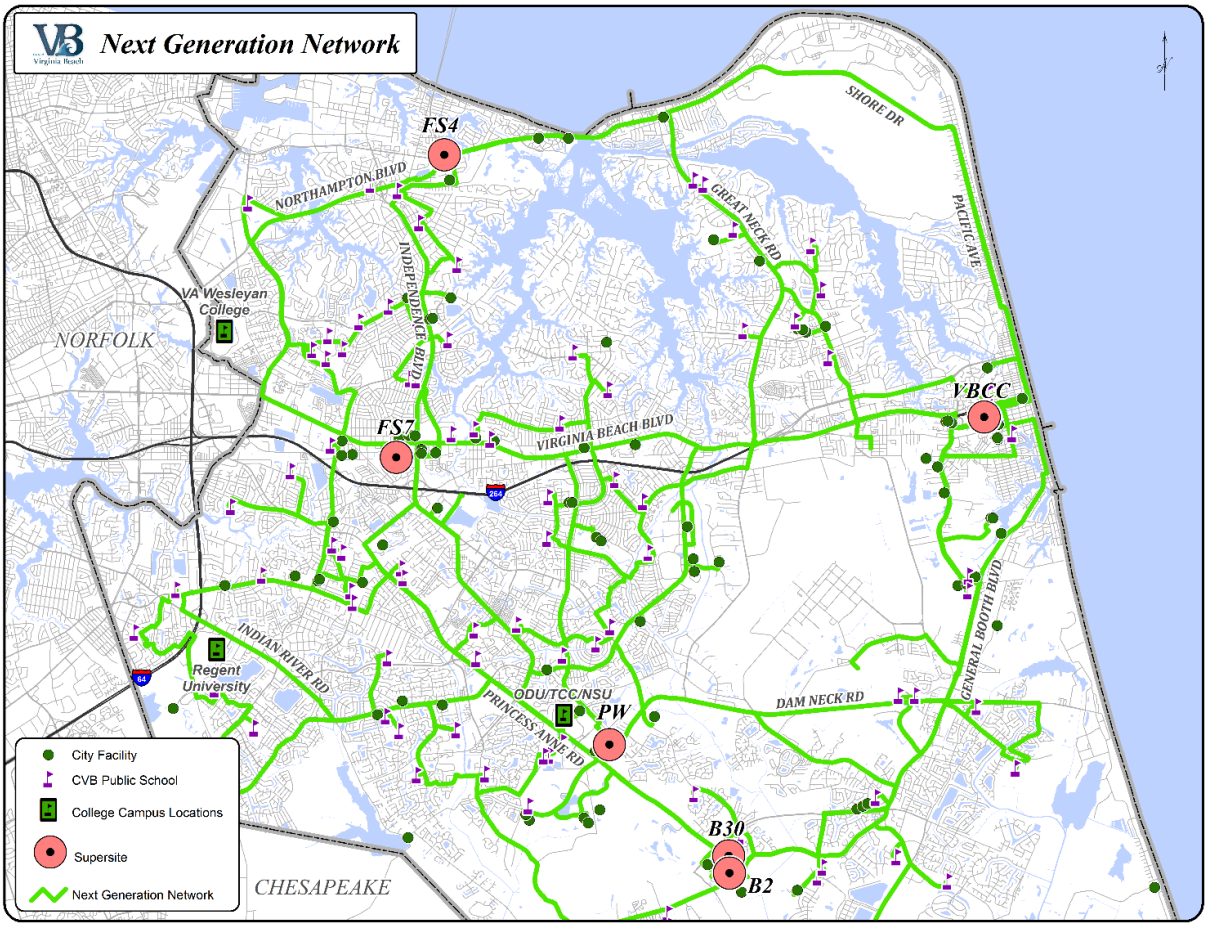


3. Explore opportunities to create a unified government network

Explore opportunities for City and VBCPS to share assets in order to create efficiencies, lower investment costs, and reduce total cost of ownership. These include opportunities to:

- Establish common architectures
- Establish a shared services model
- Establish a unified maintenance contract
- Collaboratively plan for future requirements and capacity needs

Figure 17: Goal 3: NGN Unified Government Network

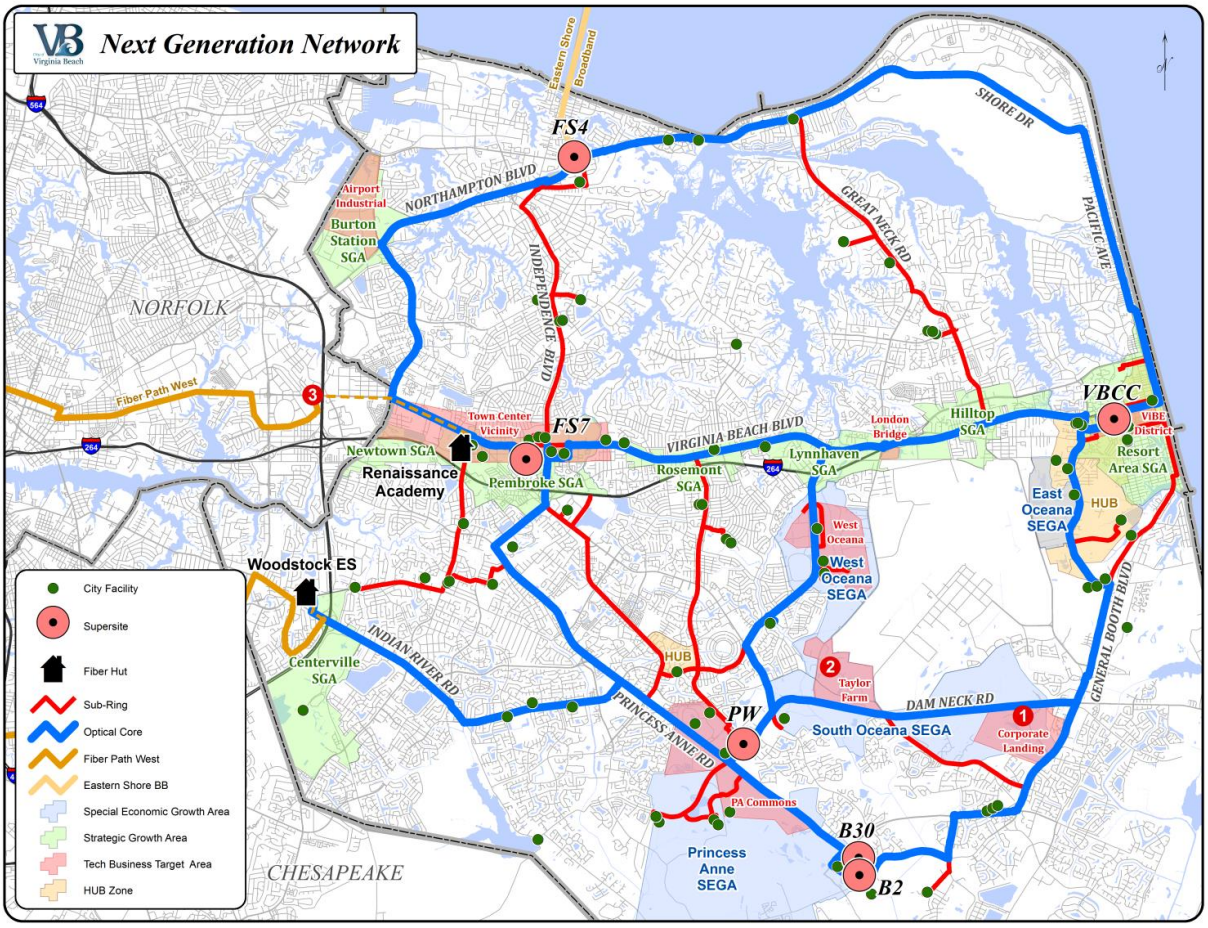


4. Leverage NGN for economic development opportunities

This goal aims to provide business entities who locate within Strategic Growth Areas (SGAs), Special Economic Growth Areas (SEGAs), and Technology Business Target Areas the opportunity to obtain fiber connectivity. The objectives of this goal include:

- Making all the areas mentioned fiber ready with direct access to dark fiber and establishing connection points close to borders of neighboring jurisdictions
- Developing a business plan and financial model for middle mile services
- Leasing conduit and fiber to business entities locating within areas listed above
- Developing trans-oceanic onboarding service delivery plan and long-term lease agreement with Camp Pendleton
- Partnering to provide middle mile services
- Strengthening local service providers by offering a middle mile that they could be leveraged to serve new customers

Figure 18: Goal 4: NGN Economic Development Opportunities

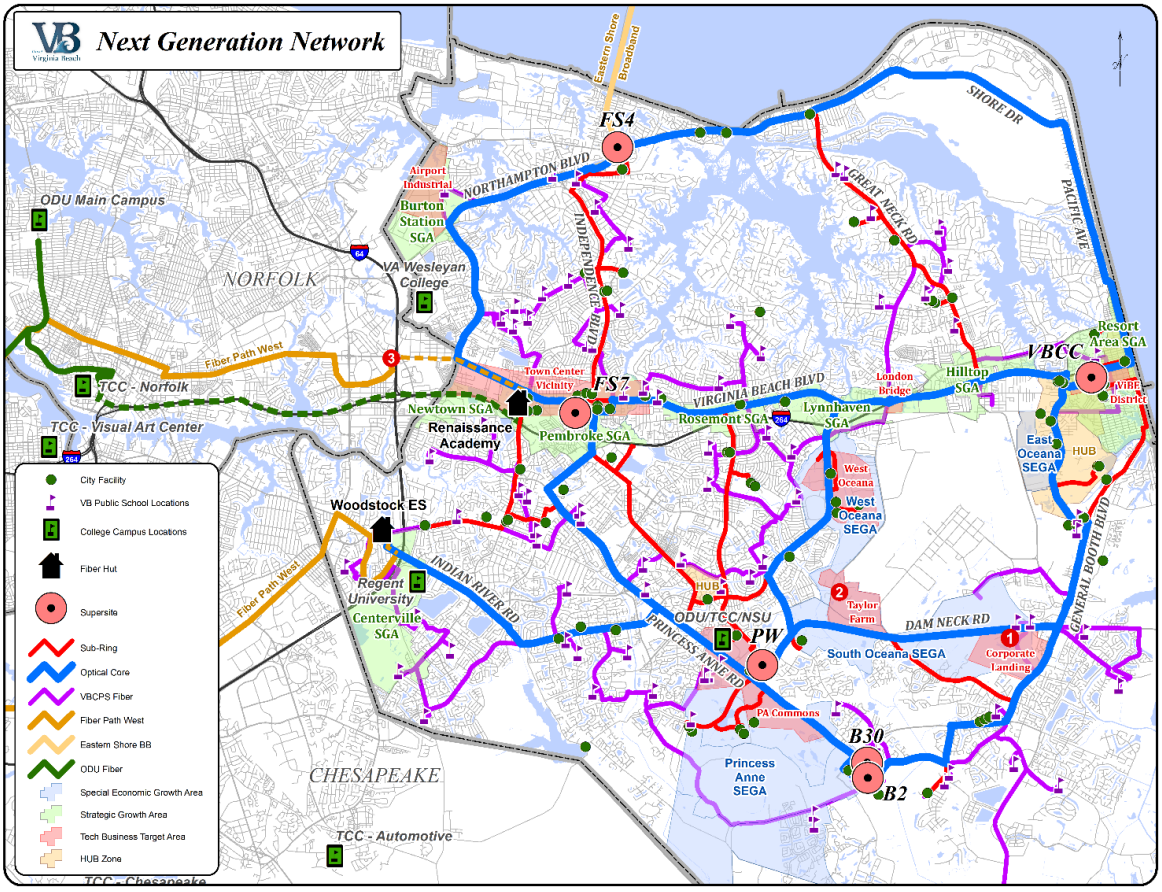


5. **Leverage NGN for regional opportunities such as offering connectivity to adjacent jurisdictions and broadband authorities**

This goal would aim to:

- Establish connection points via huts or junction boxes
- Engage neighboring cities to explore ways to connect such as through self-funding, federal grants or provider incentives
- Consider international opportunities and trans-oceanic fiber
- Build and scale aggregation sites to transport data and create cost savings
- Commit to partnering with other cities to share lessons learned, architecture, business and financial plans, etc.

Figure 19: NGN Regional Opportunities



4.4.1.1 Digital Divide and Digital Literacy

The Digital Divide i.e. the gap between the haves and have-nots in access to broadband technology and Digital Literacy i.e., knowledge or skills to use digital information are two areas commonly targeted for improvement as part of a municipality's broadband strategy. Improving connectivity to libraries can play a significant role in achieving this.

4.4.1.1.1 Digital Divide

In its 2015 Broadband Progress Report, the FCC found that broadband deployment in the United States—especially in rural areas—is failing to keep pace with today's advanced, high-quality voice, data, graphics, and video offerings. Using its updated broadband benchmark,[20] the FCC found that 55 million Americans—17 percent of the population—lack access to advanced

[20] On January 29, 2015, the FCC voted to update its broadband benchmark speeds to 25 megabits per second (Mbps) downloads and 3 Mbps for uploads in order to reflect advances in technology, market offerings by broadband providers, and consumer demand. The FCC found that the 4 Mbps/1 Mbps previous standard set in 2010 was outdated and inadequate. These benchmarks are used to evaluate whether advanced broadband is being deployed to all Americans in a timely way.

broadband. Moreover, a significant digital divide remains between urban and rural America: over half of all rural Americans (22 million people) lack access to 25 Mbps/3 Mbps service.[21]

The digital divide can be defined as an economic and social inequality according to categories of persons in a given population in their access to, use of, or knowledge of information and communication technologies. The divide may refer to inequalities between individuals, households, businesses, or geographic areas, usually at different socioeconomic levels or other demographic categories.

One of the major causes for this gap is the lack of investment by incumbent service providers in certain areas. Private companies are required by law to put the interests of their shareholders first. Because up-front costs for infrastructure are high, building out or upgrading a network may not always be profitable. When that's the case, the providers tend to focus their investments in more profitable areas. The areas they view as unprofitable include low-density areas (especially rural areas) and disadvantaged areas, where the demand for high-speed internet may be lower than in more affluent places.

The lack of broadband impacts communities in a number of ways. Businesses have trouble competing when they are forced to pay more than their competitors for slower services. Innovation is stifled when a company cannot experiment with new types of services, such as monitoring production from a remote location, or speeding the transmittal of health records. Schools cannot use the latest teaching tools, like e-learning or video. And consumers not only face fewer choices and higher costs but also have a harder time obtaining adequate healthcare or searching for jobs.

According to the FCC, "Based on the most recent data received by the Commission, it appears that 31% of urban public schools and 41% of rural public schools do not have access to fiber facilities."[22] The FCC E-rate report also cites finds from a LEAD Commission/Alliance for Excellent Education (LEAD/AEE) report. "According to the LEAD/AEE report low-income, African American, Latino, and rural students are more likely than others to be in schools with slow internet connectivity."[23]

According to ICF International, "Because of their remote locations, rural schools stand to benefit enormously from the capabilities of broadband technology, but many rural facilities and institutions remain underserved or unserved by broadband providers."[24]

[21] "FCC Finds U.S. Broadband Deployment Not Keeping Pace," FCC news release, January 29, 2015.
[22] "E-rate Data Update," *FCC*, November 17, 2014.
[23] Ibid.
[24] "Broadband and Rural Education," *academia.edu*, June 2012.

As time has passed and progress has been made, however, the digital divide definition and perspective for broadband implementation have changed. Previously, the digital divide was viewed only from the perspective that residents in underserved areas required access to broadband to function in their daily lives. Today, with broadband available to more individuals, the view is transitioning to include the need for businesses to have affordable broadband at higher speeds in order to compete, innovate, and create jobs. In this regard, high-speed broadband also needs to be affordable to residents.

The Virginia Beach Public Library (VBPL) uses the definition of the Digital Divide as provided by the Institute of Museum and Library Services' (IMLS) in its report, Toward Equality of Access: "disparities in technology usage, resulting from a lack of access, skills, or interest in using technology," and note that while internet access has grown, "…traditionally disadvantaged groups—including African Americans, Hispanics, Native Americans, and those with lower income and education levels—continue to be less likely than other segments of the population to have the access and skills to effectively use computers and the internet." VBPL currently offers free access to computers and the internet, including free Wi-Fi. They are in the process of providing laptops for customers to use in-house at targeted library locations. In this regard, the City's network can play an important role in improving library connectivity.

4.4.1.1.2 Digital Literacy

The American Library Association (ALA) Digital Literacy Taskforce defines Digital Literacy as: "the ability to use information and communication technologies to find, evaluate, create, and communicate information, requiring both cognitive and technical skills.[25] Based on this, the VBPL's new Strategic Plan expands the concept of digital literacy to include 21st Century skills as defined in the IMLS report, Museums, Libraries, and 21st Century Skills. Skills such as critical thinking, problem-solving, collaboration, and self-directed learning are components staff are integrating into the learning outcomes for our programs and classes in addition to specific technology-related or subject-related skills and/or knowledge.

VBPL's Youth and Family Services division has developed a successful partnership with 13 of the City's Title I schools to offer summer reading programs to prevent "summer slide" and improve students' basic literacy skills.[26] Over the last year, the staff has worked to develop a continuum of standardized adult classes that provide customers with opportunities to gain skills in using computers, the internet, and Microsoft Office applications. One of VBPL's goals is to also build upon these core classes into other areas including coding concepts and skills via age-appropriate

[25] http://connect.ala.org/node/181197#sthash.kjBtKjwK.dpuf, accessed June 2016
[26] http://www.urbanlibraries.org/summer-slide--a-partnership-with-title-i-schools-innovation-1086.php?page_id=428, accessed June 2016

classes. Some of these classes are now being piloted at an off-site location (in the Bayside Library service area) and VBPL has further off-site expansion plans.

The NGN can play a pivotal role to address the Digital Divide and in improving Digital Literacy. In doing so, the City can also leverage funding opportunities such as E-Rate.

4.4.2 Investment Strategies

There are four key areas in which the City may wish to strategically invest, including the network backbone, support for wireless infrastructure, a "Dig Once" policy, and new network infrastructure construction.

4.4.2.1 Network Backbone

Taken together, the approaches described here would result in the City having either 96 or 144 strands in all route segments. This would allow the City to undertake more fiber leasing on a strategic basis, such as to meet carriers' requests, to support small cell deployments, and to meet some economic development opportunities.

4.4.2.1.1 Long Haul Strategy

The City is in the process of leveraging its existing fiber and expanding the network to connect 79 City facilities that are not located on one of the City's main campuses. The expanded Next Generation Network (NGN) will provide the City with a state-of-the-art fiber and network electronics platform that will greatly improve the City's ability to provide IT services to its departments.

The City has already used the existing fiber optic network to construct the backbone of the network, called Phase 0. The City is currently connecting City facilities to the NGN using existing fiber and by constructing additional fiber segments, which create subrings of the Phase 0 backbone. This expansion is called Phase 1 of the NGN. The current construction strategy is to construct 144-count fiber optic cables where new construction is needed—leveraging the City's existing conduit containing copper wiring ("copper conduit") to the greatest extent possible (see Section 3.2.1).

With the Phase 1 design, which will cost an estimated $3.5 million, the City will be able to meet its core connectivity goals, but will have limited fiber for leases. Some segments along the fiber optic network will have only 24 strands total—and the majority of those strands will need to be reserved for either current City use or future City/public growth. On a case-by-case basis, the City may be able to look at some dark fiber leases for business customers, but leasing to a carrier will be difficult because of the City's overall lack of fiber capacity in these 24 fiber strand segments.

The City's ability to lease conduit is even more restrained. The City has a single three-inch conduit, with no inner-duct; once an additional cable is pulled, no further cables are likely to fit unless a

given segment is completely replaced. We do not recommend that the City consider leasing conduit except maybe on a case-by-case basis.

4.4.2.1.2 Candidates for Outer Rings

We recommend that the City change its proposed expansion plan, and run new subring fiber back to the hubs. This approach would increase the project cost by $1.7 million but would expand many segments to 96 or 144 strands and ensure that every new strand of fiber built can be used for City/public needs or leasing. This will help enable some strategic fiber leases, though we note that the City's capacity for leasing will still be limited when compared to some greenfield builds; Arlington County, Virginia, for example, has 864-strand fiber dedicated for leasing plus extra conduits on each route.

We also recommend that the City extend fiber to selected higher-education sites, which would increase the project cost by $800,000. The City could then provide network services to the higher education community over NGN. There may also be benefits to interconnecting higher education for joint educational and research ventures.

Similar benefits may be achieved by connecting VCBPS facilities to the NGN. Since VCBPS has its own fiber optic network, the cost of connecting their fiber network to NGN is unknown at this time. We recommend that the NGN team explore with VCBPS opportunities to link the schools to NGN.

The fiber optic network passes the City's areas that have been designated for economic development initiatives. We recommend that the NGN team work with the City's Economic Development department to identify ways that the fiber optic network can benefit economic development initiatives. One possible benefit would be providing middle mile fiber optic backhaul to an ISP wanting to server businesses in the economic development areas.

4.4.2.1.3 Enhance Strand Counts

Once the fiber network has met its short-term goals, the City should invest in enhancing the network to increase reliability and capacity. These enhancements include:

- Overbuilding the existing fiber optic network where only 24-count fiber is available;
- Converting important laterals into subrings to increase reliability of the network;
- Identify any single points of failure and remediate by constructing redundant paths;
- Provide diverse redundant paths to key locations; and
- Expand the network along key routes to support additional sites and potential demand for services.

The enhancements will increase fiber count along the routes, which maximizes the number of fiber strands that are available for the City's use as well as for offering dark fiber services to businesses in the City.

Upgrading the remaining 24-strand segments (pull cable) to either 96- or 144-strand count would add an additional $314,000 to the project.

4.4.2.1.4 Routes to Corporate Landing Park

The City could also construct two diverse routes to the edge of the City (Woodstock Elementary and Renaissance Academy from Corporate Landing) for an additional $400,000. This fiber network can provide interconnectivity with other fiber providers and governmental entities outside of the City. The routes will also allow users of the NGN to access Corporate Landing for telecommunication services such as server hosting and internet access. See Section 3.2.5 for more details.

4.4.2.1.5 Future Builds

With the increased interest in private sector entities installing conduit and fiber from Corporate Landing to locations outside Virginia Beach, the City can look for co-build, joint trenching, and other activities in the City. One of the first steps in leveraging this opportunity is the development and implementation of a Dig Once policy (see Section 4.4.2.3).

As the network footprint expands there may be opportunities to connect additional City facilities or serve other future needs and customers that cannot be cost-effectively served with the network as currently envisioned.

4.4.2.2 Wireless

Currently the wireless service providers are installing their own proprietary (non-sharable) small cells[27] and distributed antenna systems[28] (DAS). Under this situation each carrier needs its own fiber optics, power sources, and antenna mounting structures. This often results in carriers using different utility or light poles or hanging multiple sets of duplicate hardware on the same pole to serve their own customers. As an alternative one could install a carrier neutral DAS or carrier neutral small-cell that provides service to multiple wireless service providers.

One of the key questions that needs consideration is what strand counts are required for either DAS or small cell technologies. It is important to note that some solutions require more fiber than others.

[27] Low-power radio access nodes that operate in licensed and unlicensed spectrum

[28] Group of geographically separated antenna nodes connected by fiber to a common source. Used to provide wireless service within a geographic area or structure

Assuming a 500-foot spacing for DAS or small cells along the three-mile stretch of beachfront, a DAS solution would require 32 antenna locations. DAS system operators often allocate six-strands of dark fiber per location, which could not be supported with the City's existing fiber strand. However, some systems allow the reuse of strands of fiber by daisy chaining multiple antenna locations on the same fibers. For instance, if six strands could be reused three times, then you could reach 18 antennas. In this case 12 strands of fiber would be required to support the 32 antenna locations. Other solutions for carrier neutral small-cell providers require a single strand for each antenna location. In this case 32 strands are required to serve the beachfront.

These above fiber counts do not include City allowance to use sites for other technologies (Wi-Fi, security cameras, etc.). With the combination of City needs and to support a carrier neutral DAS or small cell installation, 96 strands of fiber will erode quickly.

One approach is for the City to offer the location hanging rights on City-owned light and traffic poles, and available fiber in exchange for recurring lease payments, revenue sharing, or a combination – if the operator can use the City's assets to defray the costs of building a carrier neutral DAS or small cell installation.

Then the key would be to focus on the objectives of the system in an RFI or RFP to include but not limited to:

- A carrier neutral host, supporting 3G and 4G wireless technologies
- Minimum number of acceptable carriers on the system and time limits on reaching agreements with the carriers to use the system
- Wireless coverage
- City usage of the sites for the deployment of sensors, Wi-Fi, and other City technology
- Aesthetic concerns /stealthing of DAS systems to minimize their visual impact on the beachfront
- Length of contract
- Powering
- Use of City fiber or fiber sharing agreement if additional fiber construction is required
- Options for compensating the City

Prior to that release of the RFI a more detailed analysis of fiber requirements and performance needs for the DAS or small cell is required.

4.4.2.3 Dig Once Policy

A number of cities and counties across the country have developed and implemented dig once policies. The primary motivation for municipalities has been to preserve the ROW and improve the telecommunication competition in the market. A Dig Once approach can also reduce the impact on rights-of-way and inconvenience to the public.

Utilizing a "Dig Once" policy is part of the Broadband Task Force's goals. The City may consider modifying its right-of-way ordinance to provide the City with the option of obtaining conduit on routes where excavation is being performed. In this sort of "Dig Once" environment, the City can reduce the cost of the conduit by 25 percent to 75 percent relative to the cost of a standalone construction project if it installs or has conduit installed in coordination with other excavation. We recommend that the ordinance include all excavators, though we have found that transit projects are usually the most successful because transit projects are long and continuous and there are many ways to place the conduit with minimal incremental cost to the project. Typically, routes along freeways or continuous long routes, or routes across freeways or waterways, are of high value to telecommunications providers.

4.4.2.3.1 Cost Share

The construction of fiber optic communications cables is a costly, complex, and time-consuming process. The high cost of construction creates a barrier to entry for potential broadband communications providers.

While aerial construction methods requiring attachments to utility poles is generally less expensive that underground construction, aerial installation has significant drawbacks—including a limit to the quantity of cables and attachments that can be placed on existing utility poles in more crowded areas, and greater exposure to outside conditions.

Underground construction using protective conduit generally provides scalable, flexible, and durable long-term communications infrastructure, but is also typically more expensive than aerial construction. Further, from the City's perspective, cutting roads and sidewalks substantially reduces the lifetime and performance of those surfaces. And each excavation diminishes the space available for future infrastructure.

Accordingly, encouraging or requiring simultaneous underground construction and co-location of broadband infrastructure in the PROW creates benefits for both the City and private sector communications providers.

Dig once policies reduce the long-term cost of building communications facilities by capitalizing on significant economies of scale through:

1. Coordination of fiber and conduit construction with utility construction and other disruptive activities in the PROW.

2. Construction of spare conduit capacity where multiple service providers or entities may require infrastructure.

These economies exist primarily because fiber optic cables and conduit are relatively inexpensive, often contributing to less than one-quarter of the total cost of new construction. While material costs typically fall well below $40,000 per mile (even for large cables containing hundreds of fiber strands), labor, permitting, and engineering costs commonly drive the total price toward $200,000 per mile if conducted as a standalone project.

To put the cost savings in perspective, consider two examples. If fiber construction is coordinated with a major road or utility project that is already disrupting the PROW in a rural area, the cost of constructing the fiber, communications conduit, and other materials can be as low as $10,000 per mile. However, if fiber construction is completed as part of a separate standalone project, the cost of constructing fiber and communications conduit typically range from $95,000 to $200,000 per mile, and even higher in complex urban environments.

Another motivation for coordinating construction is to take the opportunity to build multiple conduit in a closely packed bank. Banks of conduit constructed simultaneously allow a single excavation to place several conduit in the physical space usually used by one or two. Conversely, multiple conduit installed at different times must be physically spaced, often by several feet, to prevent damage to one while installing the next. Once the PROW becomes crowded, the choices of construction methods are reduced, leaving only less desirable methods and more-costly locations for construction of additional infrastructure.

The key benefits achieved through coordinated construction efforts include reduced:

- Labor and material costs, through reduced crew mobilization expenses and larger bulk material purchases

- Trenching or boring costs when coordination enables lower-cost methods (e.g., trenching as opposed to boring) or allows multiple entities to share a common trench or bore for their independent purposes

- Traffic control and safety personnel costs, particularly when constructing along roadways that require lane closures

- Engineering and survey costs associated with locating existing utilities and specifying the placement of new facilities

- Engineering and survey costs associated with environmental impact studies and approvals
- Lease fees for access to private easements, such as those owned by electric utilities
- Railroad crossing permit fees and engineering
- Restoration to the PROW or roadway, particularly in conjunction with roadway improvements
- Bridge crossing permit fees and engineering

We surveyed approaches adopted or proposed by other jurisdictions across the country. In many cases, the incremental costs of construction are borne by the jurisdiction. Many policies also provide exceptions or forego the excess conduit construction if the cost-benefit analysis is not reasonable.

Based on our experience with best practices, we identified three general approaches to dig once policies. Some cities require an excavator applying for a permit in the PROW to notify utilities and other relevant entities about the project and invite their participation. Localities with a "shadow conduit" installation policy require the excavator to install excess conduit for future use; depending on the policy, the excavator or the jurisdiction may then lease that excess capacity. Other localities, undertake a longer-term process, coordinating multi-year plans with excavators.

We recommend that a City take the following steps when creating a Dig Once ordinance:

- Prioritize projects suitable for additional construction based on a scoring mechanism
- Develop a refined estimate of the incremental costs during the design stage
- Develop a standard engineering specification for dig-once conduit
- Develop a procedure to systematically track and manage the construction and to create a repository of existing infrastructure

4.4.2.3.2 Public Utility Investment

When public utility related construction occurs within or along the ROW, such as road construction or resurfacing, roadway widening, sidewalk repairs, bridge construction, and water or gas main installation, there is an opportunity to place telecommunications infrastructure at an overall reduced cost and with reduced disruption to public ROW.

4.4.2.4 New Construction

Outside plant (OSP) is the most difficult-to-build component of an information technology and communications system. Extra care must be taken to meet safety, manufacturer, and industry standards to create a reliable, long-lasting network. In addition, risks associated with drilling underground require careful planning and construction to limit damage to other underground facilities. But proper planning, engineering, and construction will enable future network growth and long-term reliability. Appendix H provides specifications for OSP infrastructure for the City; the following sections offer brief descriptions of recommended specifications for two key elements of OSP construction—fiber count and handhole placement.

4.4.2.4.1 Fiber Count

In greenfield scenarios and other new buildouts, the City should install backbone fiber that is 144-count fiber or greater. This fiber count will ensure that in most reasonable circumstances, the City will have sufficient fiber capacity to not only meets its foreseeable future needs, but also to lease dark fiber for economic development or other purposes.

All OSP cable shall conform to international standards ITU-T G.652.D and Telcordia GR-20. Cables will be made of all-dielectric materials. Cables shall be a gel-free cable design with dry water blocking agents. Cables shall be marked in permanent white characters with the manufacturer's name, month/year of manufacture, number of fibers, and sequential length markings at a minimum of every two feet.

All new underground plant shall be placed at a minimum depth of 36 inches or other depth as directed by the engineering plans. All new conduits shall be equipped with a pull line. When the new fiber optic cable is placed a locating wire shall be pulled in at the same time.

4.4.2.4.2 Handholes

New handholes shall typically be installed at 500- to 700-foot increments. Each handhole will be equipped with a ground rod and the locating wire will be bonded to the ground rod.

One-hundred-foot coils of slack fiber shall be stored in vaults at intervals not to exceed 1,200 feet and at any location where future splicing may be required. Future splice locations shall be determined by the engineer in conjunction with the City. Conduit shall typically be 3-inch HDPE for cable in the public right-of-way and 2-inch HDPE for conduit from the street to the building or as directed by the City.

The handhole box shall be installed level with the grade elevation. All penetrations through existing handholes shall be through manufacturer-supplied knock-out(s) or corebored. Manual jack hammering or rotary drilling shall not be acceptable. Handholes shall be UL Listed to ANSI

77-2010. The standard handhole size is 17"(W) x 30" (L) x 30" (D). The large size is 24" (W) x 36" (L) x 36" (D) unless otherwise dictated on the engineering plans.

4.5 Financial Statements

In the financial model we determined the dark fiber pricing by:

1. Determining the required capital investment required to provide the foundation to meet the City's objectives.
2. Estimating the financing requirements to cover the capital investment and cash flow shortages in the earlier years of the operation; we assumed this amount would be financed over a 20-year period
3. Determining the availability of strands by first removing from consideration the strands required for public use, public use expansion, and maintenance spares
4. Estimating the percentage of strands (strand miles) that will end up isolated as licensing and leases are executed
5. Estimating a range of take rates (percentage of strands leased)
6. Estimating the operating costs, including the debt service for the required capital investment
7. Determining what pricing is required to maintain a positive cash flow
8. Comparing the required pricing to the fees charged by other entities in the region
9. Estimating the percentage of leases required to maintain a positive cash flow that might be obtained with the known opportunities
10. Presenting the dark fiber lease pricing as a base price with an estimated discount. The idea is to use the base price as the initial offer price with the early opportunities. This will allow the City to move the price down as needed during initial negotiations.

The financial model also assumes that the fiber operation is treated as an enterprise. The City may choose to operate the business as an enterprise, or have it under the IT budget. In either case we recommend that accounting is set-up to view the operation as a stand-alone entity that is charged for personnel allocations, but credited with services delivered to other departments.

The financial model does not account for costs avoided or reduced by leveraging the network. It also does not include costs for electronics or the Phase 0 fiber implementation.

4.5.1 Financing and Funding Mechanisms

For the financial model we assume that the City's financing is through a loan rather than a bond; therefore, no debt service or interest reserve is used. We assume the loan is issued at 6 percent over a 20-year period. We further assume that the principal and interest payments start in year two.

To cover the initial capital investment we estimated that the City requires a $9.2 million loan. To reduce the loan amount we have seen some public entities defer principal and interest payments in the early years of operation (e.g., to after year five or six) to improve initial cash flow.

4.5.2 City of Virginia Beach Six-Year CIP (FY18-FY24)

The time to implement the fiber additions is a balance of available budgets to the time the City could start realizing the overall benefits. To realize the benefits of avoided costs for existing services and create opportunities for leasing fiber, the majority of the $6.7 million construction needs completion. Spreading these costs over a six-year period would greatly reduce the opportunities internally and externally. For the model we assumed 75 percent of the construction is completed in year one and the remaining 25 percent in year two.

4.5.2.1 Cost Estimates

The estimated cost is $6.7 million. The costs include:

- Phase 1: $3.5 million
- Phase 1 upgrades: $1.7 million
- Higher education connections: $800,000
- Diverse routes to edge of City: $400,000
- Upgrade of segments to at least 96 strands: $314,000

Upon completion of above, we estimate the City will operate and maintain 170 miles of underground fiber located in conduit.

4.5.2.2 Operating and Maintenance Expenses

The estimated operating costs include:

- Insurance: $50,000 per year
- Locates and ticket processing: $153,000 per year (based on $3,750 per month for every 50 miles of underground plant)
- Maintenance support: $292,400 per year (based on Cox's existing contract for 150 miles, adjusted for 170 miles)

4.5.2.3 Staffing Expenses

The estimated staffing costs (allocated) include:

- Recordkeeping (allocation for GIS, strand maps, etc.): $100,000 per year
- Support (allocation for Human Resources, Finance, Legal, Administration): $100,000 per year
- Program Management (allocation): $100,000 per year

4.5.3 Revenue Reinvestments

We did not include specific revenue reinvestment. We do, however, recommend that the City consider funding system expansion with any excess cash flow. These expansions will be needed for ongoing economic development and educational opportunities as indicated above.

4.5.4 Revenue Projections

To estimate potential revenues, we first examined the availability of fiber and allocations to dark fiber leases. To start we assume that at least 96 strands are available in any given fiber segment. Of the 96 strands we allocate 24 strands to existing uses, 12 strands for future uses, and 12 strands for maintenance spares.

The above approach results in 48 strands available for lease. Of these we allocate 12 strands for maintenance spares—resulting in 36 strands available for lease. Over the 180 miles, this results in the availability of 6,120 strand-miles of fiber available for lease.

We further estimate that 50 percent of the strand miles will become "isolated" as leases are issued. This results in a net of 3,060 available strand miles of fiber.

We then assume that we will obtain leases for 25 percent of the available strand miles over the first four years of operation.

We then set a lease price that, when discounted by 30 percent, will provide a positive cash flow after expenses and debt service.

The resulting dark fiber price is $280 per strand mile per month. This pricing is in the general range of dark fiber pricing in the region; when discounted by 30 percent (e.g., as the result of negotiations with customers), it equates to $196 per strand mile per month.

The resulting cash flow for the first 10 years is shown in the following table.[29]

[29] Please note that we used a "flat-model" in the analysis. In a "flat-model," inflation and operating cost increases (including salaries) are not used in the analysis because it is assumed that operating cost increases will be offset by increases in lease payments over time.

Table 2: Estimated Cash Flow (Preliminary Financial Model)

Expenses	Year									
	1	2	3	4	5	6	7	8	9	10
Financing Issuance Cost	$ 192,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Annual P&I Payment	-	802,000	802,000	802,000	802,000	802,000	802,000	802,000	802,000	802,000
Insurance	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Locates and Ticket Processing	153,000	153,000	153,000	153,000	153,000	153,000	153,000	153,000	153,000	153,000
Pole Attachments	-	-	-	-	-	-	-	-	-	-
General Maintenance	-	-	-	-	-	-	-	-	-	-
Record Keeping (GIS, strand maps, etc.)	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
Support Allocations (HR, Finance, Legal, Admin)	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
Program Management	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
Cox Maintenance & Support	292,400	292,400	292,400	292,400	292,400	292,400	292,400	292,400	292,400	292,400
Construction	5,035,500	1,678,500	-	-	-	-	-	-	-	-
Total	$ 5,922,900	$ 3,275,900	$ 1,597,400	$ 1,597,400	$ 1,597,400	$ 1,597,400	$ 1,597,400	$ 1,597,400	$ 1,597,400	$ 1,597,400

Revenues & Financing	Year									
	1	2	3	4	5	6	7	8	9	10
Monthly Leases	$ 72,000	$ 432,000	$ 1,152,000	$ 1,619,000	$ 1,799,000	$ 1,799,000	$ 1,799,000	$ 1,799,000	$ 1,799,000	$ 1,799,000
IRU One Time Payment	-	-	-	-	-	-	-	-	-	-
IRU Maintenance Fee	-	-	-	-	-	-	-	-	-	-
Funds From Loan	9,198,000	-	-	-	-	-	-	-	-	-
Total	$ 9,270,000	$ 432,000	$ 1,152,000	$ 1,619,000	$ 1,799,000	$ 1,799,000	$ 1,799,000	$ 1,799,000	$ 1,799,000	$ 1,799,000
Net Cash Flow	$ 3,347,100	$ (2,843,900)	$ (445,400)	$ 21,600	$ 201,600	$ 201,600	$ 201,600	$ 201,600	$ 201,600	$ 201,600
Accumulated Cash	$ 3,347,100	$ 503,200	$ 57,800	$ 79,400	$ 281,000	$ 482,600	$ 684,200	$ 885,800	$ 1,087,400	$ 1,289,000
NPV 10-Year Rate at 6.5 percent discount rate	$ 1,055,000									

5 Recommendations

As we have described above, the Virginia Beach IT department has done an exemplary job in aggregating fiber and conduit assets from City departments and other resources; together, this infrastructure enable the City to meet many of its overall broadband goals—but given the limited availability of fiber and conduit, and the cost of expansion, the City must treat its infrastructure as scare resources and be strategic in managing their future use.

In that light, we make the following recommendations:

1. **Continue to build out network as planned**

With the Phase 0 design and the Phase 1 expansion (which will cost an estimated $3.5 million including service drops), the City will be able to meet its core connectivity goals but will have limited fiber for leases. Where segments only have 24 strands total—the majority of those strands will need to be reserved for either current City use or future City/public growth.

2. **Create pricing that is competitive but treats fiber asset as a scarce resource**

Consider an initial lease price of $280 per strand mile per month. This rate would allow full recovery of the City's investment, including operational costs, with a modest number of fiber leases. And, while this initial price is competitive given the City's market conditions, it also offers room for reasonable negotiation with customers. If the City were to negotiate a lease of 20 strands over 17 route miles at a price discounted by 30 percent (net of $196 per strand mile per month), it would have 44 percent of the lease volume required to breakeven.

3. **Develop policies to support fiber leasing and expansion of fiber assets**

Technical and policy considerations will influence dark fiber leasing. When managing dark fiber lease agreements, we recommend that the City implement policies to ensure that the fiber strands are used efficiently, and that considerations for potential future expansion are not compromised. In this regard, the City has to balance its interests in creating a competitive, open access environment and ensuring that the network capacity can be expanded if needed to meet demand.

With the increased interest from private sector entities in installing conduit and fiber from Corporate Landing to locations outside Virginia Beach, the City can look for co-build, joint trenching, and other opportunities for expansion of its infrastructure. One of the first steps in leveraging these potential opportunities is the development and implementation of a Dig Once policy.

4. **Prioritize fiber construction and consider adding higher fiber counts along routes where businesses have shown interest in leasing fiber**

On a case-by-case basis, the City may be able to look at some dark fiber leases for business customers. In a similar vein, we believe the City should market dark fiber services to customers along the fiber routes and to customers of Corporate Landing.

However, in the current state, leasing to a carrier (e.g., the recent request for 20 strands) might be difficult both because of the limits on the City's overall fiber capacity and its overall public goals.

The City's ability to lease conduit is even more restrained. The City has a single three-inch conduit, with no inner-duct; once an additional cable is pulled, no further cables are likely to fit unless a given segment is completely replaced. We do not recommend that the City consider leasing conduit except maybe on a case-by-case basis.

5. **Enhance the fiber optic network to eliminate any bottlenecks where only 24-count fiber is available, to connect higher-education sites, and to build routes to the edge of the City**

We recommend that the City enhance its proposed Phase 1 expansion plan, and run new subring fiber back to the hubs. This approach would increase the project cost by $1.7 million but would expand many segments to 96 or 144 strands and ensure that every new strand of fiber built can be used for City/public needs or leasing. This will help enable some strategic fiber leases, though we note that the City's capacity for leasing will still be limited when compared to some greenfield builds; Arlington County, Virginia, for example, has 864-strand fiber dedicated for leasing plus extra conduits on each route.

The next recommendation is to extend fiber to selected higher-education sites, which would increase the project cost by $800,000.

The City could also construct two diverse routes to the edge of the City (Woodstock Elementary and Renaissance Academy from Corporate Landing) for an additional $400,000.

Upgrading the remaining 24-strand segments (pull cable) to either 96- or 144-strand count would add an additional $314,000 to the project.

Segments to K-12 schools and economic development sites would need to be evaluated and priced on a case-by-case basis.

6. Seek collaboration to expand the benefits of the NGN

The City should consider pursuing a range of options for collaboration to expand the NGN's reach. For example, it could seek to bring additional local and regional governmental agencies on to NGN. It could work with service providers (e.g., those that may install conduit and fiber from Corporate Landing to locations outside Virginia Beach) on joint trenching, fiber sharing, and other mutually beneficial approaches to expanding the fiber footprint. And the City could explore ways to use the City's NGN resources to expand wireless coverage to targeted parts of the community, such as along the beachfront, using small cell technology. (As we note below, we recommend that the City issue an RFI or RFP to identify a partner for targeted use of fiber strands to support a small cell build.)

We also recommend that the City develop a capacity as a data repository for tracking public fiber assets not just within Virginia Beach, but in the region as a whole. Items to consider tracking and documenting include:

- Fiber routes – indicate whether overhead or underground
- Fiber count by segment – total, used, maintenance spares, allocated, and available
- Fiber type by segment
- Conduits routes – size, use of innerduct (type and size), cables in each duct

Strand mapping and other documentation needed for maintenance, customer connections, and other operations needs to be maintained by each entity, with a recognition that keeping accurate records is critical for each individual entity and for regional activities.

7. Continue to augment use of City staff with contractors

We recommend that the City continue to hire contractors to perform maintenance tasks; while this is a cost-effective approach, given the City's limited in-house resources for such tasks, the IT department should monitor the contractor's performance and costs on a regular basis. Similarly, we recommend that the City consider hiring contractors to perform fiber locates and ticket processing. We believe the City should keep in-house all fiber documentation, mapping, and record-keeping; those are critical tasks both for ongoing operations and future strategic planning.

8. Leverage fiber assets as part of a small cell strategy

Across the country, cellular carriers are installing or seeking to construct new distributed antenna system (DAS) networks and small cells to meet users' demand for mobile broadband data. The City should consider creating a policy regarding small cell deployments.

We also recommend that the City explore options for leveraging its existing fiber to encourage a coordinated small cell build—including by potentially issuing an RFI or RFP for a carrier-neutral DAS or small cell implementation for the downtown beachfront.

9. Consider difference between the terms "lease" and "license"

While we have used the term "lease" throughout the document (to match the City's nomenclature, and the common usage in the industry), we recommend that the City get advice from its qualified legal counsel on the use of the term "license" instead of "lease" for short-term dark fiber contracts. As we understand the evolving use of those terms, a "license" would allow the City to provide a connection between two end points via any path—while a "lease" requires the City to provide specific fibers along a specific route. A lease might be appropriate for long-term IRUs (and for conduit), but a license might be a better strategic approach to short-term dark fiber agreements.

Appendix A: Dark Fiber Pricing Examples

This appendix is provided as a standalone document.

Appendix B: Conduit Pricing Summary

This appendix is provided as a standalone document.

Appendix C: Fiber Swap Overview

This appendix is provided as a standalone document.

Appendix D: Current State of the Market (Competitive Analysis)

Service Providers in the City

This section provides an overview of competitive providers for dark fiber and lit services with respect to enterprise customers in the City of Virginia Beach. These services would typically serve medium to large business customers.

During the course of our research, we identified 10 service providers in the Virginia Beach region that offer a range of services, from dark fiber connectivity to data transport services, with speeds that range from 1 Mbps to 100 Gbps. (We expect to see continued consolidation of competitors through mergers and acquisitions.)

While many providers do not own infrastructure in the City, they are able to offer lit services through agreements with other local providers. Individual providers tailor these services to customers' requirements (speed, class of service, etc.). Greater proximity of the service location to the provider's existing network infrastructure results in lower service pricing. They prefer to offer transport services between locations on their networks (on-net) and provision Multiprotocol Label Switching (MPLS) based services for connecting locations that are off-net, such as by obtaining last-mile connectivity from Verizon.

Comprehensive pricing comparisons are difficult, if not impossible, to compile for two reasons. First, service providers rarely make pricing publicly available, and will typically provide quotes only for a bona fide potential customer. Second, enterprise service providers do not have standard rates. Unlike the residential services that Cox and Verizon deliver for a set monthly fee, enterprise services such as these are customized to individual customers' specific needs, and priced accordingly.

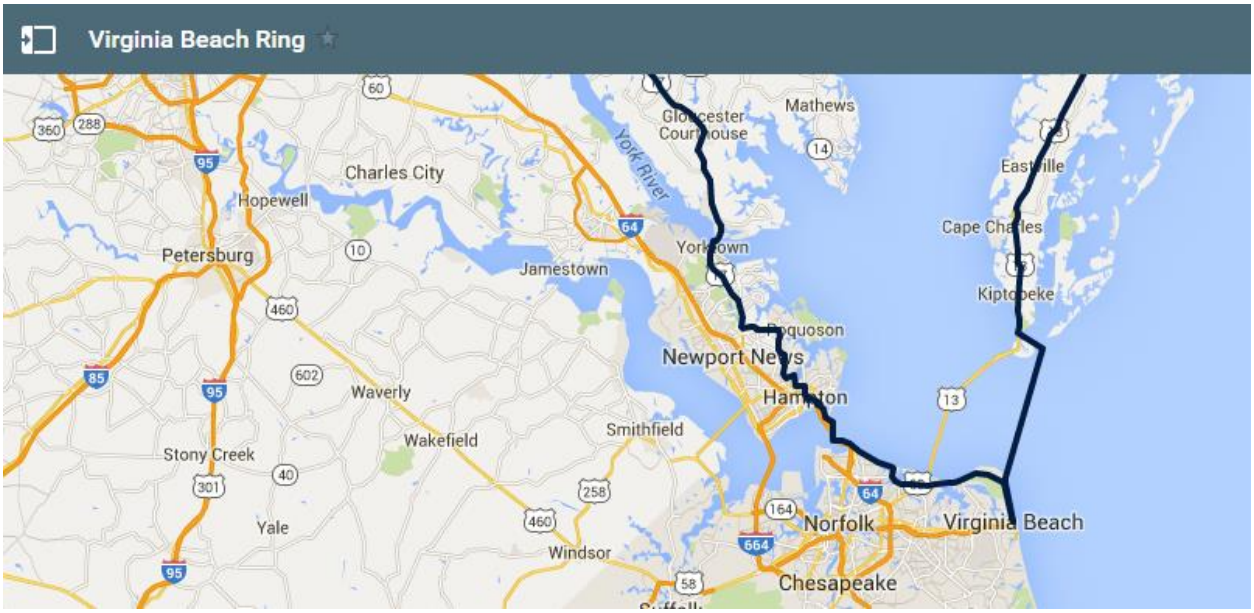
Dark Fiber Services

Dark fiber refers to fiber strands that are installed (e.g., in conduit or on aerial poles) but are not "lit" by network electronics. Local governments and network operators often install excess fiber to meet future needs, or install dark fiber specifically to lease to enterprise customers that have the technical capabilities to operate the fiber on their own. Based on our research dark fiber connecting two on-net locations within Virginia Beach would range in price from $1,700 to $5,000 per month per strand mile.

Three service providers in the Virginia Beach region offer dark fiber services: FTS Fiber, Lumos, and Level 3.

FTS Fiber has a fiber presence in a number of cities primarily on the East Coast including Virginia Beach as depicted in Figure 20.[30] FTS provides customer solutions to meet individual requirements. Pricing follows after a preliminary design is done to provide better insight into the details of any construction required to fulfill customers' requirements.

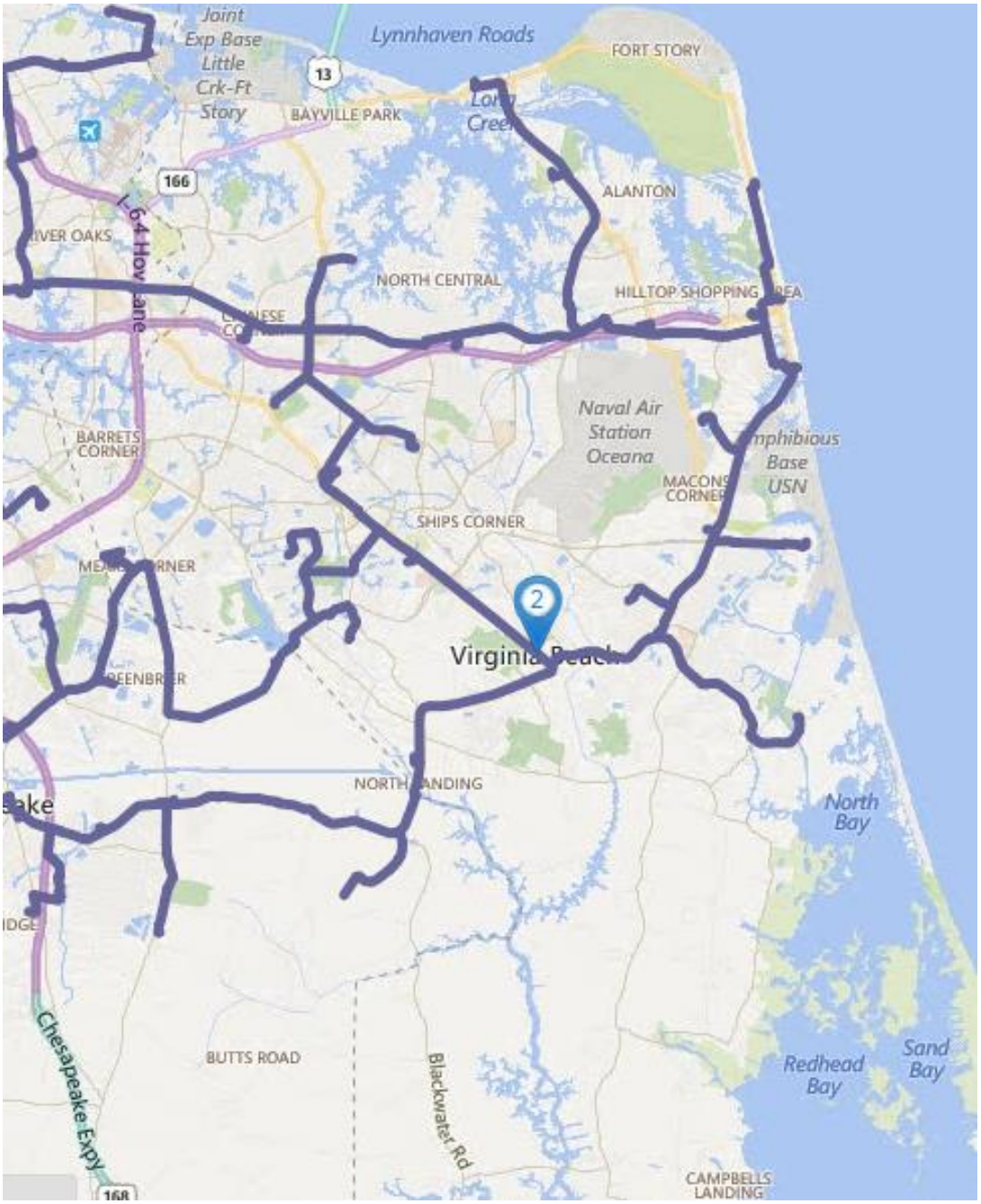
Figure 20: FTS Fiber Network Map



[30] http://ftsfiber.com/network/ , accessed April 2016

Lumos is another provider that owns dark fiber in Virginia Beach. The map in Figure 21 below illustrates the company's routes in the region.[31]

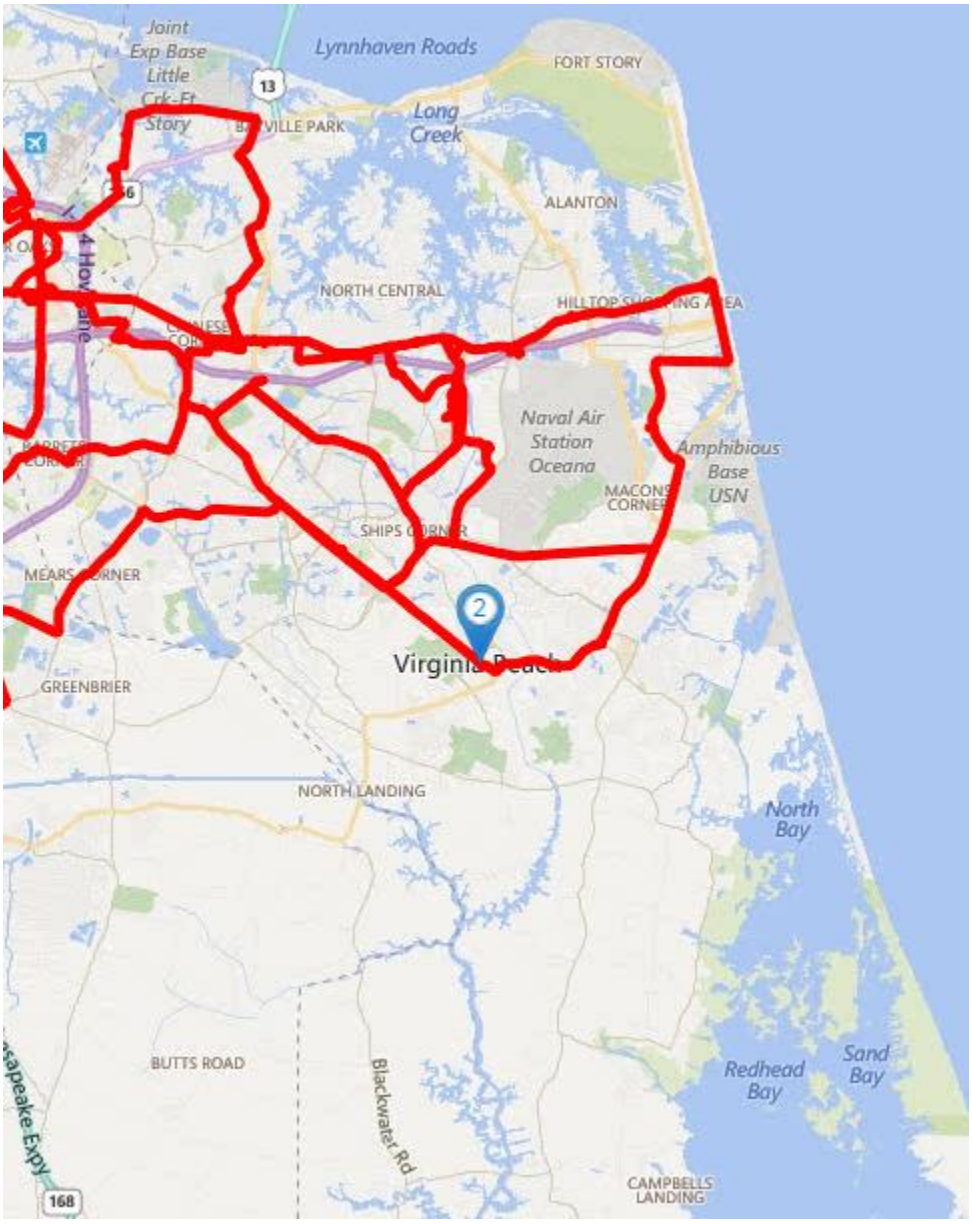
Figure 21: Lumos Network Map



[31] https://www.lumosnetworks.com/ accessed April, 2016

Level 3 has multiple dark fiber routes in Virginia Beach as depicted in Figure 22. Services are offered only to select customers based on their application requirements. Dark fiber pricing varies individually, based on distance from the provider's fiber ring. A difference in a few tenths of a mile can lead to significant differences in the price of dark fiber connectivity due to additional construction costs.

Figure 22: Level 3 Dark Fiber Routes[32]



[32] http://maps.level3.com/default/, accessed April 2016

Lit Fiber Services: Ethernet and DIA

Almost all existing service providers offer Ethernet and Dedicated Internet Access (DIA) services. Bandwidths typically range from 1 Mbps to 100 Gbps. Ethernet service can be classified into three types: Ethernet Private Line, Ethernet (EPL or E-Line), Ethernet Virtual Private Line (EVPL) and ELAN. These may be known by different names among providers. The EPL is a dedicated, point-to-point high bandwidth Layer 2 private line between two customer locations. The EVPL service is similar to EPL but is not dedicated between two locations. Instead, it provides the ability to multiplex multiple services from different customer locations onto one point on the provider's network (multiple virtual connections) to another point on the network. The ELAN is a multipoint to multipoint connectivity service, that enables customers to connect physically distributed locations across a Metropolitan Area Network (MAN) as if they are on the same Local Area Network (LAN). The internet services over Ethernet are typically classified under two categories: Dedicated Internet Access (DIA) and MPLS IP Virtual Private Networks (IP-VPN). Providers prefer to offer MPLS based IP-VPN services when the service locations are off-net thus avoiding construction and installation costs. MPLS based networks provide high performance for real-time applications such as voice and video and are typically priced higher.

The customer can choose a type of Ethernet service based on their bandwidth demands and the number of locations they would need to connect. Typically, Ethernet services are used by large business that have IT staff to manage their network.

The carriers that provide these services in the Virginia Beach region are AT&T, Level3, Cogent Communications, Comcast, Cox Communications, Lumos, Verizon, Windstream Communications, and XO Communications. Prices depend on the bandwidth, location, and network configuration, whether the service is protected or unprotected, and whether the service has a switched or mesh structure. Based on our research, we have seen a 1 Gbps DIA service's price range from $1,200 to $5,000 per month in the City. We have seen a 1 Gbps point-to-point Ethernet circuit price range from $2,000 to $3,060 per month in the City. Additional non-recurring charges will be present.

AT&T has four different types of Ethernet products—GigaMAN, DecaMAN, Opt-E-MAN, and Metro Ethernet. GigaMAN provides a native-rate interconnection of 1 Gbps between customer end points. It is a dedicated point-to-point fiber optic based service between customer locations which includes the supply of the GigE Network Terminating Equipment (NTE) at the customer premises. DecaMAN connects the end points at 10 Gbps and is transmitted in native Ethernet format similar to GigaMAN, only 10 times faster. Opt-E-MAN service provides a switched Ethernet service within a metropolitan area. It supports bandwidths ranging from 1 Mbps to 1,000 Mbps, and configurations such as point-to-point, point-to-multipoint, and multipoint-to-

multipoint. Metro Ethernet service provides various transport capabilities ranging from 2 Mbps through 1 Gbps while meeting IEEE 802.3 standards.[33]

Cogent Communications' Ethernet services are available at speeds of 1.5 Mbps to 10 Gbps.[34] The company provides middle mile services in Virginia Beach with the last mile service provisioned through local exchange carriers (LEC) such as Verizon. Often, more competitive pricing and better customer support is available through Cogent even though the company uses the LECs' last-mile services. Cogent's customer support team is local to Virginia and is available 24/7.

Comcast provides DIA and Ethernet services such as Ethernet Private Line. Their EPL service enables customers to connect their Customer premises equipment (CPE) using an Ethernet interface, as well as using any Virtual Local Area Networks (VLAN) or Ethernet control protocol across the service without coordination with Comcast. EPL service is offered with 10Mbps, 100Mbps, 1 Gbps or 10 Gbps Ethernet User-to-Network Interfaces (UNI) and is available in speed increments from 1Mbps to 10 Gbps.[35]

Cox offers Ethernet LAN Service, Ethernet Private Line (EPL), and Ethernet Access Services to locations within Virginia Beach.[36]Cox is also able to offer scalable, symmetric DIA service up to 1 Gbps speeds in certain locations in the City.[37]

Level 3's Metro Ethernet dedicated service is available in bandwidth options of 3 Mbps to 1 Gbps and its Ethernet Virtual Private Line (VPL) offers in speeds ranging from 3 Mbps to 1 Gbps. It is an end-to-end Layer 2 switched Ethernet service delivered via a Multi-protocol Label Switched (MPLS) backbone.[38]

Lumos offers Ethernet speeds up to 10 Gbps with Ethernet LAN Service, Ethernet Line, Ethernet Access and DIA service in Virginia Beach.[39]

Verizon offers Ethernet services under three different product categories—Ethernet Local Area Network (LAN), EPL, and EVPL. The Ethernet LAN is a multipoint-to-multipoint bridging service at

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[33] http://www.business.att.com/service_overview.jsp?repoid=Product&repoitem=w_ethernet&serv=w_ethernet&serv_port=w_data&serv_fam=w_local_data&state=California&segment=whole, accessed April 2016

[34] http://www.cogentco.com/en/products-and-services, accessed April 2016

[35] http://business.comcast.com/ethernet/products/ethernet-private-line-technical-specifications, accessed April 2016

[36] https://www.cox.com/business/networking/metro-ethernet.html, accessed April 2016

[37] https://www.cox.com/content/dam/cox/business/documents/internet/Cox_Business_Optical_Internet_Overview.pdf, accessed April 2016

[38] http://www.level3.com/en/products-and-services/data-and-internet/vpn-virtual-private-network/evpl/, accessed April 2016

[39] https://www.lumosnetworks.com/products/ethernetmpls, accessed April 2016

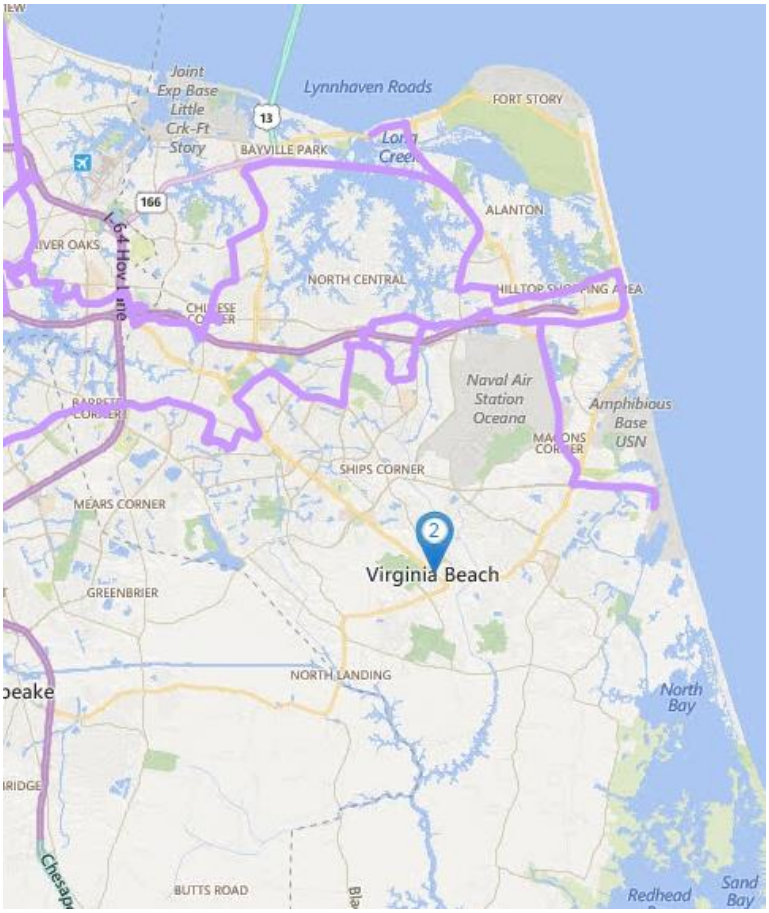
native LAN speeds. It is configured by connecting customer User-to- Network Interfaces (UNIs) to one multipoint-to-multipoint Ethernet Virtual Connection or Virtual LAN (VLAN), and provides two Class of Service options—standard and real time. The Ethernet Private Line is a managed, point-to-point transport service for Ethernet frames. It is provisioned as Ethernet over SONET (EoS) and speeds of 10 Mbps to 1 Gbps are available. The EVPL is an all-fiber optic network service that connects subscriber locations at native LAN speeds; EVPL uses point-to-point Ethernet virtual connections (EVCs) to define site-to-site connections. It can be configured to support multiple EVCs to enable a hub and spoke configuration and supports bandwidths from 1 Mbps to 1.000 Mbps.[40] Pricing for a 1 Gbps DIA service in Virginia Beach was recently $5,000 per month for a three-year term.

Windstream Communications has a nationwide presence serving major metropolitan areas, including Virginia Beach, with speeds up to 1 Gbps.[41]

Figure 23 depicts Windstream's fiber routes in Virginia Beach.

[40] http://www.verizonbusiness.com/products/data/ethernet/, accessed April 2016
[41] http://www.windstreambusiness.com/, accessed April 2016

Figure 23: Windstream Fiber Network Map



XO Communications can offer Ethernet services at multiple bandwidth options from 3 Mbps to 100 Gbps over their Tier 1 and partnership networks.[42]

[42] http://www.xo.com/carrier/transport/ethernet/, accessed April 2016

Appendix E: Financial Analysis

This appendix is provided as a standalone document.

Appendix F: Broadband Definitions

Access Fiber – The fiber in a fiber-to-the-premises (FTTP) network that goes from the fiber distribution cabinets (FDCs) to the optical taps that are located outside of homes and businesses in the rights-of-way (ROW).

AE – Active Ethernet; a technology that provides a symmetrical (upload/download) Ethernet service and does not share optical wavelengths with other users. For subscribers that receive AE service—typically business customers that request a premium service or require greater bandwidth—a single dedicated fiber goes directly to the subscriber premises from the distribution hub with no optical splitting (home run fiber connection).

Broadband – High-speed internet access that is always on and faster than the traditional dial-up access. In 2015, the Federal Communications Commission (FCC) updated the legal definition of broadband to refer to services providing at least 25 Mbps download and 3 Mbps upload.

CPE – Customer premises equipment; the electronic equipment installed at a subscriber's home or business.

Data Center Tiers

- **Tier 1** - Non-redundant data center components (single uplink and single server).
- **Tier 2** - Tier 1 data center with the addition of redundant components.
- **Tier 3** - Tier 2 data center with the addition second source power and multiple uplinks.
- **Tier 4** – Tier 3 data center with having fault-tolerant components (uplinks, storage, HVAC, servers). All components with second source power.

Dark fiber – Fiber that is unused or not connected to electronics which "light" the fiber. This can also refer to fiber that is provided in a "dark" state to be connected and lit by the customer.

Distribution Fiber – The fiber in a Fiber-to-the-Premises (FTTP) network that connects the hub sites to the fiber distribution cabinets.

Drop – The fiber connection from an optical tap in the right-of-way (ROW) to the customer premises.

FDC – Fiber distribution cabinet; houses the fiber connections between the distribution fiber and the access fiber. FDCs, which can also house network electronics and optical splitters, can sit on a curb, be mounted on a pole, or reside in a building.

FTTP – Fiber-to-the-premises; a network architecture in which fiber optics are used to provide broadband services all the way to each subscriber's premises.

GPON – Gigabit passive optical network; the most commonly provisioned Fiber-to-the-Premises (FTTP) service—used, for example, by Verizon (in its FiOS systems), Google Fiber, and Chattanooga Electric Power Board (EPB). GPON uses passive optical splitting, which is performed

inside FDCs, to connect fiber from the Optical Line Terminals (OLTs) to multiple customer premises over a single GPON port.

Home Run – dedicated fiber goes directly to the subscriber premises from the distribution hub with no optical splitting.

IP – Internet Protocol; the method by which computers share data on the internet.

IRU – Indefeasible Right of Use; an agreement, typically 10 to 20 years, where the customer has the right to use dark fiber strands on a network for the length of the contract.

ISP – Internet Service Provider; an organization which provides services that enable customers to connect to the internet.

Internet Provider Tiers

- **Tier 1 –** A network carrier that connects to all other tier 1 networks without paying for peering and other connections.
- **Tier 2 –** A network carrier that connects to the internet through a mix of paid and un-paid connections (peers with some providers but purchases transport or pays settlements to reach portions of the internet).
- **Tier 3** - A network carrier that solely purchases transport from other networks to participate in the internet.

LEC – Local Exchange Carrier; a public telephone company that provides service to a local or regional area.

MDU – Multi-dwelling unit; a large building with multiple units, such as an apartment or office building.

Monthly Dark Fiber License/Lease– A contract to license/lease dark fiber, typically for a shorter term than in an IRU agreement, paid on a month-to-month basis.

OLT – Optical line terminal; the upstream connection point (to the provider core network) for subscribers. The choice of an optical interface installed in the OLT determines whether the network provisions shared access (one fiber split among multiple subscribers in a GPON architecture) or dedicated AE access (one port for one subscriber).

OSP – Outside plant; the physical portion of a network (also called “layer 1”) that is constructed on utility poles (aerial) or in conduit (underground).

OSS – Operational Support Systems (OSS); includes a provider’s provisioning platforms, fault and performance management systems, remote access, and other OSS for Fiber-to-the-Premises (FTTP) operations. The network’s core locations house the OSS.

OTT – Over-the-top; content, such as voice or video service that is delivered over a data connection.

Passing – A potential customer address (e.g., an individual home or business).

POTS – Plain old telephone service; delivered over the PSTN.

PSTN – Public switched telephone network; the copper-wire telephone networks that connect landline phones.

QoS – Quality of service; a network's performance as measured on a number of attributes.

ROW – Right-of-way; land reserved for the public good such as utility construction. ROW typically abuts public roadways.

VoIP – Voice over Internet Protocol; telephone service that is delivered over a data connection.

Appendix G: Best Practices for Broadband Deployment

This appendix is provided as a standalone document.

Appendix H: Outside Plant (OSP) Cable and Infrastructure Specifications

This appendix is provided as a standalone document.

Appendix I: Residential and Business Broadband Survey Results

This appendix is provided as a standalone document.

Appendix J: Next Generation Network (NGN) Responsible-Accountable-Consulted-Informed (RACI) Matrix

This appendix is provided as a standalone document.