MIDDLE PENINSULA
PLANNING DISTRICT COMMISSION

MPPDC Region Broadband Plan and Final Recommendations

SEPTEMBER, 2017

Table of Contents

Executive Summary

This report describes the approach that the localities and the Pamunkey Tribe of the Middle Peninsula Planning District could pursue (the "Project", or "PamunkeyNet") as an effort to expand access to improved and more affordable broadband coverage throughout the region.

The broadband study convened by the Middle Peninsula Planning District Commission was to provide the PDC with an effective and actionable course of action that will promote the availability of affordable, high speed broadband and Internet services in the PDC region . The overall goal of this effort is to:

- Identify the kind, type and cost of a highly resilient and redundant broadband network needed to support the activities of residents, businesses, and local governments in the Middle Peninsula region.
- Specify the cost and technical characteristics of a high performance, affordable wireless broadband network that would leverage existing assets, including existing towers and the King and Queen network, existing public safety towers, and where feasible, some commercial cellular towers.
- Specify the cost and technical characteristics of a first phase Fiber Technology Corridor on Route 33 that would be integrated with the planned Telework Center.
- Specify the cost and technical characteristics for a fiber to the home initiative on the Pamunkey Reservation.
- Identify financially feasible and sustainable strategies to achieve these goals.
- Identify the steps needed to be taken to initiate and develop the project if a decision is made to move forward.

Vision Statement

In the Middle Peninsula region, PamunkeyNet will:

- Build and operate a modern high performance wireless and fiber broadband infrastructure that provides the region with an economic development tool to retain existing businesses, attract new businesses, and help create jobs.
- Provide a robust broadband infrastructure using both wireless and fiber technologies that provides rural residents with improved Internet and Internet-based services at affordable prices.
- Support small businesses, home-based businesses, and home-based workers with affordable Internet access and Internet-based business services.
- Provide businesses and residents with a choice of competitive service providers and a choice of Internet-based services at a variety of affordable price points.
- Create a new Pamunkey Tribe business enterprise (PamunkeyNet) that will assist with funding, oversee network operations, and manage the business aspects of the Project.

Overview of the Strategy

The approach for this project has three primary objectives:

- Create a new business enterprise owned by the Pamunkey tribe.
- Create a network of existing and new wireless towers throughout the Middle Peninsula region that will have a high performance backbone between towers and local access radios on each tower to provide affordable business, residential, and institutional broadband Internet service.
- Create a fiber-based Technology Corridor on Route 33 between Rappahannock Community College, the planned Telework Center, and the Middle Peninsula airport.
- Provide the Pamunkey Tribe with state of the art Gigabit fiber services on the reservation.

The project will use and expand upon the existing successful King and Queen wireless network. Tower locations will be identified using several criteria:

- Make best possible use of existing local government (e.g. county) tower assets, including public safety towers and public safety backbone radio systems.
- Where affordable, lease space on privately owned towers to keep capital costs as low as possible.
- Build new towers where existing tower assets are not available or affordable, including the Pamunkey Reservation

Tower site identification and placement will be based on a goal of providing the maximum service coverage possible in each of the six counties in the Project area. The relatively flat terrain of the Middle Peninsula lends itself well to providing excellent wireless broadband service, but heavy tree cover will create line of sight problems for some potential users. Some businesses and residents may find it necessary to install a wooden or steel utility pole to get the customer radio above local tree cover.

Design Goals

A network initiative in partnership with the Pamunkey Tribe should have the following characteristics:

- Equal access to all residents and businesses over time – The goal of the initiative should be to deliver high performance broadband services to all residents, businesses, and local governments/agencies as rapidly as possible consistent with fiscally conservative operations.
- Scalable - The initial design of the network should support a graceful expansion over time.
- Small and home-based business support - The network should be able to support business needs, especially small businesses, business from home, and work from home opportunities. This is particularly important for future business attraction success.
- Enterprise business support - Provide business and carrier-class services over a fiber backbone to attract medium and large businesses to the region.

- Redundancy and Resiliency – The network should be designed to achieve a redundant "ring" architecture to minimize downtime from accidental fiber cuts and network equipment failures. Residents, schools, businesses and anchor tenants should have a high reliability network.
- Business Approach - Infrastructure investments by the enterprise should be carefully targeted to be financially sustainable over the long term. The goal should be operational expenses managed on a cost-plus basis.
- Funding Strategy - The enterprise should develop a "basket" of funding options, including long term service commitments from anchor tenants (e.g. K12 schools, the local public safety agencies, etc.), state and Federal grant opportunities, revenue from the network itself, and one time fees for costs associated with connecting a new customer to the network.

Next Steps

Next steps include:

- Identify the initial partners and interested parties that are ready to commit to the project, including the Pamunkey Tribe, the Middle Peninsula PDC, Rappahannock Community College, and other regional entities.
- Identify legal counsel for advice on company formation and tax rules. While tribal businesses are exempt from Federal taxes and may be exempt from state taxes, the entity may still have to register with the Virginia State Corporation Commission (SCC) and file annual reports even if there is not tax liability.
- Formation of the legal entity that will be responsible for the ownership and governance of PamunkeyNet. This would be formed by and owned by the Pamunkey tribe with a governing board/partners that include regional entities like the Middle Peninsula Planning District Commission and Rappahannock Community College.
- Once the entity is formed, it should register as an ETC (Eligible Telecommunications Carrier), which would give it access to certain kinds of Federal and state grants and loans.
- Identify a basket of funding sources for capital projects (fiber backbone, colocation facility, and regional wireless expansion).
- Begin working with the counties to identify additional county-owned sites where towers could be located.
- Begin close coordination with county-level and any regional public safety tower projects, which could provide a valuable source of funding where towers could support dual use—public safety voice/data communications and wireless broadband access.
- Identify additional planning funds to support detailed network design activities for both the wireless and fiber portions of the planned network.

Improving Broadband Access

In the Middle Peninsula region, both fiber and wireless technologies and systems are going to be important to meet the goal of improving access to broadband. The rest of this section provides more detail and some specific build out strategies. There are three major parts of any modern network:

- The **Core Network** provides access to the Internet, a place for service providers (ISPs) to distribute their services locally on the network, and for larger institutional and business customers to meet service providers. The King and Queen network has an existing wireless core network. As the network expands regionally, a colocation facility and meet point at the Telework Center will provide the equipment space and facilities to support continuous expansion of both the fiber and wireless portions of the network.
- The **Distribution** portion of the network connects the Core Network with collections of users. The Distribution network will include both fiber and wireless portions of the network.
- The **Access or Last Mile** portion of the network connects individual users and businesses to the network, and like the Distribution network, that connection will be by fiber or by a wireless link.

For improved wireless access in the region, the Project can use existing and new towers to improve access to broadband services. The well-established model of local fiber access supported by a high capacity wireless link can be used as an important business attraction and retention tool. This hybrid wireless-fiber model can also be used to provide rural residential fiber service to support work from home and business from home opportunities.

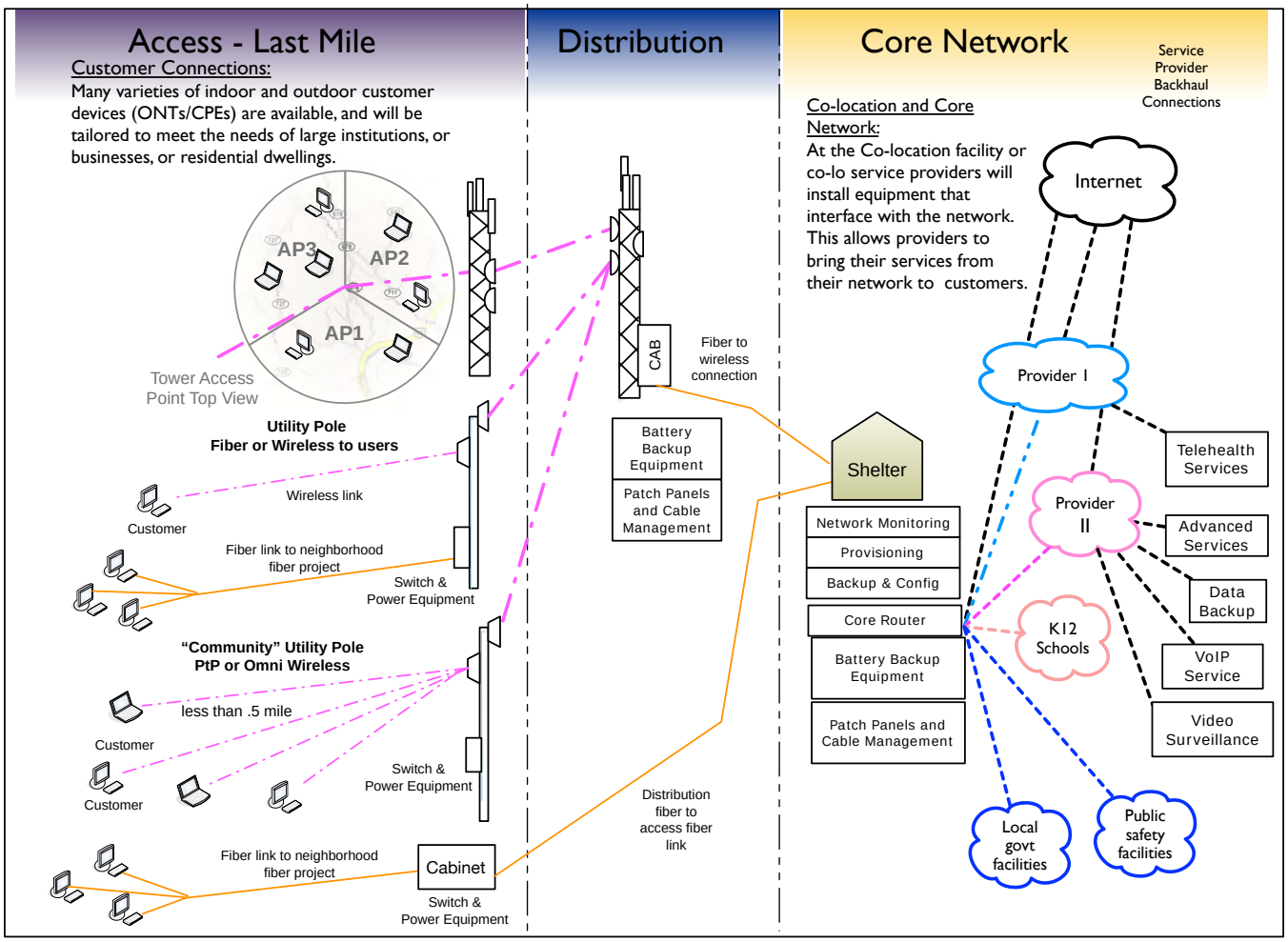
Businesses and residents in the region may obtain Internet service:

- With a small radio directly attached to their home or business that receives a signal directly from one of the Project towers.
- With a small radio attached to a utility pole (60 or 70') to improve line of sight to a Project tower.
- With a small radio directly attached to their home or business that receives a signal from a "community" utility pole. The "community" pole with receive a signal from a distant Project tower and redistribute it locally to a cluster of customers (typically within a half mile).
- With a fiber connection to the fiber installed along Route 33 and in other areas as additional fiber network segments are added.

The existing King and Queen network uses point to point wireless component which provides backhaul between towers and for redundancy and improved service reliability.

The table below summarizes how fiber and wireless can work together in a variety of ways.

Distribution Type	Access Type	Capacity
Wireless	Wireless	Typical customer connection starting at 5 to 10 Megabits, can be higher, with 50 Meg connections common. More dependent on the capacity of the wireless Distribution link.
Wireless	Fiber	Users can have fiber Gigabit connections locally, but total throughput dependent upon the capacity of the wireless link, which can be up to a Gigabit, depending on distance and budget.
Fiber	Fiber	Any amount of bandwidth needed, with standard connection typically a Gigabit (1,000 Megabits).
Fiber	Wireless	Typical customer connection starting at 5 to 10 Megabits, can be higher, with 50 Meg connections common.

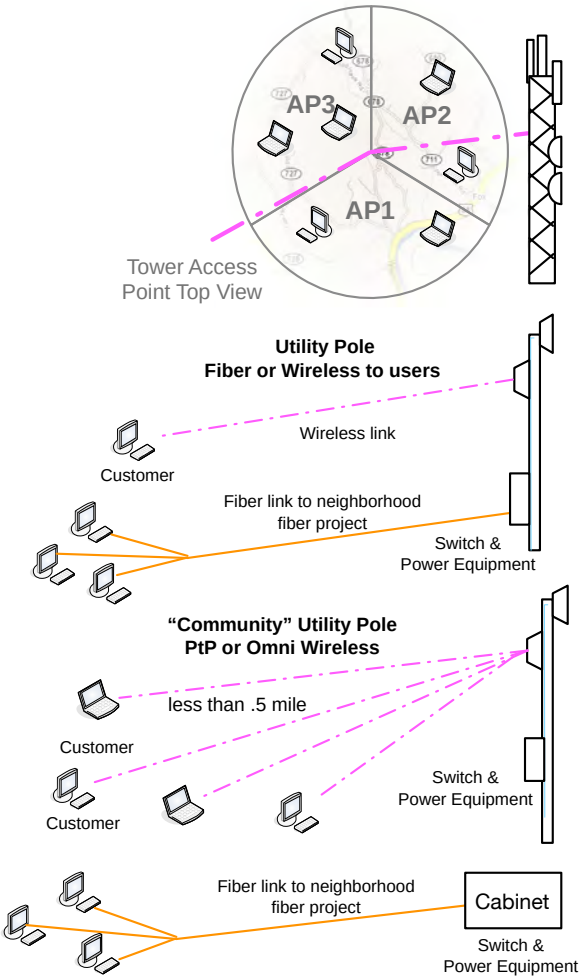


Last Mile Access

The Last Mile Access is the portion of the network that connects customers to their service provider and the Internet. Both broadband wireless and fiber links can be utilized to provide service.

There are several ways that customers can receive service:

- Service providers can install their own local access radios on the Distribution towers, using both point to multi-point and point-to-point radios to deliver service to their customers.
- A single user utility pole (or inexpensive steel lattice tower) can be installed on the property of a single resident or business. A radio at the top of the pole receives service from another tower site (typically one of the Distribution towers).
- A utility pole (or inexpensive steel lattice tower) can be installed near a cluster of homes (e.g. a rural residential sub-division, several homes in close proximity on a rural road). Service providers can install their point to multi-point radios on this pole and provide economical service to several customers from a single pole.
- A utility pole (or inexpensive steel lattice tower) can be installed in a rural subdivision. A service provider installs a point to point radio on the pole, and fiber cable can be run from the pole past several homes to offer fiber service with wireless backhaul.



- Customers near existing fiber can have a fiber drop installed directly to their home or business.

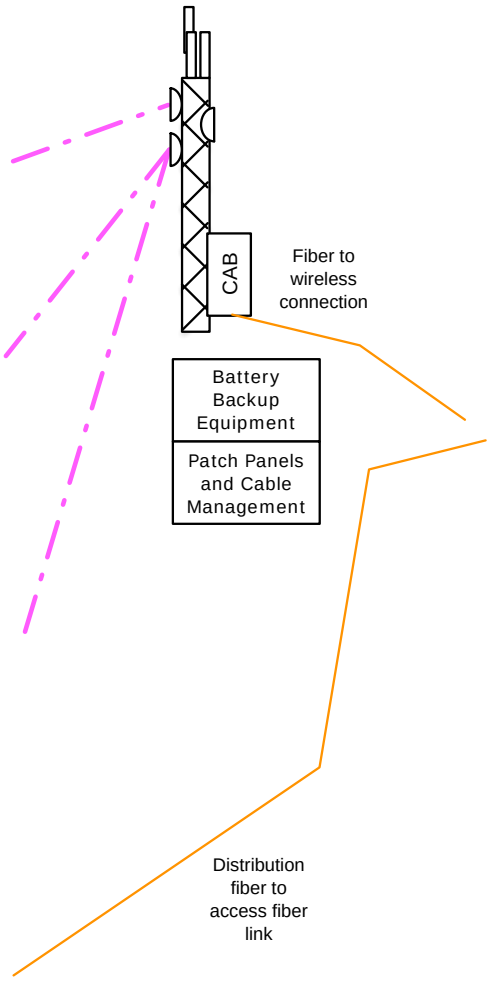
For the fiber to the home project on the Pamunkey Reservation, fiber will be deployed to the premises in the cluster of homes and community buildings in the area around the Pamunkey Indian Museum (about 40 homes and community buildings). A wireless tower will provide high performance Internet backhaul connectivity to the local fiber.

Distribution Network

Distribution is the portion of the network between the Distribution sites to the Last Mile Access portion of the network. It is desirable for each distribution site to have a connection back to more than one Distribution site (tower) on a redundant ring. This ring topology protects against hardware failure at the port level and does provide some protection if one of the tower to tower wireless links is disabled by an equipment failure.

These tower sites are typically 120' to 180' tall to provide the height needed to enable Line Of Sight (LOS) between towers, and for local access, to enable service providers to mount point to multi-point radios on the towers. That is, the towers provide two functions:

- Space for backhaul connections to other towers in the region.
- Space for local access radios to provide Internet access within 2-3 miles of the tower (or farther with good Line Of Sight).
- The existing King andQueen network provides good coverage in many parts of that county, and this model will be expanded to provide service in the other Middle Peninsula counties.
- The Technology Corridor between Rappahannock Community College, the Telework Center, and the Middle Peninsula airport will provide the first phase of middle mile (distribution) fiber. Additional fiber segments can be added as needed.

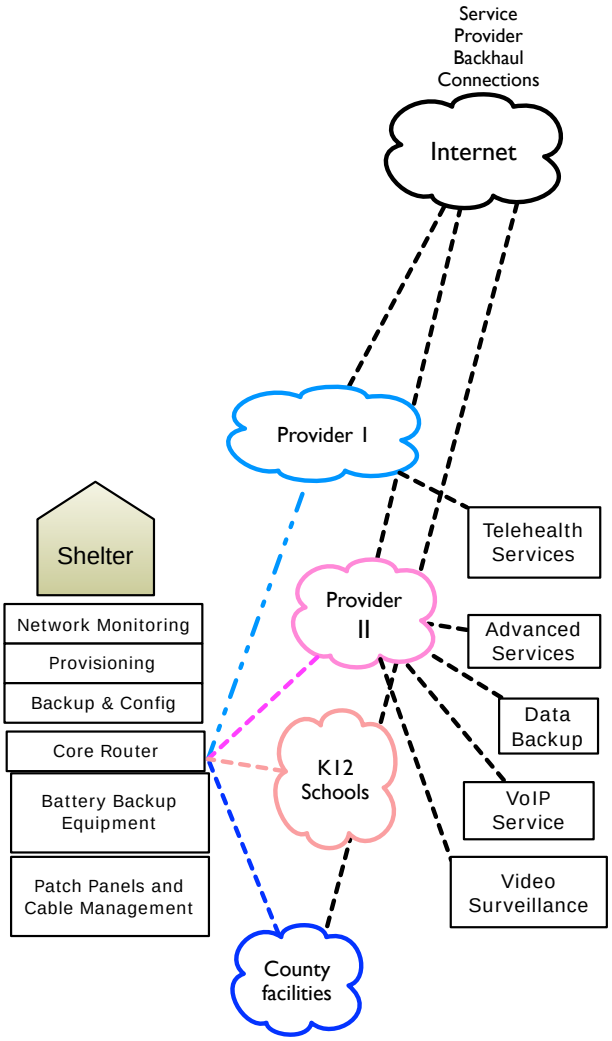


Core Network and Service Providers

In the past, the telephone company switch office (Central Office, or CO) has provided that function. Today, many communities have either a community-owned data center or a privately owned data center that offers an affordable range of options for customers of broadband services.

The Co-Location facility provides a meet point for various public and private fiber cables and networks to inter-connect. In the Middle Peninsula, the planned Telework Center, on the Route 33 first phase fiber segment, would be an ideal location for a colocation facility and service provider meet point.

A colocation facility is a controlled environment (i.e. secure, heated, and air-conditioned) room with Internet access through wired and/or wireless systems. The colocation facility is a place where fiber, wireless, and copper-based network facilities meet. It is equipped to house high-end network equipment, servers, and other electronic gear. A variety of middle layer network components and services can be located within the co-lo including, for example, directory services, replicated content servers, routing services, and other elements needed to deliver new multimedia services to the home and small office from multiple, competing providers.



Characteristics of the colocation facility are:

- A reliable source of AC electric power is required, with backup UPS (Uninterruptible Power Supply) service, and additional power backup available by an onsite generator.
- Controlled access to the facility (e.g. by electronic keycard) 24 hours/day, seven days a week.
- Racks for locating network equipment and servers, and optionally locked cages for equipment racks.
- Sufficient cooling capacity for the network's current and long-term needs.

Network Design and Cost Estimates

About the Cost Estimate Summaries

The estimate tables in this section shows the estimated costs for the tower improvements and new towers. Additional cost estimate information will be included in the next draft of this report.

Tower Construction

The line items for each named tower include the cost of the tower, site preparation, estimated cost of electric service, generator cost and placement, cost of the tower, and labor to assemble and erect the tower, and backbone equipment.

Fiber Construction

Line items contained in the fiber construction estimate include the labor needed to install underground conduit, place the fiber in the conduit, place handholes and splice closures, and the equipment needed to provision the lit network.

Project Management

Project Management, Network Integration, Configuration, and Testing for a telecom build requires thorough and detailed planning, experience in procuring construction materials for a telecom project, and the ability to oversee and convey project information to contractors through the duration of the project, including construction inspection work (ensuring construction contractors have done their job properly).

Some configuring and testing will take place after the network is built and before it is ready for use. This fee includes all of the project management, contractor supervision, procurement activities, and many other activities related to getting the network/towers built.

Engineering, Construction Inspection, and Permitting

This work include a full design of the outside plant network (towers), cabinet specifications, and extensive detail (CAD drawings where needed) that specifies how the wireless towers and network equipment (if any) is to be installed. These documents have to be completed prior to bidding out any construction work, and are usually included as part of a construction bid package. The detail site plan engineering if required, and any other engineering, inspection work, and permitting necessary to complete construction.

Some costs will be incurred based on the permitting requirements of the project. If shelters/cabinets are able to be placed on some properties at no charge, the cost of leases will be lower. If cabinets or shelters have to be placed on private property, the cost of the land or long term leases will increase. Some property owners prefer to receive ten or twenty years of lease payments up front, which can make this cost unpredictable. The cost of permits needed for crossing wetlands, streams, other sensitive areas, and State, County, or City permits are also included in this category.

Miscellaneous Fees and Technical Services

Many projects routinely incur a variety of mostly small amounts for fees and services. Typical items might include railroad crossing fees, lease and title fees, notary fees, legal fees for lease agreements or other legal matters, fees for archeological studies, etc.

Bookkeeping and Administration

Network projects create substantial amounts of paperwork, invoices, and related bookkeeping requirements. This amount may vary based on whether or not the Project has the work done by an outside firm or by Project staff. Projects funded by federal or state grants often have additional reporting requirements that increase the requirements placed on staff and grant administrators.

Contingency

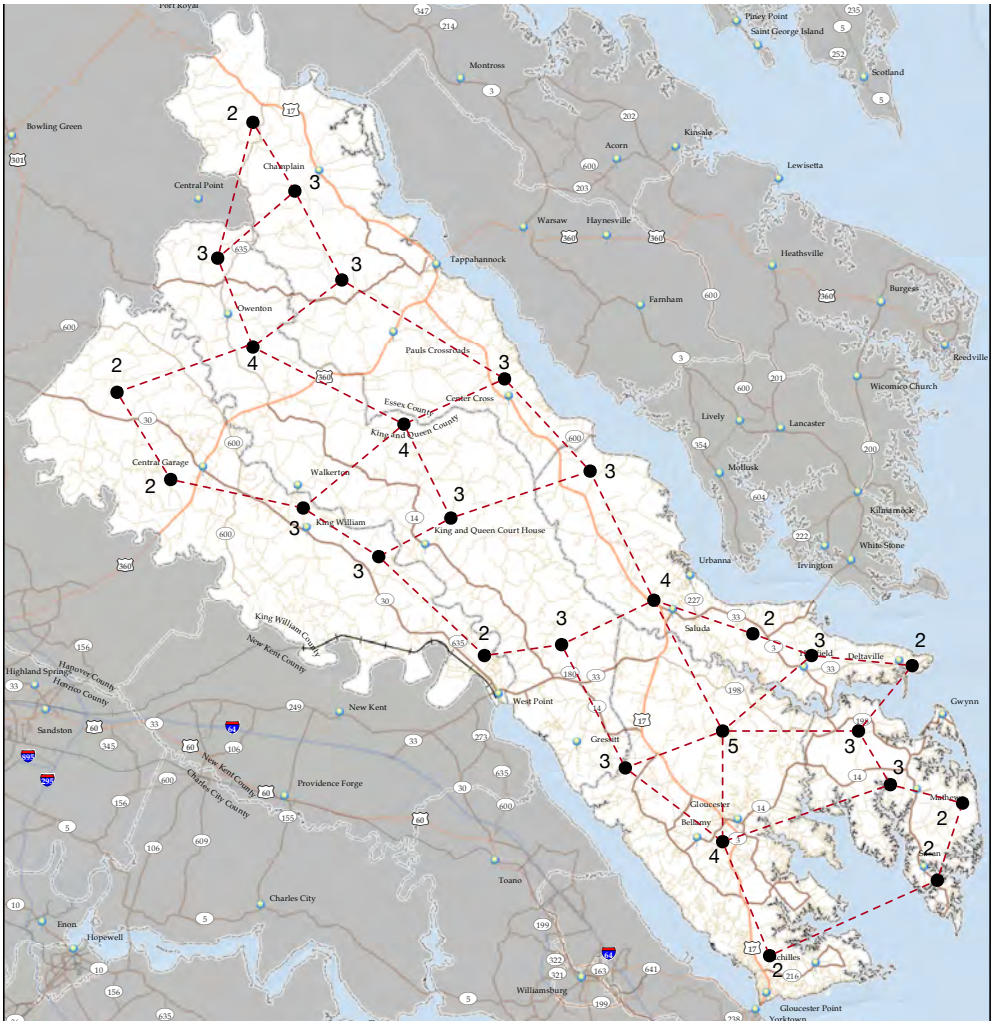
We recommend that a small contingency fund be allocated for unanticipated expenses which could include higher than expected construction costs or retail costs, higher site leases than expected, archeological discovery and research, right of way acquisition, and other unplanned costs.

Wireless Network Design

A conceptual network design for a regional broadband network is illustrated below, using a wireless architecture similar to that currently employed in King and Queen County. The design includes:

Full redundancy — Each of the 27 (estimated) sites is connected to 2, 3, 4, or 5 other sites. Failure of any single link will not interrupt customer service. Two thirds of the sites have links to three other sites, meaning they can tolerate two point to point link failures and continue to function.

Licensed frequencies — The point to point links will use licensed radio frequencies to minimize interference problems and to improve performance.



Excellent coverage — The estimated number of sites is based on the propagation studies in the previous section that indicates 90% or better coverage is available. Individual customers may still have line of site issues, which can generally be addressed with a local utility power or inexpensive steel tower.

Segmentation — The multiple point to point links, coupled with careful traffic routing, will enable the network to provide good bandwidth based on local customer traffic demands. Internet feeds can be accommodated in several locations throughout the network.

Wireless Tower Cost Estimates

This section of the report provides an estimate of the cost of constructing new towers where they may be needed.

Any placement of new towers should be preceded by a careful viewshed analysis (how much area/ users are likely to be able to receive service). Site acquisition and site preparation costs can affect the overall cost of such a project. Existing county properties (e.g. fire/rescue stations, county parks, dump transfer sites, etc.) may be candidates for towers.

Tower- Space Only Cost Estimate

For towers currently owned by the localities (e.g. public safety towers) that might be candidates for Project use, modest upgrades to equipment at the base of the tower would make them "broadband-ready." Upgrades to existing towers typically may include adding or upgrading generators, additional cabinet or shelter space for service provider equipment, and sometime fencing and physical access changes.

1	ITEM/PROJECT	UNITS	Estimated Cost (Conservative)	BEST ESTIMATE (WEIGHTED AVERAGE)
2	Small Telecom Cabinet	1	$6,000	$6,000
3	10kW Liquid Propane Generator	1	$6,000	$6,000
4	Cabinet Foundation and Installation	1	$800	$800
5	Spare Fuses	1	$20	$20
6	Power System Installation Materials	1	$40	$40
7	Samlex 1000W Inverter	1	$450	$450
8	Samlex SEC1230-UL Battery Charger	1	$300	$300
9	100ah 12v Non Spillable Backup Battery	1	$350	$350
10	DC Voltage Monitoring Device	1	$60	$60
11	Unmanaged Rack Mount PDU (6O)	1	$45	$45
12	Cabinet Installation Labor	1	$1,000	$1,000
13	Power System Installation Labor	1	$500	$500
14	Generator Installation Labor	1	$1,700	$1,700
15	Ubiquiti Access Point + 120° Sector	3	$375	$1,880
16	Project Management		18%	$3,446
17	Estimated Construction Cost			$22,591

New Tower Only Cost Estimate

New towers have a range of configurations and cost options. This estimate is for a new 180' tower with no radio equipment (that is, the cost of the bare tower). If located on existing county properties, the time needed to plan for construction can be shortened. If site acquisition or a site lease (of private property) is required, purchase or lease negotiations can add several months to the process. Note that some counties may require a full permitting process even if a new tower is placed on existing county-owned property. The permit process can add sixty to one hundred and twenty days to the time needed to put a new tower in service

1	ITEM/PROJECT	UNITS	COST(HIGH)	BEST ESTIMATE (WEIGHTED AVERAGE)
2	Small Telecom Cabinet	1	$3,000.00	$3,000
3	10kW Liquid Propane Generator	1	$6,000.00	$6,000
4	Cabinet Foundation and Installation	1	$800.00	$800
5	New Power Service / Installation	1	$1,250.00	$1,250
6	180' Self Supporting Tower Construction Materials	1	$22,000.00	$22,000
7	Spare Fuses	1	$20.00	$20
8	Power System Installation Materials	1	$40.00	$40
9	Samlex 1000W Inverter	1	$450.00	$450
10	Samlex SEC1230-UL Battery Charger	1	$300.00	$300
11	100ah 12v Non Spillable Backup Battery	1	$350.00	$350
12	DC Voltage Monitoring Device	1	$60.00	$60
13	Unmanaged Rack Mount PDU (6O)	1	$45.00	$45
14	Tower Site Land Clearing and Site Development	1	$12,500.00	$12,500
15	180' guyed Tower Construction Labor	1	$26,000.00	$26,000
16	Cabinet Installation Labor	1	$1,000.00	$1,000
17	Power System Installation Labor	1	$500.00	$500
18	Generator Installation Labor	1	$1,700.00	$1,700
19	FCC License Coordination	1	$1,500.00	$1,500
20	Construction Total:			$77,515
21			Project Management, Network Engineering, Testing	$23,260
22			Site Engineering, Surveying, viewshed analysis Etc.	$9,500
23			Misc Fees, Technical Services	$7,500
24			Bookkeeping and Administration	$5,000
25			Contingency	$12,280
26			TOTAL:	$135,055

180' Tower Cost Estimate with Two Backhaul Links

This cost estimate includes the cost of both point to point backhaul radios to connect the tower to two other towers in the network and the cost of the local access radios that would deliver service to nearby businesses and residents. This is for a self-supporting tower, and a similar guyed tower would be somewhat less expensive.

1	ITEM/PROJECT	UNITS	COST (LOW)	COST (HIGH)	TOTAL (LOW)	TOTAL (HIGH)	BEST ESTIMATE (WEIGHTED AVERAGE)
2	Small Telecom Cabinet	1	$4,000	$6,000	$4,000	$6,000	$4,600
3	10kW Liquid Propane Generator	1	$4,000	$6,000	$4,000	$6,000	$4,600
4	Cabinet Foundation and Installation	1	$1,000	$1,500	$1,000	$1,500	$1,150
5	New Power Service / Installation	1	$1,250	$3,000	$1,250	$3,000	$1,775
6	Tower Construction Materials	1	$25,000	$35,000	$25,000	$35,000	$28,000
7	Spare Fuses	1	$10	$20	$10	$20	$13
8	Power System Installation Materials	1	$20	$40	$20	$40	$26
9	Samlex 1000W Inverter	1	$350	$450	$350	$450	$380
10	Samlex SEC1230-UL Battery Charger	1	$200	$300	$200	$300	$230
11	100ah 12v Non Spillable Backup Battery	1	$250	$350	$250	$350	$280
12	DC Voltage Monitoring Device	1	$40	$60	$40	$60	$46
13	Unmanaged Rack Mount PDU (6O)	1	$35	$45	$35	$45	$38
14	Tower Site Land Clearing and Site Development	1	$7,500	$12,500	$7,500	$12,500	$9,000
15	Tower Construction Labor	1	$25,000	$32,000	$25,000	$32,000	$27,100
16	Cabinet Installation Labor	1	$600	$1,000	$600	$1,000	$720
17	Power System Installation Labor	1	$300	$500	$300	$500	$360
18	Generator Installation Labor	1	$1,250	$1,700	$1,250	$1,700	$1,385
19	FCC License Coordination	2	$750	$1,500	$1,500	$3,000	$1,950
20	Dragonwave Horizon Quantum 11GHz Link (includes below)	2	$19,500	$22,500	$39,000	$45,000	$40,800
21	Horizon Quantum Radio		$0	$0	$0	$0	$0
22	Dragonwave 4' to 6' dish		$0	$0	$0	$0	$0
23	Coaxial Cabling		$0	$0	$0	$0	$0
24	Dragonwave Power Supply		$0	$0	$0	$0	$0
25	DPRM - Dual Pol Radio Mount		$0	$0	$0	$0	$0
26	Tower Site Switch	1	$1,700	$2,300	$1,700	$2,300	$1,880
27	Ubiquiti Access Point + 120° Sector	3	$375	$500	$1,125	$1,500	$1,313
28	Construction Total:				$113,005	$150,765	$124,333
29	Project Management, Network Engineering, Testing						$31,090
30	Site Engineering, Surveying, Etc.						$7,500
31	Misc Fees, Technical Services						$10,000
32	Contingency						$17,300
33	TOTAL:						$190,223

180' Tower Cost Estimate with Three Backhaul Links

This cost estimate includes the cost of both point to point backhaul radios to connect the tower to three other towers in the network and the cost of the local access radios that would deliver service to nearby businesses and residents. This is for a self-supporting tower, and a similar guyed tower would be somewhat less expensive.

1	ITEM/PROJECT	UNITS	COST (LOW)	COST (HIGH)	TOTAL (LOW)	TOTAL (HIGH)	BEST ESTIMATE (WEIGHTED AVERAGE)
2	Small Telecom Cabinet	1	$4,000	$6,000	$4,000	$6,000	$4,600
3	10kW Liquid Propane Generator	1	$4,000	$6,000	$4,000	$6,000	$4,600
4	Cabinet Foundation and Installation	1	$1,000	$1,500	$1,000	$1,500	$1,150
5	New Power Service / Installation	1	$1,250	$3,000	$1,250	$3,000	$1,775
6	Tower Construction Materials	1	$25,000	$35,000	$25,000	$35,000	$28,000
7	Spare Fuses	1	$10	$20	$10	$20	$13
8	Power System Installation Materials	1	$20	$40	$20	$40	$26
9	Samlex 1000W Inverter	1	$350	$450	$350	$450	$380
10	Samlex SEC1230-UL Battery Charger	1	$200	$300	$200	$300	$230
11	100ah 12v Non Spillable Backup Battery	1	$250	$350	$250	$350	$280
12	DC Voltage Monitoring Device	1	$40	$60	$40	$60	$46
13	Unmanaged Rack Mount PDU (6O)	1	$35	$45	$35	$45	$38
14	Tower Site Land Clearing and Site Development	1	$7,500	$12,500	$7,500	$12,500	$9,000
15	Tower Construction Labor	1	$25,000	$32,000	$25,000	$32,000	$27,100
16	Cabinet Installation Labor	1	$600	$1,000	$600	$1,000	$720
17	Power System Installation Labor	1	$300	$500	$300	$500	$360
18	Generator Installation Labor	1	$1,250	$1,700	$1,250	$1,700	$1,385
19	FCC License Coordination	3	$750	$1,500	$2,250	$4,500	$2,925
20	Dragonwave Horizon Quantum 11GHz Link (includes below)	3	$19,500	$22,500	$58,500	$67,500	$61,200
21	Horizon Quantum Radio		$0	$0	$0	$0	$0
22	Dragonwave 4' to 6' dish		$0	$0	$0	$0	$0
23	Coaxial Cabling		$0	$0	$0	$0	$0
24	Dragonwave Power Supply		$0	$0	$0	$0	$0
25	DPRM - Dual Pol Radio Mount		$0	$0	$0	$0	$0
26	Tower Site Switch	1	$1,700	$2,300	$1,700	$2,300	$1,880
27	Ubiquiti Access Point + 120° Sector	3	$375	$500	$1,125	$1,500	$1,313
28	Construction Total:				$133,255	$174,765	$145,708
29	Project Management, Network Engineering, Testing						$36,430
30	Site Engineering, Surveying, Etc.						$7,500
31	Misc Fees, Technical Services						$10,000
32	Contingency						$19,970
33	TOTAL:						$219,608

180' Tower Cost Estimate with Four Backhaul Links

This cost estimate includes the cost of both point to point backhaul radios to connect the tower to four other towers in the network and the cost of the local access radios that would deliver service to nearby businesses and residents. This is for a self-supporting tower, and a similar guyed tower would be somewhat less expensive.

1	ITEM/PROJECT	UNITS	COST (LOW)	COST (HIGH)	TOTAL (LOW)	TOTAL (HIGH)	BEST ESTIMATE (WEIGHTED AVERAGE)
2	Small Telecom Cabinet	1	$4,000	$6,000	$4,000	$6,000	$4,600
3	10kW Liquid Propane Generator	1	$4,000	$6,000	$4,000	$6,000	$4,600
4	Cabinet Foundation and Installation	1	$1,000	$1,500	$1,000	$1,500	$1,150
5	New Power Service / Installation	1	$1,250	$3,000	$1,250	$3,000	$1,775
6	Tower Construction Materials	1	$25,000	$35,000	$25,000	$35,000	$28,000
7	Spare Fuses	1	$10	$20	$10	$20	$13
8	Power System Installation Materials	1	$20	$40	$20	$40	$26
9	Samlex 1000W Inverter	1	$350	$450	$350	$450	$380
10	Samlex SEC1230-UL Battery Charger	1	$200	$300	$200	$300	$230
11	100ah 12v Non Spillable Backup Battery	1	$250	$350	$250	$350	$280
12	DC Voltage Monitoring Device	1	$40	$60	$40	$60	$46
13	Unmanaged Rack Mount PDU (6O)	1	$35	$45	$35	$45	$38
14	Tower Site Land Clearing and Site Development	1	$7,500	$12,500	$7,500	$12,500	$9,000
15	Tower Construction Labor	1	$25,000	$32,000	$25,000	$32,000	$27,100
16	Cabinet Installation Labor	1	$600	$1,000	$600	$1,000	$720
17	Power System Installation Labor	1	$300	$500	$300	$500	$360
18	Generator Installation Labor	1	$1,250	$1,700	$1,250	$1,700	$1,385
19	FCC License Coordination	4	$750	$1,500	$3,000	$6,000	$3,900
20	Dragonwave Horizon Quantum 11GHz Link (includes below)	4	$19,500	$22,500	$78,000	$90,000	$81,600
21	Horizon Quantum Radio		$0	$0	$0	$0	$0
22	Dragonwave 4' to 6' dish		$0	$0	$0	$0	$0
23	Coaxial Cabling		$0	$0	$0	$0	$0
24	Dragonwave Power Supply		$0	$0	$0	$0	$0
25	DPRM - Dual Pol Radio Mount		$0	$0	$0	$0	$0
26	Tower Site Switch	1	$1,700	$2,300	$1,700	$2,300	$1,880
27	Ubiquiti Access Point + 120° Sector	3	$375	$500	$1,125	$1,500	$1,313
28	Construction Total:				$153,505	$198,765	$167,083
29	Project Management, Network Engineering, Testing						$41,780
30	Site Engineering, Surveying, Etc.						$7,500
31	Misc Fees, Technical Services						$10,000
32	Contingency						$22,640
33	TOTAL:						$249,003

180' Tower Cost Estimate with Five Backhaul Links

This cost estimate includes the cost of both point to point backhaul radios to connect the tower to five other towers in the network and the cost of the local access radios that would deliver service to nearby businesses and residents. This is for a self-supporting tower, and a similar guyed tower would be somewhat less expensive.

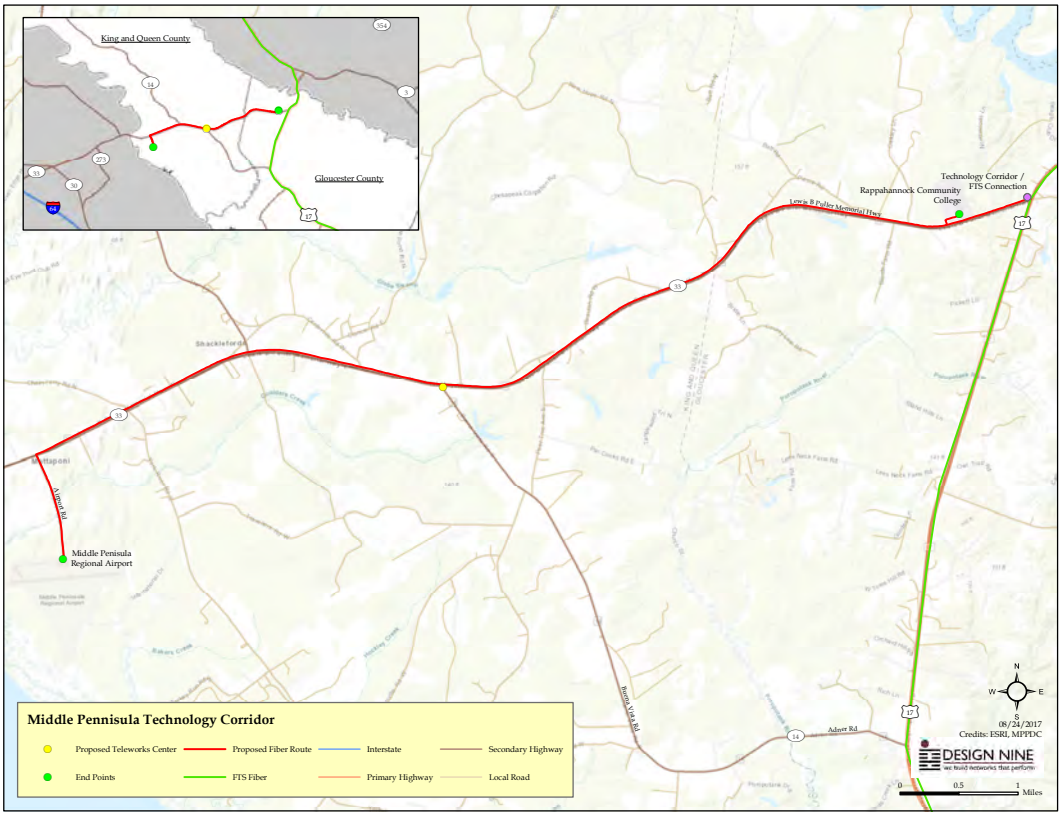
1	ITEM/PROJECT	UNITS	COST (LOW)	COST (HIGH)	TOTAL (LOW)	TOTAL (HIGH)	BEST ESTIMATE (WEIGHTED AVERAGE)
2	Small Telecom Cabinet	1	$4,000	$6,000	$4,000	$6,000	$4,600
3	10kW Liquid Propane Generator	1	$4,000	$6,000	$4,000	$6,000	$4,600
4	Cabinet Foundation and Installation	1	$1,000	$1,500	$1,000	$1,500	$1,150
5	New Power Service / Installation	1	$1,250	$3,000	$1,250	$3,000	$1,775
6	Tower Construction Materials	1	$25,000	$35,000	$25,000	$35,000	$28,000
7	Spare Fuses	1	$10	$20	$10	$20	$13
8	Power System Installation Materials	1	$20	$40	$20	$40	$26
9	Samlex 1000W Inverter	1	$350	$450	$350	$450	$380
10	Samlex SEC1230-UL Battery Charger	1	$200	$300	$200	$300	$230
11	100ah 12v Non Spillable Backup Battery	1	$250	$350	$250	$350	$280
12	DC Voltage Monitoring Device	1	$40	$60	$40	$60	$46
13	Unmanaged Rack Mount PDU (6O)	1	$35	$45	$35	$45	$38
14	Tower Site Land Clearing and Site Development	1	$7,500	$12,500	$7,500	$12,500	$9,000
15	Tower Construction Labor	1	$25,000	$32,000	$25,000	$32,000	$27,100
16	Cabinet Installation Labor	1	$600	$1,000	$600	$1,000	$720
17	Power System Installation Labor	1	$300	$500	$300	$500	$360
18	Generator Installation Labor	1	$1,250	$1,700	$1,250	$1,700	$1,385
19	FCC License Coordination	5	$750	$1,500	$3,750	$7,500	$4,875
20	Dragonwave Horizon Quantum 11GHz Link (includes below)	5	$19,500	$22,500	$97,500	$112,500	$102,000
21	Horizon Quantum Radio		$0	$0	$0	$0	$0
22	Dragonwave 4' to 6' dish		$0	$0	$0	$0	$0
23	Coaxial Cabling		$0	$0	$0	$0	$0
24	Dragonwave Power Supply		$0	$0	$0	$0	$0
25	DPRM - Dual Pol Radio Mount		$0	$0	$0	$0	$0
26	Tower Site Switch	1	$1,700	$2,300	$1,700	$2,300	$1,880
27	Ubiquiti Access Point + 120° Sector	3	$375	$500	$1,125	$1,500	$1,313
28	Construction Total:				$173,755	$222,765	$188,458
29	Project Management, Network Engineering, Testing						$47,120
30	Site Engineering, Surveying, Etc.						$7,500
31	Misc Fees, Technical Services						$10,000
32	Contingency						$25,310
33	TOTAL:						$278,388

Fiber Technology Corridor estimate

The Middle Peninsula Technology Corridor fiber would be anchored by the Telework Center, Rappahannock Community College (RCC), and the Middle Peninsula airport. The PamunkeyNet colocation facility would be located in secure space in the Telework Center, and would serve as a meet-me point for service providers, and would have additional rack space available for lease by public and private interested parties who need secure off-site space for servers, data backup, and other uses.

The fiber will continue past RCC to meet FTS fiber on route 17. Meeting FTS would give PamunkeyNet a reliable and redundant fiber connection to Norfolk and D.C.—where inexpensive sources of Internet backhaul will be available—FTS has a fully redundant fiber ring around the Bay. The fiber-enabled Technology Corridor will give the Middle Peninsula essential economic development tools:

- A local fiber backbone that provides ten miles of Gigabit service availability that can be used to attract high technology companies to the region.
- A high performance connection out of the region with a fully redundant backhaul connection that will be of great interest to relocating companies.



The cost tables below provide a pre-engineering estimate of the cost of construction 10.4 miles of underground fiber construction along Route 33. Handholes would be placed every four hundred feet for convenient customer fiber access (shorter fiber drops at less cost). Both business and residential Gigabit fiber connections would be available to any location along the entire route. The standard customer connection for both business and residential customers would be a Gigabit of bandwidth, and both GPON and Active Ethernet services can be offered. Active Ethernet is particularly important so that business class/carrier class services can be offered on the network.

The network can be extended easily in either direction (east or west) with additional fiber segments, and any additional fiber switch capacity required would be placed in the Telework Center colo facility. The network will support 10Gig, 100Gig, and light path services as requested by larger and enterprise business customers.

With the connection to the FTS fiber on Route 17, the Technology Corridor will be able to offer businesses whatever amount of bandwidth they need to compete globally at affordable prices, giving the Middle Peninsula the network needed for economic growth and jobs attraction.

Middle Peninsula Technology Corridor - Route Overview

0	ITEM/PROJECT	VALUE
1	Miles of Fiber / Conduit Installed	10.4
2	Number of Handholes Installed	92
3	Splice Closures Installed	31
4	Cabinets Installed	0
5	Number of Customers Connected	48

Middle Peninsula Technology Corridor - Cost Summary

0	ITEM/PROJECT	ESTIMATED
1	Middle Peninsula Technology Corridor - Construction Materials	$188,378.00
2	Middle Peninsula Technology Corridor - Distribution Labor	$617,110.00
3	Middle Peninsula Technology Corridor - Drop Construction	$100,920.00
4	Network Construction Subtotal	$906,408.00
5	Project Management, Network Engineering, Integration, and Testing	$147,651.60
6	Engineering, Permitting (15% of construction costs)	$57,200.00
7	Misc Fees, Advertising, Technical Services	$10,000.00
8	Bookkeeping and Administration	$2,500.00
9	Other Costs Subtotal	$217,351.60
10	Project Total	$1,123,759.60
11	Contingency at 10%	$112,375.96
12	Gigabit fiber backbone Total (with contingency)	$1,236,135.56

Colocation Facility Cost Estimate

If space is allocated at the Telework Center, it would be an ideal location for a colocation facility and meet-me point. Two hundred fifty to five hundred square feet would be entirely adequate. The room would require 24/7 controlled access from an exterior door, dedicated HVAC (primarily enhanced cooling), some battery back up UPS (Uninterruptible Power System), and outdoor space adjacent to the room for a small generator to provide power during an extended power outage.

The space could be 250 to 500 square feet, and would be initially provisioned with six enclosed racks. PamunkeyNet equipment would use less than one rack, leaving five additional racks of leasable space. The facility costs also include the network equipment required to support up to 48 fiber customers with Gigabit service. There would be ample space to increase capacity with additional fiber switches, and 1000 or more fiber customers could be easily served out of the facility.

The facility would also be used to house servers and other equipment needed to support the wireless network. Dedicated redundant Juniper core routers would provide routing and access to service providers selling Internet and other services on the network.

1	ITEM	UNITS	BEST ESTIMATE (WEIGHTED AVERAGE)
2	Network Room fit up in Telework Center	1	$22,500.00
3	Network Room Lighting / Electrical Fit-up	1	$14,500.00
4	Dedicated Network Room Cooling - Split Mini Unit 24k BTUs	2	$6,000.00
5	Enclosed Rack	6	$5,250.00
6	Patch Panel (144 port)	2	$7,500.00
7	New Power Service / Installation	1	$4,000.00
8	Unmanaged Rack Mount PDU (6O)	12	$1,200.00
9	Patch Cables (POP)	48	$936.00
10	Calix 48V DC System Retrofit Kit	1	$1,700.00
11	Calix E7-2 Chassis	2	$1,650.00
12	Calix E7-2 GE-24 Card	4	$17,500.00
13	Calix Advantage System Support and Maintenance (1 year)	1	$3,000.00
14	CMS Server	1	$3,750.00
15	Dell Server	1	$3,000.00
16	Juniper core router for service provider network access	2	$25,000.00
17	Rack Mount UPS (AC)	2	$1,450.00
18			$118,936.00

Gigabit Fiber on the Pamunkey Reservation

For the fiber to the home project on the Pamunkey Reservation, fiber will be deployed to the premises in the cluster of homes and community buildings in the area around the Pamunkey Indian Museum (about 40 homes and community buildings). A wireless tower will provide high performance Internet backhaul connectivity to the local fiber.

The map below shows the area where approximately 6.5 miles of fiber will be installed underground, connecting 34+ homes and several community buildings, including the Museum. The Gigabit fiber infrastructure will provide the tribe with a state of the art network and a long term asset that will support telemedicine and telehealth services, distance learning and access to college classes, jobs from home, and businesses from home.

The table on the next page provides a breakdown of costs. For the wireless backhaul, one of the towers in the previous cost estimate will be installed at an appropriate location and be connected to the local fiber.

Pamunkey Reservation FTTH Cost Summary

0	ITEM/PROJECT	ESTIMATED
1	Pamunkey Reservation FTTH Construction Materials	$57,246.16
2	Pamunkey Reservation FTTH Distribution Labor	$254,528.00
3	Pamunkey Reservation FTTH Structures, Cabinets, and Equipment	$38,311.00
4	Pamunkey Reservation FTTH Drop Construction	$46,800.00
5	Network Construction Subtotal	$396,885.16
6	Project Management, Network Engineering, Integration, and Testing	$59,532.77
7	Engineering, Permitting	$35,750.00
8	Misc Fees, Advertising, Technical Services	$10,000.00
9	Bookkeeping and Administration	$2,500.00
10	Other Costs Subtotal	$107,782.77
11	Project Total	$504,667.93
12	Contingency at 10%	$50,466.79
13	Project Total (with contingency)	$555,134.73

Summary Project Cost Estimate

The first table below shows both a "worst case estimate" if no existing towers are available other than what is available with the existing five towers in the King and Queen network and a more likely estimate using some existing tower space (e.g. public safety towers). If approximately 30% of the 22 estimated towers are available for use at a reasonable fee (or no fee) and are in locations that provide appropriate coverage, we estimate that the total cost for tower construction and tower enhancement would be approximately $3.4 million.

Tower Type	Number of Towers	Per Tower Construction	Totals
Two backhaul links	7	$190,223	$1,331,561
Three backhaul links	10	$219,608	$2,196,080
Four backhaul links	4	$249,003	$996,012
Fiver backhaul links	1	$278,333	$278,333
Total estimate for all new towers	22		$4,801,986
Estimated total using 30% existing towers			$3,361,390
Customer radio fund for 500 new customers			$87,500
Total wireless expansion cost			$3,448,890

The table below summarizes the costs of the three portions of the network, along with a recommended operational reserve for the first two years of operations.

Region-side wireless expansion (some use of existing towers)	$3,448,890
Technology Corridor Gigabit fiber backbone	$1,236,136
Telework Center colocation facility	$118,936
Pamunkey Reservation FTTH project	$555,135
PamunkeyNet two year operational reserve	$500,000
Total	$5,859,096

Neighborhood Utility Pole Access Costs

A single wooden utility pole with a wireless connection to a 180' tower and local access radios could provide access to any residence with line of sight within a half mile or more. This would spread the cost of pole construction and equipment costs across several households or businesses. There are many rural areas in the Middle Peninsula region where there is a cluster of homes along a relatively short stretch of road. All of those homes could share the use of a single local utility pole access site.

V1	VARIABLE	VALUE	NOTES
V2	Weight Variable	5	0-10 scale used in Best Estimate column (10 is best)
V3	Towers	1	Number of Towers
V4	Height	60	Tower Height
V5	Type	Wooden Utility Pole	Tower Type
V7	Backbone Radio System Licensed / Un-licensed	Un-licensed	
V8	Backbone Links	1	
	Site Development (Average)	1,000	

1	ITEM/PROJECT	UNITS	COST (LOW)	COST (HIGH)	TOTAL (LOW)	TOTAL (HIGH)	BEST ESTIMATE
2	Site Development (Clearing, Road Improvements, etc.)	1	- n/a -	- n/a -	- n/a -	- n/a -	$1,000
3	3x3 NEMA Box	1	$300.00	$600.00	$300.00	$600.00	$450
4	New Power Service / Installation	1	$500.00	$1,250.00	$500.00	$1,250.00	$875
5	60' Wooden Utility Pole Construction Materials	1	$2,500.00	$3,500.00	$2,500.00	$3,500.00	$3,000
6	Spare Fuses	1	$10.00	$20.00	$10.00	$20.00	$15
7	Power System Installation Materials	1	$20.00	$40.00	$20.00	$40.00	$30
8	Samlex 1000W Inverter	1	$350.00	$450.00	$350.00	$450.00	$400
9	Samlex SEC1230-UL Battery Charger	1	$200.00	$300.00	$200.00	$300.00	$250
10	100ah 12v Non Spillable Backup Battery	4	$250.00	$350.00	$1,000.00	$1,400.00	$1,200
11	DC Voltage Monitoring Device	1	$40.00	$60.00	$40.00	$60.00	$50
12	Unmanaged Rack Mount PDU (6O)	1	$35.00	$45.00	$35.00	$45.00	$40
13	60' Wooden Utility Pole Construction Labor & Contracting	1	$2,000.00	$3,000.00	$2,000.00	$3,000.00	$2,500
14	Power System Installation Labor	1	$300.00	$500.00	$300.00	$500.00	$400
15	Ubiquiti IsoBeam PTP System	2	$200.00	$400.00	$400.00	$800.00	$600
16	Ubiquiti Access Point + 120° Sector	3	$375.00	$500.00	$1125.00	$1500.00	$1,313
17	Total:				$8,780.00	$13,465.00	$12,122.50

Planning for Tower Development

New Tower Siting Considerations

There are many factors in choosing sites to develop for towers. The cost of site prep in an area with unfavorable conditions can quickly outweigh the cost of the actual tower.

Site work - Land acquisition and leases are not included in tower estimate. Site preparation is estimated and assumes a typical site with some small vegetation and work needed. If a site will require more extensive land clearing or road improvement work it should be estimated on a site by site basis.

Generator - a small liquid propane generator is included in the estimate for this tower. The estimate does not include a tank and tank install because in our experience this cost is typically covered by the local gas company as long as there is a service contract.

Cellular Carriers and Upgrades - Towers at this size must be specifically engineered for their location and equipment load. The pricing shown above is estimated at a size which will support one cell provider, and WISP/Public Safety equipment. Designing to accommodate multiple cellular providers should be expected to increase the cost by $7,500 to $15,000.

- Favorable site leasing or purchasing conditions such as county properties, infrastructure sites, industrial areas, or areas with other towers.
- The site must be useful to the network from the wireless engineering standpoint. Evaluate how the new site will fit into the wireless network and determine if it desirable early in the process.
- Proposed tower sites should be close to a road and accessible by truck. Improving access to a site and repairing damage caused by construction is expected, but constructing new roads on a site will increase costs dramatically.
- Proposed sites should be close to grid power. While evaluating a site locate the nearest utility poles or pedestals. If there is no transformer near the site, within 500 feet, there will likely be higher costs to bring power in.
- Mostly flat, or gently sloping sites cost less to develop than sites with steep terrain. When considering tower sites look for flat areas to place the tower and compound. It may be worth sacrificing some altitude or doing some additional clearing to avoid major ground disturbances and earth work.
- It is common to clear some trees and vegetation while developing a tower site, but excessive clearing requirements will raise costs. If sites are in a wooded area look for locations where vegetation is sparse and the tree growth is somewhat young (e.g., 8-10" in diameter). Large trees or very dense brush will be more expensive to clear.
- Look for secure sites with limited access. Sites are better off in an area that doesn't get frequent visitors.

- Look for tower sites with the potential to connect to fiber networks. Access to multiple fiber providers on a wireless network will be very important to potential tenants and the economic viability of the network.

Things to avoid

- Avoid dense residential areas and retail areas when evaluating tower sites.
- Avoid parcels with creeks or other water features that could be an impediment to construction.
- Large concrete trucks will have to access the site while constructing the towers. During site evaluation consider the entire route that trucks will have to take.
- Avoid locating tower sites near areas where permitting could be an issue. Historic Districts, airports, scenic locations, and areas with strict zoning should be avoided.

Funding Options

The relatively low cost of tower upgrades and new tower construction suggests the most expedient funding is direct financial support from the Project. If grant funds are needed (e.g. several new towers are proposed), working with public safety officials to combine public safety grant opportunities and public safety capital funds could be very beneficial.

Operation and Management Considerations

Towers are passive infrastructure, and if properly designed and constructed, require minimal maintenance. If the tower is shared with public safety users, those agencies will install their own radios, antennas, and electronics, which could relieve the Project of any responsibility for equipment management and configuration, and equipment repairs and replacement. A contract with a qualified tower maintenance and tower climbing firm will be required to do tower climbs and repairs to equipment on the tower.

Recommendation and Next Steps

An preliminary analysis of existing county towers and potential county-owned sites for new towers suggests that good coverage could be obtained with careful site analysis. If the Project moves forward, line of sight and viewshed studies are recommended for existing towers and for any possible new sites.

Next steps would include securing funding, line of sight and viewshed analysis of existing sites, identification of county-owned property for new towers, line of sight and viewshed analysis of the new sites, determination of tower type for new towers (guyed or self supporting), and discussions with service providers. final identification of sites, complete detailed network engineering including site layouts and Line of Sight engineering, and work with public safety officials.

Typical Construction Schedule

The timeline and activities describe the typical process for constructing a tower. Combining multiple sites into a single construction project will expand the timeline below but overall will save

time and expense. Delays in the site identification and procurement stages of a project are the most common delays for counties and cities.

- *Month One*
  - Project kick-off
  - Site identification
  - Network design
  - Prep work and site plan development needed for permitting

- *Month Two*
  - Pre-construction site planning
  - Lease / MOU negotiation
  - Procurement
  - Submission of permit application

- *Month Three*
  - Processing of permit applications, public meetings and ballon tests as needed.
  - Permit approval
  - Submission of purchase orders for tower, radios, equipment.

- *Month Four-Five*
  - Site clearing and preparation
  - Tower materials shipping
  - Foundation construction
  - Inspection
  - Tower construction
  - Construction wrap-up

- *Month Six*
  - Equipment installation and network testing
  - Tower is put in service

Creating the Enterprise

The Middle Peninsula Broadband Network (PamunkeyNet) will be operated as an independent entity owned by the Pamunkey Tribe. This will provide the network with two important requirements:

- The enterprise will have the business and management flexibility needed to make decisions efficiently and effectively in the fast-moving broadband business environment.
- As a Pamunkey enterprise, it will be vested in the community and can be managed on behalf of the broader community and economic development goals of the community.

The network will be operated as a single high performance hybrid wireless and fiber optic network available to any and all service providers, including incumbent providers who want access to the significant market opportunity represented by the network. This shared business model is fundamentally different from the twentieth century copper-based networks where each provider has to build and operated a completely duplicated network (i.e. two providers each build a separate and duplicated network to reach the same customers, which results in higher costs across the board for customers).

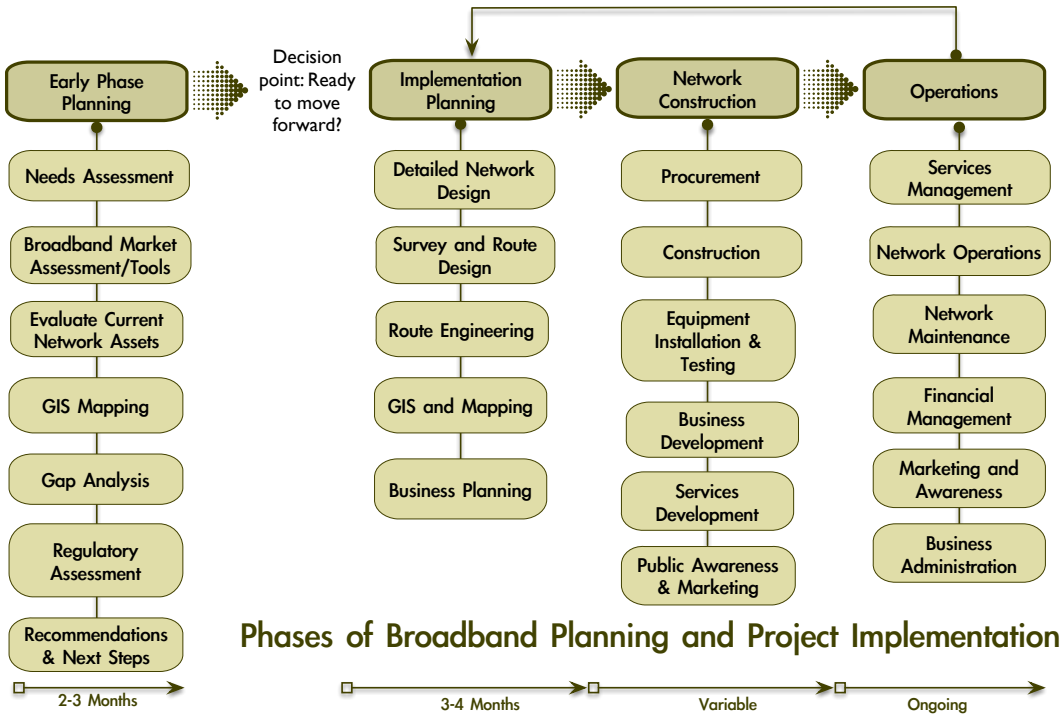
The Project will have several essential roles:

- ***Contract and Staff Management*** - The Project will hold contracts for outsourced network operations, outsourced network repairs and maintenance, outsourced construction of network extensions, and service provider contracts for the services offered on the network. The Project will need a small number of staff, but the scope of the network should minimize staff requirements.
- ***Financial Management*** - The Project will be responsible for the financial oversight of the network. The routine bookkeeping and accounting will likely require, at most, a full time bookkeeper and a part time or full time billing clerk.
- ***Public Awareness*** - The Project will need to maintain a modest, ongoing public awareness campaign to ensure that residents and local businesses are aware of the opportunity to obtain higher performance, broadband services from the Project. The Project will need a sharp focus on name and brand awareness in the Middle Peninsula region to be successful.
- Project Development/Management - As funding sources are developed for individual network projects, the Project will provide financial and project oversight of these projects during the implementation and construction phase.

For the Project, the development of a successful Pamunkey-owned network will require attention in several areas including the technical (network equipment selection), engineering and construction, and business and financial planning. It is important to note that the business and financial planning are critical elements that will in large part determine the long term success of the effort. This section provides an overview of the key task areas and activities.

The illustration below shows the sequence of key phases and activities in the course of a network project. On the pages following this diagram is more detailed information about the individual

tasks and activities that will lead to successful completion of a fully operational network, including the business processes required.



To be successful, the Project requires a plan that ensures the right resources are available at the appropriate times during the various phases of development. Some resources must be identified and procured during the planning phase, some during the implementation and construction phases, and some during the operations phase.

Financial Planning – Financial planning includes the development of short term and long term budget estimates and pro-formas. These materials form the basis of developing a funding plan, as well as providing a solid base for ongoing evaluation of the success of the enterprise.

Business Model – The business model selected determines the kind and type of revenue that will be generated by the project, and also affects the kind and type of expenses that are incurred. Following the King and Queen business model, the Project will provide retail broadband Internet service purchased on a wholesale basis from a private sector Internet provider.

Legal Counsel – Whether the retail or wholesale business model is chosen, there is a short term and long term need for legal counsel familiar with telecom and broadband business agreements and contracts. Well written contracts with construction companies, wholesale Internet providers, and other contractors protect the Project.

Engineering – For new tower sites, engineering services will be required to prepare site plans, manage the permit process paperwork, provide support where public meetings are provided prior to permit approval, and to handle other tower site work (e.g. balloon tests). Where fiber

cable is being deployed, if it is hung on utility poles or placed underground in conduit, prior to construction, the routes must be surveyed and engineered drawings must be developed to meet DOT (Dept. of Transportation) requirements and to provide contractors with the information needed to construct the network to industry and state technical requirements.

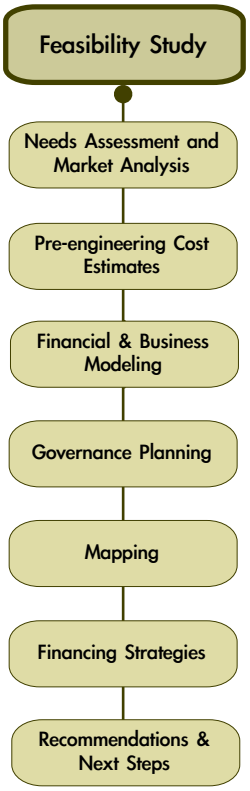
Network Design – The logical design of the network must be matched to expected public and private uses (e.g. support for shared public safety use, business uses, K12 use, residential and small business use). The network design must also meet the requirements of large and small businesses, and for large businesses with extensive broadband and data needs, the network must be capable of meeting both current needs and future growth.

Equipment – Once a network design is complete, an evaluation of equipment vendors must take place, ideally via a bidding process to ensure that the selected equipment will meet all of the business and technical requirements of the network, at the best possible price. A Total Cost of Ownership (TCO) evaluation should be completed to ensure that the right initial price is balanced with the longer term costs of extended warranties and technical support. The least expensive purchase price for equipment may be more expensive over time than equipment from a vendor with a higher initial equipment cost but lower support and warranty fees.

Build Out – While community network build outs are generally much less expensive than other typical community projects like water and sewer development, care must be taken to select contractors with the appropriate experience constructing towers or installing fiber. The cost of construction can vary widely, so the development of very specific bid documents that include the right engineering information as well as a carefully structured proposal response on pricing is needed to ensure the community obtains the right contractor at the right price.

Early Phase Planning

The work in this report represents some of the activities of the early phase planning. The early phase work should include:



Needs Assessment and Market Analysis – An evaluation of current assets and projections of future needs, based on local business and economic conditions. Design Nine is working with the PDC and the counties to map existing tower and fiber assets, incorporate the logical and physical King and Queen network into a regional design, and to perform propagation studies to identify where towers should be located to maximize Internet access regionally.

Pre-engineering Cost Estimates – Pre-engineering cost estimates of potential network projects provide a baseline for understanding the costs of getting started, provide necessary inputs to the financial pro forma development, and also inform funding strategies.

Financial and Business Modeling – A ten year financial pro forma, using inputs from the business requirements analysis and the cost estimates, provides an early test of the financial sustainability of the project and provides a long term road map for financial management.

Governance Planning – Before making a commitment to move to implementation planning, it is necessary to have a basic understanding of the key operations and management tasks related to operating the enterprise.

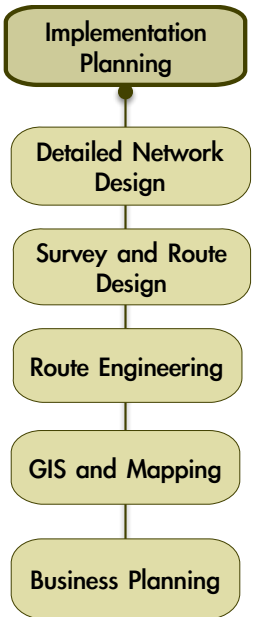
Mapping – Mapping of current assets, areas and business locations of needs, economic growth areas, and key customers and stakeholders informs the development of the network architecture and the financial pro forma.

Funding Strategies – Before moving to the next steps, it is vital to understand where the planning, engineering, and initial construction funds will come from. There are many options available.

Next Steps – A list of key activities and milestones needed to move the project ahead.

Implementation Planning Phase

This phase produces the equipment and construction specifications needed to bid out the work of constructing new network assets (e.g. towers, access radio equipment, backhaul radios and frequencies, etc.).



Business and Financial Planning – The Project Manager and Network Integrator perform detailed business and financial planning. This includes planning how the business front office and back office will be run.

Governance Model - The formal governance model is determined and legal arrangements between governing entities are negotiated and contracts signed. For PamunkeyNet, the tribe would probably form a tribe-owned LLC with a governing board and/or partners like the MPPDC.

Funding Sources - Funding sources are identified and fun raising commences. Partner agreements which may include network resources (IRUs) or dividends from network income are determined.

Business Administration Planning - Determining how the actual network business will be operated is determined at this time. Front and back office operating models are identified, outsourced business functions are identified and planned.

Tower Site and/or Route Engineering – An on the ground survey is needed to complete tower layouts and a final site/route design. This work is performed by an engineering firm that also has the responsibility to produce the engineered design and obtain required permitting. The field survey confirms that the final route can be built to the necessary standards and regulations.

Construction Methodology (Design vs. Design/Build) - One method to shorten the design and build phases of a project are to award up front a "design build" contract where the engineering firm is also responsible for construction. This approach can shorten this part of the project significantly and is often recommended for projects where time is of the essence.

Engineered Drawings and Cost Estimates – The full set of engineered drawings or site plan and tower specifications is attached to the construction bid documents and becomes the basis for the awarded construction contract.

Permitting - The engineer or design/build firm will prepare all required permit forms and submit the permits with the plans. Some permits will require that Project pay a fee to the permitting entity. It is important to start the permitting process early to avoid delays.

Network Architecture Design (Detailed) – Final analysis of vendor equipment is performed and selection is made.

Equipment Selection -Analysis is performed to determine which equipment offers the lowest Total Cost of Ownership (typically analyzed over ten years or more).

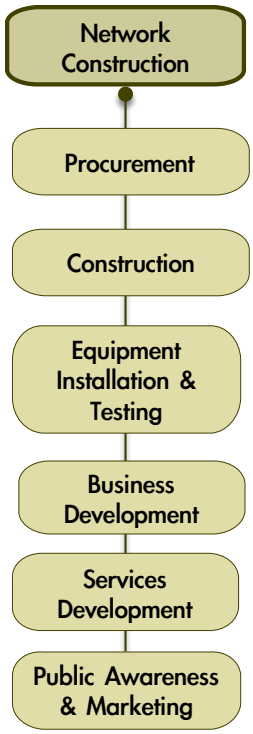
Detailed Network Architecture - The detailed network design starts with the completed network architecture and completely specifies all of the equipment, cabinets, patch cables,

power supplies, radios, batteries, and all other necessary parts and equipment needed to create a functional network. The output is a complete Bill Of Materials (BOM) used to create purchase orders for equipment, as well as specifications for the configuration of routers and switches.

Equipment and Materials Specifications – The engineering or design/build firm also completes a detailed list of all equipment required for the construction. Bill Of Materials includes all wireless equipment, fiber, conduit, handholes, fiber splice enclosures, and related hardware needed to install the fiber cable underground and/or on utility poles.

Construction Phase

The documents produced in the Implementation Phase are used to bid out the construction work and to procure the network equipment needed to produce an operational network.



Procurement – At the beginning of the construction phase the Project will bid out the project construction.

- Construction Contracts - Multiple contractors may be involved depending on how the engineering and construction documents were planned in earlier phases.
- Other Physical materials - The network integrator will also be responsible for procuring all physical assets not the responsibility of the construction contractors which may include shelters, cabinets, generators.
- Network Equipment - All network equipment such as servers, switches, and routers must be purchased and tracked.
- Operating Contracts - If outsourced business functions are to be used, the agreements have to be drafted and qualified outsourced firms need to be selected.

Construction Management – The construction work is bid out and an award is made to a qualified contractor with the best price. It is common to negotiate the final cost of this work once a firm has been selected.

- Engineering Inspection - Depending on how the construction contracts were awarded will determine if the engineering firm is responsible for inspecting the contractors work performed during construction.

Network Equipment Installation – Network equipment is ordered from a vendor that meets the technical specifications. Equipment must be tested, installed in cabinets or shelters, powered up, and connected to the fiber cable. After installation and

- Staging - The site where equipment will be installed must be designed with the correct power circuits, racks, and grounding for equipment. Cable trays and other accessories will be installed to accommodate the physical connections to equipment.
- Installation - Equipment must be configured which may involve staging in a laboratory or bench. Once on site equipment will be installed in the racks, and the physical cable connections made. Equipment will then be powered up and can be configured.
- Configuration/Integration - Prior to installation equipment can be pre-configured in a lab or staging area. After installation the initial configuration is completed or confirmed and con-

nections to other network equipment is tested. Adding one device can require modifications to the configuration throughout the network.

- Testing - When equipment is installed and configured, end to end network testing of the equipment must be completed. Testing will confirm that network elements are communicating properly. Testing is required not only when new network elements are installed, but also when new services or features are configured on the network.

Business Process Development – During the construction phase, business and operational decisions must be made to produce a set of business processes that will guide the day to day operations of the network.

- A business process will be developed for essentially all recurring activities on the network, including new customer provisioning, service provider billing, utility locating, processing invoices, and so on.
- Some functions can be outsourced to create local private sector jobs (e.g. field maintenance, utility locating).
- Internal processes overlapping with the network configuration will be created for new customers joining the network, and the definition of new services.
- Legal contracts and other related business documents must be developed as part of this process.

Services Development– Negotiations with qualified service providers continues.

- Additional development and specification of the Master Agreements and Service Level Agreements (the contracts between the network and the Service Providers) are finalized
- The network and the providers enter into contractual agreements.
- Wholesale Internet providers will work with the Network Operator to define services and configure the delivery of the service over the network.

Contracts, Agreements, and Leases – The construction phase will generate the need for a variety of legal documents. Some will be related directly to the construction (e.g. an easement agreement to have conduit cross property)

- Typical documents include the development of the Master Network Agreement that is used to sign service providers to the network. Other contracts would include the development of a draft network operations agreement if network operations is outsourced, and a similar agreement for outside plant maintenance and repairs.

Marketing and Public Awareness – As the network is constructed, a modest but ongoing public awareness and publicity effort is required to ensure that business customers, schools, local government agencies and other potential users of the network are aware of the project and the possibility of reducing costs and obtaining more and better services.

Operational Considerations

As construction is approaching completion PamunkeyNet must begin to put the human resources and business processes in place to support, monitor and maintain the network.

The goal is to create a financially sustainable tribal enterprise that over the long term creates good-paying jobs for Pamunkey tribe members. During the first two or three years, a training period will be needed to train tribe staff and to ensure that they have the business, operations, and maintenance experience to support the enterprise. During that time, one or more third party firms may be needed on a contract basis to provide some of the operations and maintenance functions of the network. Any companies contracted for support should be under contract at least two to three months before the first customer comes online.

Network Monitoring – The Project will need on or two months of testing and configuration before the first customer is brought online. This time will be spent configuring monitoring equipment, configuring alerts, setting up internal processes, and bringing NOC (Network Operations Center) staff up to speed on the new environment.

Outside Plant Maintenance – As soon as the contractor completes construction the Project will be responsible for maintaining the network. Some responsibilities such as utility locating, fiber repairs, and maintenance of generators, HVAC systems, and other assets will begin before the network is under full operations.

Internet Service – As the Project signs on wholesale Internet providers they will need time to bring their connections into the co-lo, install equipment, and configure their network for the new services. If construction is involved this process could take several months.

Going Beyond Internet Service

Even though the Network is will start with just Internet service, the network will become more valuable and useful to businesses and residents of the region if additional services are offered over time. These can either be new "traditional" services (VoIP telephone, IPTV) or can be niche services like security (e.g. closed circuit video), healthcare, gaming or any other service which can be delivered over the network.

Overview of Roles and Responsibilities

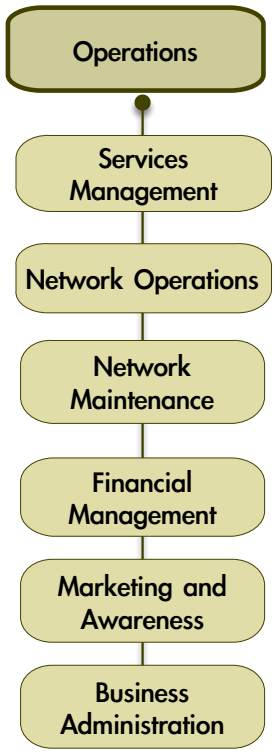
PamunkeyNet will have a range of roles and responsibilities. The table below provides a summary of key activities and responsibilities. Additional detail on the tasks and activities of the enterprise are discussed in more detail in the next section.

Activity	Responsibility
Financial Oversight	Enterprise Board
The Board will provide financial oversight and fiscal agency.	
Bookkeeping and Accounting	Enterprise Board
The network will generate a set of accounts payable and accounts receivable tasks, along with normal financial reporting (e.g. income statement, cash flow statement, balance sheet, etc.).	
Network Monitoring	Tribe or outsourced
The enterprise must have a 24/7 process in place to respond to emergency repairs. This can be based on alerts received from dark fiber users and/or active monitoring equipment put in place by the to provide additional alert capability independent of dark fiber customers.	
Break-Fix	Designated break-fix firm
The enterprise must have a contract in place for 24/7/365 emergency repairs to conduit and fiber.	
Equipment Replacement - scheduled	Enterprise staff
Routine and preventative maintenance on the passive network components will be occasional at best, but enterprise staff and/or a qualified fiber contractor must be able to make routine (scheduled) repairs.	
Utility Marking Services	Enterprise staff or third party locating service
The enterprise will have to be registered with the Virginia 811 service and must be prepared to manage locate requests (which have to be completed in a specified period of time. Enterprise staff could be trained to do the locates or a third party could provide this service.	
Site Maintenance	Enterprise staff
Enterprise staff will perform regular maintenance activities at the sites, including mowing, painting, replacing lights, and related maintenance.	
Network Operations	Enterprise staff
Enterprise staff must be able to respond to emergency break-fix alerts and be prepared to manage the repair process on nights and weekends.	
Inventory Management	Enterprise Staff
Enterprise staff will maintain an inventory of in-use conduit, fiber cable, handholes, and patch panel ports, and also maintain the spares inventory.	

Tier 2 Support	Enterprise staff
The enterprise must provide support to dark fiber lessees who report connectivity problems with their fiber strands.	
Tier 1 Support / Direct Customer Support	Enterprise staff
Service Providers provide end user support to their customers.	
End User Billing	Enterprise staff
Customers will get invoiced monthly.	
Sales to End Users	Enterprise staff
Service providers are responsible for selling their services to customer prospects, obtaining contracts, and providing Tier 1 customer support.	
Network Marketing and Awareness	Enterprise staff, PDC, localities
The Enterprise will develop and maintain a modest and ongoing public awareness and marketing effort to ensure that the Enterprise receives the maximum economic and community benefit from the network.	

Operations Areas of Responsibility

Once the Project has integrated the existing King and Queen network with new network assets, customers will begin (or continue) to receive service. At that point, the enterprise becomes operational and a variety of ongoing activities begin to take place.



Management and Oversight

The Enterprise needs a board of directors and a senior manager responsible for day to day oversight. The senior manager should have a strong business background with experience in successfully starting and managing new businesses.

Services Management

Services are a vital part of any Network. In essence the Service Providers are the customers of the network. The actual network end users (institutions, businesses, and residents) are the Enterprises's customers.

Network Operations

Operations can be managed in-house, but start-up networks sometimes find it less expensive to out-source operations to a qualified firm. Operations must include 24/7/365 activities, and it is generally better in the first several years, when the network is small, to use a service rather than bear the expense of several dedicated technical staff that would be needed to cover nights, weekends, holidays, and vacations.

Financial Management

The Enterprise will have to maintain a budget, pay contractors and staff, collect revenue, and bill for services provisioned on the network. Bills need to include a level of detail meaningful to customers. During the planning phase, the Enterprise needs to determine several items about billing such as partial month billing, credits for service outages, and credits for bad payers.

Monthly bills need to be created and sent to the service providers. Tracking payment and handing billing disputes needs to be performed. Often the NOC staff are responsible for creating the bills and handing billing inquiries while an accounting office is responsible for sending invoices and tracking payments. In the event of billing disputes the NOC staff, the customer (in most cases a Service Provider), and the accountant are involved in developing a remedy for a billing dispute.

Prudent and careful financial management is needed for accounts receivables and accounts payables, along with other normal bookkeeping activities--chart of accounts maintenance, bank deposits, check writing, and other related tasks. A part time bookkeeper may be an affordable solution in the early days of operations.

Accounting Budget Support

As the Open Network is a business enterprise, maintaining an operational budget is required. The network will have operational costs such as pole rentals, locate costs, annual equipment maintenance, electric bills, debt service, or other costs. Having an accounting office is often out of the reach of a small network so these functions can be completed by an outsourced company or even completed by NOC staff.

Marketing and Awareness

The Enterprise is responsible for marketing the network. Marketing incentives can be time based, geography based, or revenue based. While service providers will be responsible for their own marketing and sales efforts, an ongoing modest awareness/marketing campaign is required to ensure that customer take rate targets are met.

Annual Pricing Review

The Project should plan to have all tower leases renew around the same time so that it may review the market and make adjustments to the monthly lease rate if necessary. Working with providers before making any changes will be an important factors in meeting the Project's goals.

Network Operations Center (NOC)

Network Operations Center or NOC is a 24/7/365 staffed facility with many tools to manage, operate, debug and assist the NOC staff in identifying the root cause of issues reported, in monitoring network electronics, and to keep the network running smoothly. The NOC operators will be available during extended business hours (Monday-Friday, 8 AM to 8 PM) to deal with routine customer needs, and the NOC will provide 24/7/365 monitoring the network and connected customers for outages and follow up repairs. The NOC can be an outsourced remote center or can reside on the network.

Help Desk

The Enterprise is responsible for handling Tier 1 support to their customers--the network end users. This Help Desk is part of the NOC, and should be staffed to handle problems during both normal business hours and on nights and weekends.

Monitoring

One of the tools available to the NOC is software which monitors the active elements of the network. Some monitoring systems are available from the manufacturers of the network hardware, known as Element Management Systems (EMS), as well as systems which use standards-based software tools to monitor the network for problems. Monitoring takes a variety of forms, including a standard uptime monitor that periodically checks the status of the Network Elements as well as more sophisticated tools that monitor bandwidth, CPU cycles, temperature, fan speeds, etc.

Monitoring systems are useful not only during troubleshooting with a service provider or end user but as well as providing proactive capabilities to prevent problems or outages. As an example, a

sophisticated monitoring system could provide NOC technicians with alarms when bandwidth exceeds a set threshold, allowing the technician to take proactive actions to prevent an outage.

Ticketing

Trouble Ticketing or just Ticketing is a system or process that uses software to manage and track reported troubles, outages, orders, or questions submitted online via Web forms or via email and phone calls. NOC staff are responsible for tracking all tickets and timestamps as well as allowing the providers visibility into the system to see what action is being taken or what is planned for an outage or other problem that arises on the network.

Ticketing systems include Web based portals, text messaging tools, and e-mail based responders, and can receive and respond to tickets in a variety of ways including phone calls, emails, SMS, or other means.

Outage Reporting

When an outage is discovered via monitoring or a call to the Help Desk, outage reports can be broadcast to Service Providers or end users. This type of proactive reporting can reduce the burden of calls to the NOC by notifying the service providers of pre-existing outages.

Provisioning and Order Management

Provisioning is the act of setting up services on the network. Provisioning can be for service providers, end users, or can be required for core network requirements. For service provider and end user provisioning, the end result is usually a billable event such as adding, changing, or terminating a end user service.

Once a new customer has been identified, the fiber or wireless link has to be provisioned. This process is initiated via a self service portal, an order ticket, or some other automated mechanism and flows through a defined process which may include external work orders to contractors and ultimately ends in a billing event when the customer is active and will be billed for services.

While provisioning is the setting up of services on the actual network elements, Order Management is a higher level activity that can include dispatch of physical assets, estimating of network build costs, or processing a more complex order for Network changes. Order Management can be provided through a Ticketing system or can be a stand alone system in larger networks.

Performance Reporting and Metrics

To provide proactive feedback to network operators, owners, and service providers there can be systems dedicated specifically to reporting on the health and reliability of the network. Metrics can also be created out of the ticketing system, provisioning system, or order management. Overall the performance of not only the network, but also of contractors, outsourced providers, vendors, and even data on service providers can be reported on and used as a mechanism to view the health of the network and entities charged with providing services. As an example, a ticketing system report could indicate the average length of time before a ticket is addressed by NOC personnel, or the

monitoring system can report on the total number and average length of time for outages in a given period.

Change Management

Any time there are changes made to the network via provisioning, repair, or otherwise, it is vital that those changes be managed and tracked. Simple methods of Change Management include keeping a record of every update in a spreadsheet, or keeping configuration files in a directory on a server. More complex methods involve using change tracking software to automatically capture network changes and provide capabilities for reversing changes in the event of an outage or interruption of services.

Network Maintenance

While routine maintenance (e.g. replacement of worn out equipment) may be limited in the first year or two of operations, non-routine/emergency maintenance support must be in place as soon as the network has customers. Maintaining network equipment involves regular patching of firmware or software upgrades as well as performing physical maintenance if required. Network elements must be patched when critical security or performance updates are released from the manufacturer. Maintenance which can potentially cause an outage need to be scheduled with the NOC and these events often occur as scheduled maintenance windows during non critical times (typically on weekends at 2-5am). Examples of required physical maintenance can include keeping equipment in clean working conditions such as cleaning fans, testing UPS systems, or replacing batteries as needed.

Security

Security is both a physical and logical problem in keeping networks operational. Physical security includes protecting expensive or sensitive equipment with access controls or locks. Logical security can include required password rotation, keeping equipment on the latest security release of software, and protecting confidential information of end users and service providers. Firewalls are needed to protect the network not only from outside threats, but the network needs to be protected against internal attacks as well.

Outside Plant Maintenance

Wireless networks are susceptible to occasional damage from severe weather, including lightning strikes, ice damage, and water damage. Radios near the tops of towers experience extremes of heat and cold repeatedly, and repairs or replacement is more frequent than for fiber network equipment, which is usually installed at ground level in more protected cabinets or shelters.

Fiber is occasionally damaged (e.g. tree limb falling on aerial fiber, backhoe damaging buried fiber), and a qualified firm must be available to make repairs within two to four hours. This service is almost always outsourced to a qualified private sector company and is referred to as "break-fix"

In addition to break-fix underground utilities often need to be "located" when new construction, street repairs, or other activities disturbing the earth occur near buried cable. The network should

belong to the local dial-before-you-dig service and should respond to tickets originating from those systems. Utilizing an accurate inventory of the network if digging will occur in close proximity to owned plant, NOC staff will dispatch a locator to locate the fiber cable. This is often part of the break-fix contract, but can be outsourced to another entity specializing in such work. In small municipal networks, the Public Works department will often locate fiber optic cable as they are already locating water and sewer assets.

Backups and Configuration Management

NOC staff are responsible for keeping secure backups of all Network Element configurations, backups of critical systems mentioned in this chapter including ticketing, provisioning, and billing. Backups should be stored locally for a quick restoration in the event of a failure, but also should be kept offsite in a physically diverse location.

Inventory Management

Keeping track of all Network Elements and all network assets is key to keeping a network reliable and operational. Inventory systems should:

- Track equipment location, in-service dates, serials numbers, model numbers
- Link equipment with end-users or service providers
- Provide location reports for technicians and service providers
- Store logical information such as IP addresses, OS versions, etc.

Managing the physical assets is also required in a network. Tracking all Outside Plant (OSP) assets reduces the time needed to find and solve outages, and reduces the time required to provision new services, or create work orders for changes to the physical network. A network asset management system provides an overall view of the physical state of the network. Fiber optic OSP management systems should:

- Track conduit, cables, buffer tubes, individual fiber, splices.
- Generate reports and information for splice work.

Wireless OSP management systems should:

- Track all in-service radios (location, model, type, serial number).
- Maintain adequate spare radios for all makes/models in-use.

Outreach

Outreach is often required to make sure that the local and regional community are aware of the network. Working with local economic developers, chambers of commerce, local technology companies is often required. Additionally municipal and Open Access Fiber projects receive regional and national awareness. Local, regional, state and even national elected officials need to be aware of the network, how it was funded, and how it is benefiting local constituents.

Growing the Network

Often the network is built in stages. There may be a pilot phase or a small deployment followed by larger deployments. These deployments need to be planned and managed, but the PamunkeyNet board of directors should constantly be looking for new funding opportunities like state or federal grants. While the network is being expanded, the NOC staff will be responsible for bringing newly constructed segments of the network into operations.

Operations Costs and Revenue

Annual Expense Projections

Budget Item	Description	Annual
Network Ops	Outsourced network monitoring and operations contract expense.	**$48,000**
PamunkeyNet Staff	At least three staff members will be needed during the first two years (Project Manager, bookkeeper, and technician).	**$225,000**
Legal Services	Legal counsel on an as-needed basis for review of construction and service contracts, IRU agreements, and other business documents.	**$7,500**
Accounting	Part time accounting and bookkeeping services will be required	**$4,800**
Maintenance	Generators require periodic maintenance, along with other routine tasks. This can be performed by PamunkeyNet staff.	**$2,400**
Training	PamunkeyNet staff will require technical training on an annual basis, including fiber construction techniques, wireless network management, fiber splicing, and server administration.	**$25,000**
Internet backhaul	PamunkeyNet will follow the King and Queen model of providing retail Internet, purchased from a qualified service provider.	**$72,000**
Spares/Supplies	Spare radios, replacement fiber equipment, cables, and other supplies.	**$24,000**
Utilities	Each tower site requires electric power, and the colocation facility will also require electric service. Will vary depending on number of sites.	**$12000**
Locates	Once some fiber has been constructed, it will be necessary to provide locates. PamunkeyNet staff can be trained to do this work.	**$1,500**
Pole Use Fees	No aerial fiber is anticipated for the Technology Corridor first phase fiber, but aerial fiber may be deployed in later phases.	**$0**
Storage	Storage space for spare conduit, fiber, splice closures, handholes and other spare parts will be needed. A rental storage unit or used shipping container would be adequate.	**$1,800**
Site Leases	Some towers and/or fiber switch equipment may be placed on private property which would require annual site leases. This will vary depending on the availability of local government properties that may be available for tower placement.	**$12,000**
Break-Fix reserve fund	PamunkeyNet will need a fund to cover fiber damage and wireless repairs. A regular annual contribution to the fund will be needed.	**$35,000**
Insurance	Some insurance is likely to be needed (general liability, unemployment, asset insurance, umbrella policy).	**$15,000**
Office administration	Expenses related to providing office space, office equipment (printers, computers, laptops, etc), office supplies for two employees.	**$34,200**
Marketing activities	PamunkeyNet will need a well-designed and consistent marketing plan to ensure the project meets its customer subscriber goals.	**$35,000**
Total Costs	**Projected annual expenses**	**$555,200**

Revenue Discussion

Operating as a retail service provider, PamunkeyNet will need 1000+ customers to break even by the end of the second year. The table below shows one possible scenario for expected revenue. Several assumptions have been made in this projection.

- PamunkeyNet will have a cash reserve adequate to fund operational shortfalls (revenue does not exceed expenses) in the first two years. This should be a minimum of 50% of expected expenses, or about $500,000 for the first two years.
- PamunkeyNet has a capital fund for adding fiber customers that are adjacent to the Technology Corridor fiber (i.e. within 500 to 1000 feet). Some fiber drops have been included in the cost estimate, but adding more customers will require funding the fiber drop connections (average about $1500/drop).
- The initial capital funding of PamunkeyNet includes the full cost of building the Technology Corridor fiber and colocation facility.
- The initial capital funding of PamunkeyNet includes the full cost of adding a minimum of ten new wireless access points on new or leased towers.
- PamunkeyNet takes over operations of the existing King and Queen network, including all existing customers.
- Each of the towers in the expanded PamunkeyNet (about 15 access sites) is able to have an average of 50-60 customers per site at the end of the first two years (15 sites * 60 = 900 customers).

Revenue Projections

Service Item	Description	Monthly Fee	Estimated Customers	Projected Annual Revenue
5Meg down/1 Meg up Residential Wireless	Expected to be the most popular and affordable service.	$35	650	**$273,000**
10 Meg down/10 Meg up Residential and Smalll Business Wireless	A higher bandwidth service that would meet work from home needs.	$90	200	**$216,000**
100/25 Business class fiber service	Business class GPON fiber service.	$150	12	**$21,600**
Gigabit residential fiber service	Best effort GPON Gigabit residential service	$75	10	**$9,000**
Gigabit business fiber service	Business class Active Ethernet fiber service	$850	3	**$30,600**
Installation fees	Non-recurring wireless and fiber one time installation fees			**$15,000**
Total	Total estimated annual revenue			**$565,200**

Funding the Enterprise

Funding Needs

PamunkeyNet will need a basket of funding to support various tasks, activities and capital expenses. These include:

Capital Expenses — As outlined in previous portions of this report, there are three major capital expenditures: the Gigabit fiber backbone, the Telework Center colocation facility, and the wireless expansion to all of the Middle Peninsula counties.

Operational Expenses — PamunkeyNet, managed carefully, should have a growth path to sustainability within two years, but will need a cash reserve to cover revenue deficits, especially in the first year. While the goal should be that revenue will cover all operational expenses as quickly as possible, an operational reserve will provide a financial cushion for early operations.

Training — While training is a relatively minor cost compared to capital and operational expenses, funds to train Pamunkey tribe members will be a critical success factor.

Customer Connections — The capital cost estimate includes the cost of connecting some fiber and wireless customers, but successful networks have a strategy for underwriting one time connection fees. This is particularly important for adding new fiber customers, where the drop cost connection from the existing backbone can be anywhere from $750 to several thousand dollars. Some projects subsidize these costs directly, and others have had success providing low interest or no interest financing.

Fiber Expansion — PamunkeyNet will be successful financially in part by continued expansion of the fiber network to other areas of the PDC. Fiber customers, especially business fiber customers, provide higher levels of revenue that can help fund further expansion.

Funding Opportunities

As a Federally recognized tribe, the Pamunkeys bring a unique opportunity to the Middle Peninsula. As a sovereign nation, the tribe is not subject to a number of state-level and Federal regulations that have often hindered other community broadband efforts. Federally recognized tribes are not subject to Federal taxes, among other benefits.

Federally recognized tribes are also eligible for a variety of Federal funds that are not available to other communities and local governments. These include:

USDA Community Connect grants — Tribes are eligible for these telecommunications grants. Grant funds are limited, but many communities have difficulty meeting the unserved/underserved requirements. The Pamunkey tribe may be well-positioned to be competitive.

USDA Distance Learning and Telemedicine — The DTL program is designed to assist rural areas with education and health needs. Eligible entities providing education and medical care via

telecommunications include Indian tribes or tribal organizations, state or local units of government, consortia, and private for-profit or not-for profit corporations. 15% match is required.

Tribal Mobility Fund — On Tribal lands, eligible telecommunications carriers (ETCs) that provide service on these lands, have access to spectrum capable of 3G or better, and are financially capable of providing service are eligible to participate in spectrum auctions. Provisions have also been provided for a tribally-owned or controlled entity that is not yet an ETC to participate in an auction as long as that entity has a pending ETC designation application using a short-form application in time to meet a set deadline. Providing cellular voice/data services is more technically challenging that broadband only wireless services, but there may be opportunities for the tribe to partner with a cellular carrier for certain areas of the region.

FirstNet — FirstNet is the First Responder Network Authority, an independent authority within the Department of Commerce's National Telecommunications and Information Administration (NTIA). Congress charged FirstNet to take "all actions necessary" to build, deploy, and operate the network, in consultation with Federal, state, ***tribal***, and local public policy entities. The Act provides $7 billion in funding towards deployment of this network, as well as $135 million for a new State and Local Implementation Grant Program administered by NTIA to support State, regional, tribal and local jurisdictions' efforts to plan and work with FirstNet to ensure the network meets their wireless public safety communications needs.

Dept. of Homeland Security — More than $1.6 billion was allocated to DHS grant programs provide funding to state, local, ***tribal*** and territorial governments to improve the nation's readiness in preventing, protecting against, responding to, recovering from and mitigating terrorist attacks, major disasters and other emergencies. There may be significant opportunities for PamukeyNet to partner with public safety initiatives in the region to qualify for these funds.

USDA Telecom Infrastructure Loans and Loan Guarantees — Federally recognized tribes are eligible for these loan packages. A loan may not be ideal for funding initial capital expansion, but once PamunkeyNet is financially in the black, loans for fiber expansion could be useful source of funding.

Dept. of Justice Coordinated Tribal Assistance Solicitation — This program is intended to address tribal criminal justice and public safety needs. PamunkeyNet and local public safety officials may be able to combine efforts to qualify for these funds.

HUD Indian Community Development Block Grants — Eligible applicants for assistance include any Indian tribe. Provides funds to eligible grantees for housing rehabilitation, land acquisition, community facilities, infrastructure construction, and economic development activities.

Planning for Success

With more than a dozen years of operation for a variety of community-owned network infrastructure projects around the country, there is very little "experimentation" that is still necessary. With more than three hundred communities making investments in broadband infrastructure, there is now enough information about what works and what does not work to be able to identify best practice across nearly all areas of operations, planning, management, and finance.

Develop Partnerships with Public Safety

The Project should develop partnerships with public safety entities in the region. These partnerships could be expanded as well as new partnerships created to jointly work on activities involving mapping and needs assessment, tower siting, pursuing grant funding, advertising and marketing, and others.

Training is Essential

If PamunkeyNet is to grow into a sustainable tribal enterprise with good jobs, training of tribe members with the aptitude and interest for technically challenging work will be essential. PamunkeyNet should develop a partnership with Rappahannock Community College (RCC) and other technical training resources to ensure that over a period of two or three years, more tribe members have the qualifications and training to join the PamunkeyNet staff. Over time, the goal should be to reduce reliance on outsourced resources.

RCC currently has some technically oriented courses that will useful, but additional programs like the Cisco Network Academy and Microsoft server and networking certifications (e.g. MTA, MCSA, MCSE) will be important to develop workers with technical skills not just for PamunkeyNet but to create a pipeline of trained workers for private sector companies that want to locate in the fiber-enabled Technology Corridor.

Outsource Where Sensible and Economical

Overstaffing on start up networks has been a common source of early financial difficulties for some community broadband projects. Given the relatively small scope of the proposed initial projects, PamunkeyNet should seek to outsource some maintenance and operational tasks where using internal staff may be more expensive.

Use grants Prudently

Grants can be extremely important in the early stages of an effort to support planning activities and/or to fund a Phase One build out initiative. But grants rarely will allow spending on operational expenses. Grants should be used as one time cash injections to support very specific capital expansion goals (like the initial wireless and fiber "phase one" portions of PamunkeyNet). Communities that have relied too heavily on "the next grant" as a key source of expansion or operational funding usually experience financial problems within two or three years.

Manage finances

Broadband infrastructure projects require hard-nosed financial oversight. Projects that have developed financial problems have usually over-estimated early revenue, under-estimated expenses, and/or simply spent too much without aligning expenses with revenue. Volunteer board members who are contributing time while also maintaining a full time job (often in local government) may not provide enough financial oversight to ensure that staff use the budget as a tool to measure financial performance.

Use Market Demand Testing to Drive Expansion

The initial business plan should have a minimum three to ten year projection of connected premises (i.e. the take rate), including K12 schools, local government facilities, large and small businesses, health care facilities, and residential customers (if fiber to the home is part of the business plan). Take rates directly affect revenue: if take rate projections are not being met, revenue shortfalls are likely. Take rates (both raw numbers and month to month growth rates) should be analyzed at least quarterly (monthly would be preferable).

Increased Wood Utility Pole Use

Tree cover is a constant problem for rural residents and businesses, as good line of site is required for fixed wireless Internet services. Even newer technologies like white space and LTE systems work better with clear line of sight to distant towers.

The increased use of wooden utility poles is already common in some other Virginia counties, and increased use of this technique to get the customer CPE radio/antenna above tree cover is a relatively simple solution.

The utility poles would normally be placed on private property, subject to existing or updated ordinances governing the placement of wooden utility poles. The local government would have no responsibility for maintenance and repairs.

Depending on the source of the poles and the location where it is mounted the cost of installing a new pole with wireless equipment could be in the $10,000 to $15,000 range. Major cost factors include the cost of moving construction equipment to site, the cost of labor, and the cost of shipping the pole. At remote locations the cost to install a electric utility service can also be high. This is a conservative estimate for a single pole. Constructing multiple sites at once and identifying local sources of labor could reduce the cost substantially. Some Virginia counties provide "by right" permitting of these poles if they are placed on private property, which can reduce the cost of installing them.

Plan for marketing and public awareness efforts

If the Project move forward, it will be necessary to have a modest but regular marketing and awareness campaign to ensure that area businesses know that the new network is available, that they know what services are available on the network, and they know how to order service.

Plan for Expansion

Most community-funded efforts start small. This minimizes financial risk. But some projects tend to stall out after the first year or two. The underlying problem is twofold: even small networks have a certain amount of fixed operational costs regardless of size, and the network needs enough revenue to pay those expenses, as well as make principal and interest payments on any loans. The second problem is that network infrastructure wears out and needs routine maintenance. Lack of funding to keep the network in good condition will degrade service over time. The solution is to have an expansion plan (which could be modest) that contributes to revenue growth over time.

Budget for Customer Connections

If the network is going to achieve financial sustainability, new customers have to be added on a schedule that matches the financial projections. For wireless networks, the cost of the customer radio installed at the premises has to be included in growth cost projections. For fiber networks, this means the project must have the funds to support adding customer "drops" from the distribution fiber on poles or underground in right of way at the edge of the street or road. This is where careful budgeting and adequate funding is a necessity. The worst possible outcome is to have business and residents requesting a connection to the network but having a lack of the funds to make that "last hundred feet" connection. There are a variety of charge back and fee-based strategies for raising the capital needed to complete drops, and a plan that supports funding of new customer connections is essential.

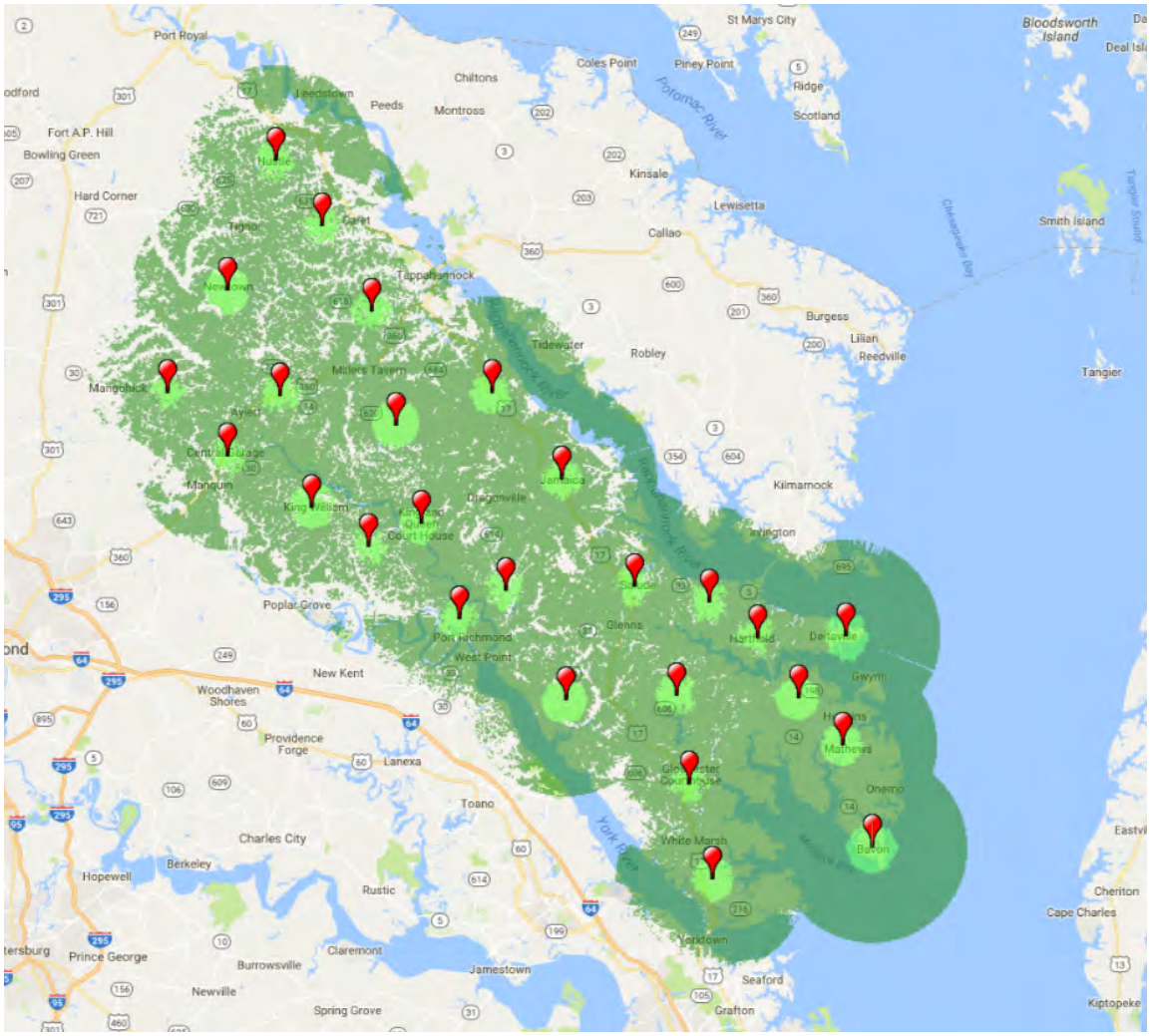
Maintain a Towers Opportunity Map/List

The Project should maintain a list or map of wireless tower opportunities. At least quarterly the Project should reach out to local planning and permitting departments to see if any new towers are under development in the region and identify co-location opportunities. The list could be expanded to include underground projects and available properties for tower development.

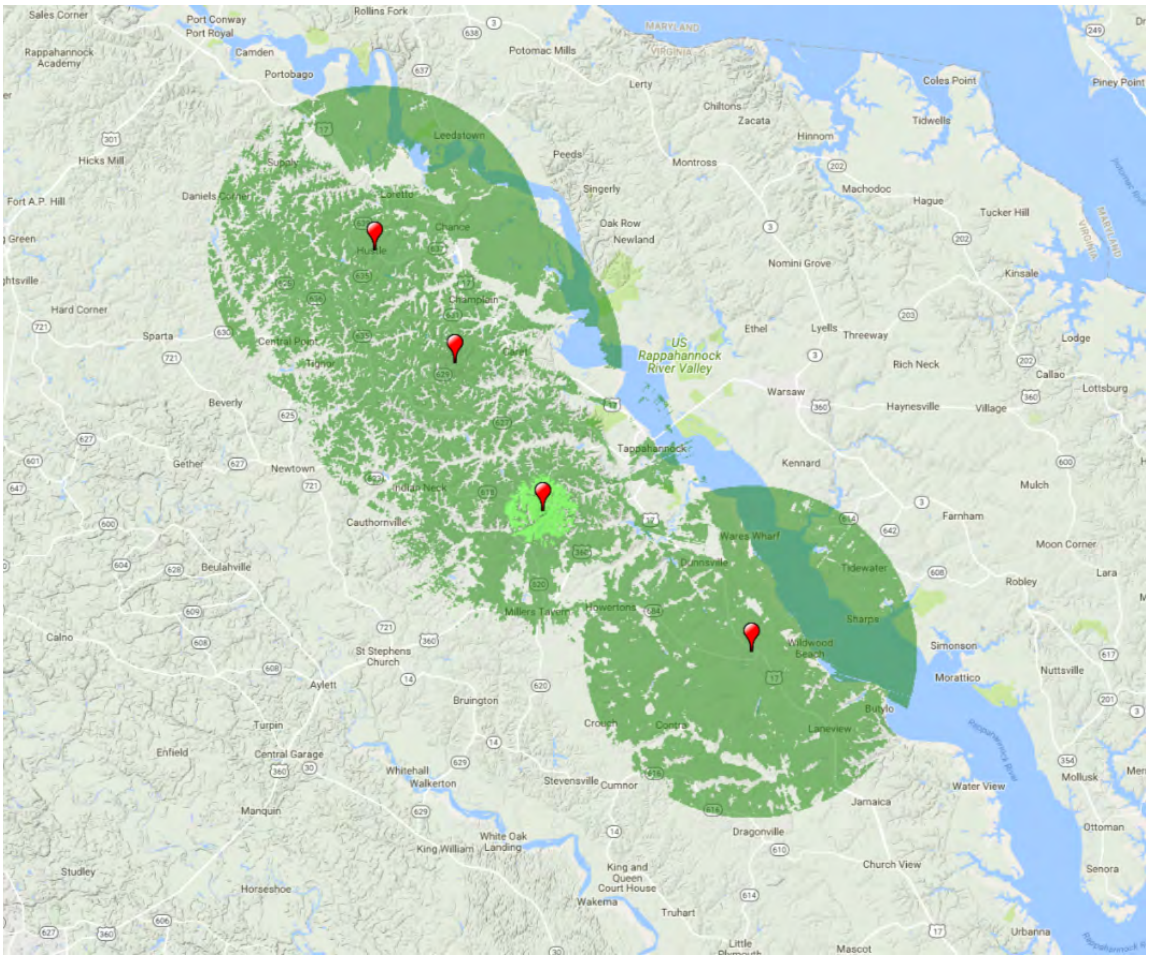
Appendix A: Propagation/Coverage Studies

The studies on the following pages provide a view of estimated tower coverage using the newer LTE radio frequencies. Tower sites have been placed to optimize coverage for this estimate, and if the project moves forward, site assessment and identification would be an early project task. The goal should be to utilize existing local government towers as much as possible, but some new towers may be needed to provide good coverage. There should be close coordination between public safety tower needs (used for first responder/public safety voice communications) and broadband tower expansion. It may also be possible to lease space on some privately owned cellular towers if lease rates are affordable.

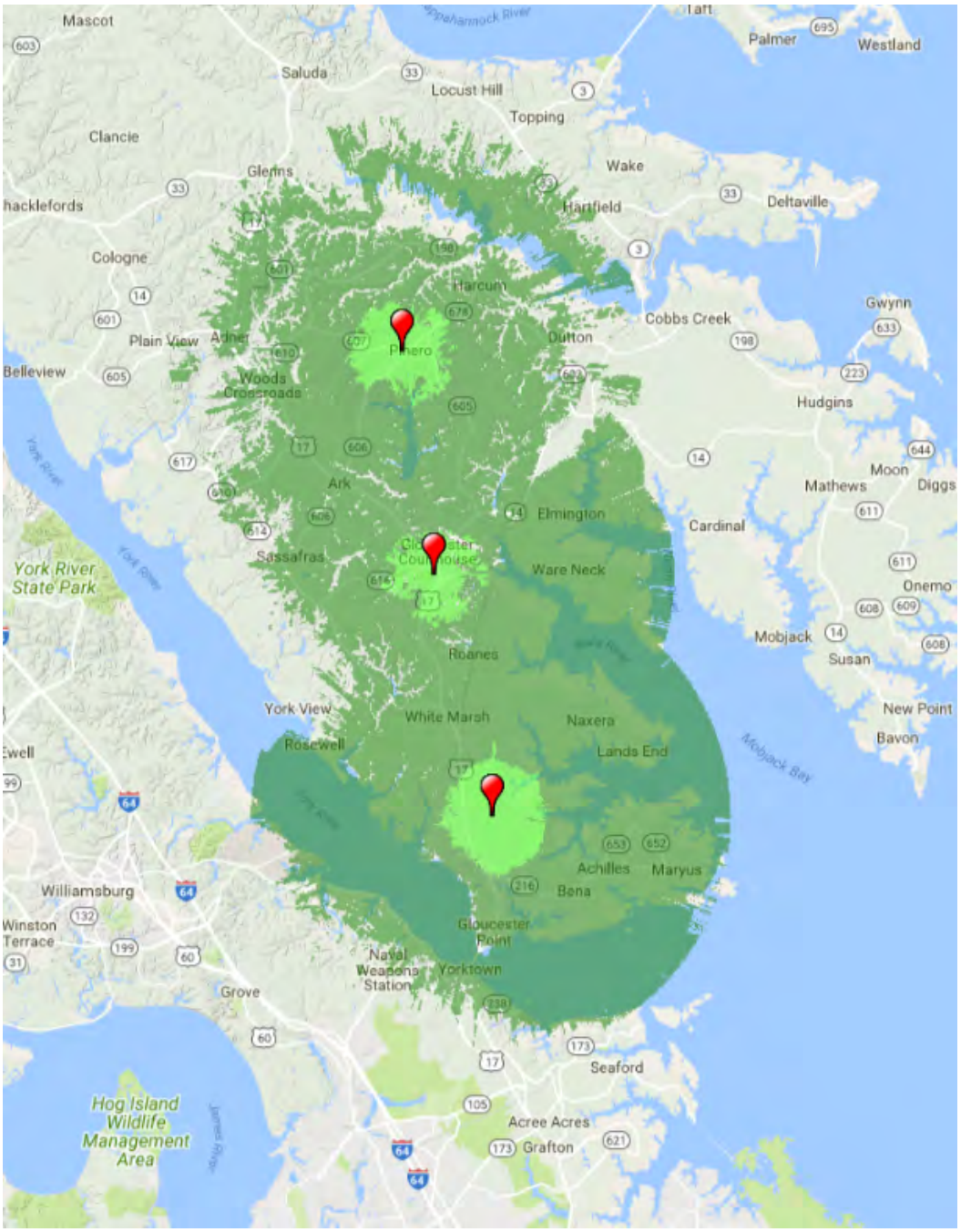
Regional Study



Essex Study


Sales Corner
Port Conway
Port Royal
Rollins Fork
Rappahannock Academy
Camden
Portobago
Potomac Mills
MARYLAND
VIRGINIA
Lerty
Coles Point
Piney Point
Chiltons
Zacata
Tidwells
Hinnom
Leedstown
Hicks Mill
Peeds
Montross
Machodoc
Hague
Tucker Hill
Fort A.P. Hill
Daniels Corner
Singerly
Oak Row
Newland
Nomini Grove
Kinsale
Hard Corner
Sparta
Champlain
Ethel
Lyells
Threeway
Lodge
US Rappahannock River Valley
Rich Neck
Callao
Lottsburg
Warsaw
Haynesville
Village
Beverly
Tappahannock
Kennard
Mulch
Gether
Newtown
Cauthornville
Farnham
Ware Wharf
Moon Corner
Beulahville
Dunnsville
Tidewater
Robley
Lara
Millers Tavern
Howertons
Sharps
Calno
Wildwood Beach
Simonson
Nuttsville
St Stephens Church
Aylett
Morattico
Bruington
Turpin
Crouch
Centa
Laneview
Burylo
Enfield
Central Garage
Whitehall
Walkerton
Stevensville
Cumnor
Mollusk
Water View
Jamaica
Manquin
Dragonville
Ottoman
White Oak Landing
King William
Studley
King and Queen Court House
Church View
Senora
Horseshoe
Wakema
Truhart
Urbanna
Little
Mascot

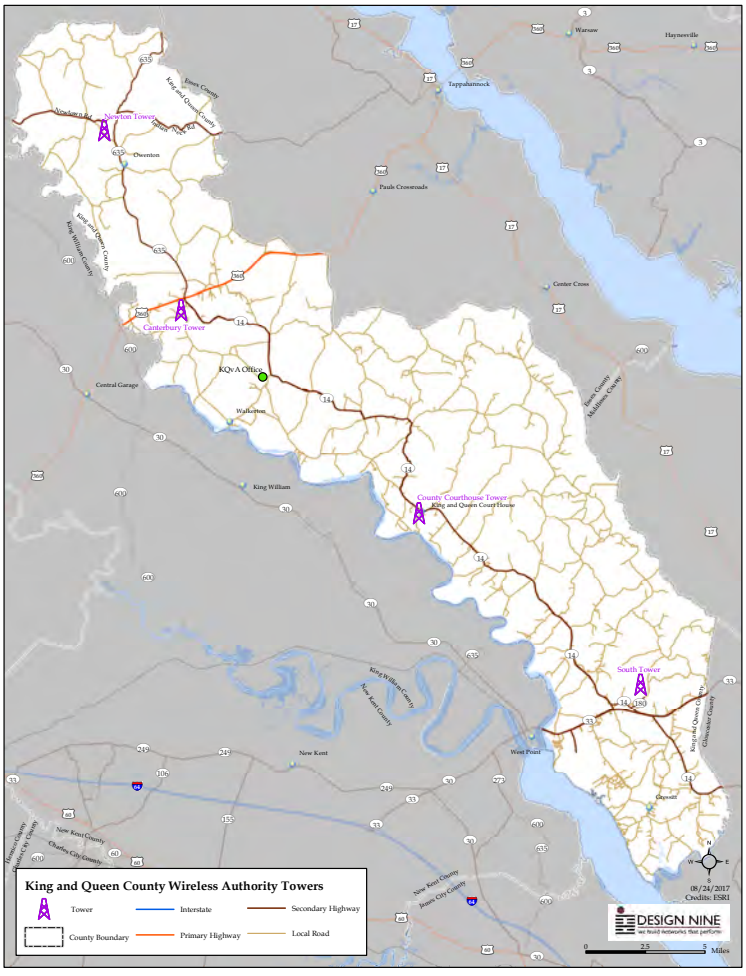
GLOUCESTER STUDY



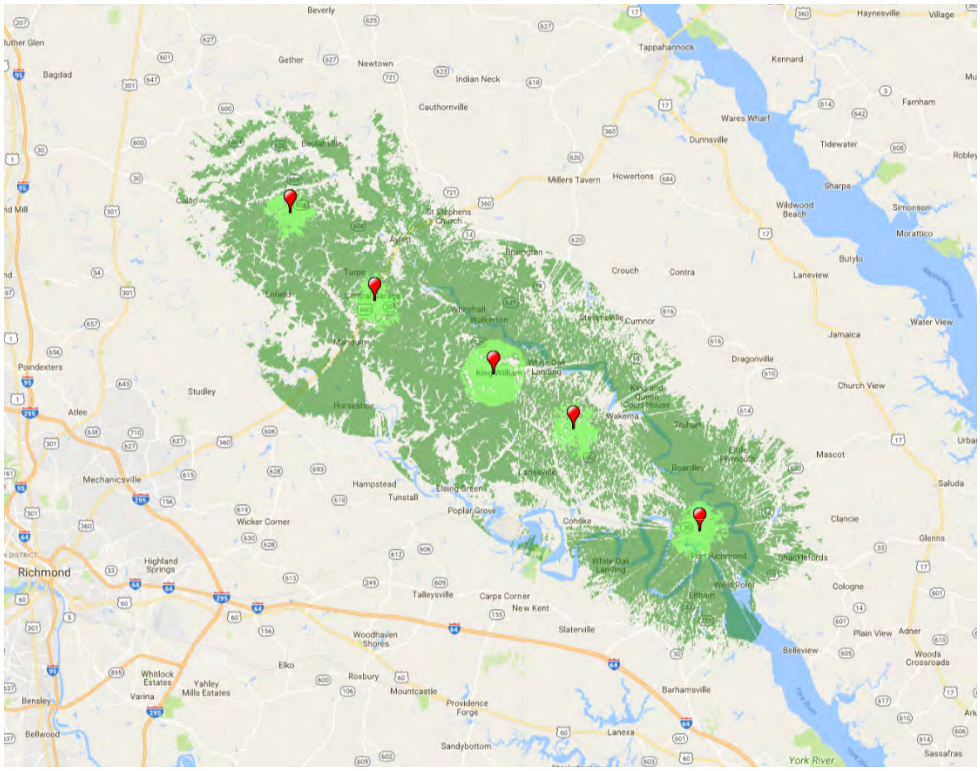
King and Queen Study

The existing King and Queen network has existing tower sites (shown in the map below) that provide good coverage throughout the county. The network offers a range of five different wireless services. PamunkeyNet will benefit by taking over the existing network and would have a revenue stream from existing customers while new tower sites and the Route 33 fiber is being constructed.

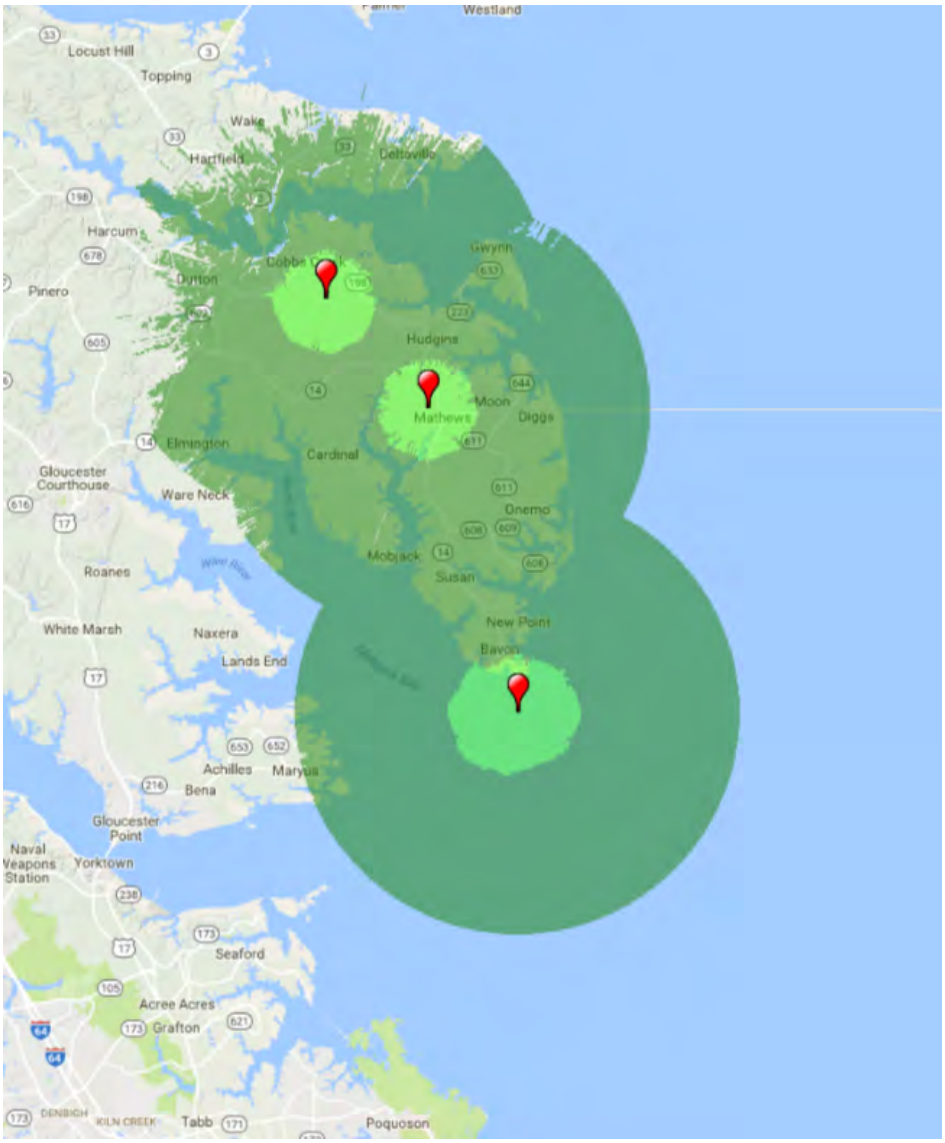
Wireless Service	Description	Monthly Fee
512 Kb down/128 Kb up	Basic "lifeline" service	$30
1 Mb down/512 Kb up	Standard service for light Internet use	$40
2 Mb down/768 Kb up	Supports some streaming video	$50
3 Mb down/3 Mb up	Supports streaming video, some work from home	$60
6 Mb down/6 Mb up	Small business class service, multiple residential users	$90



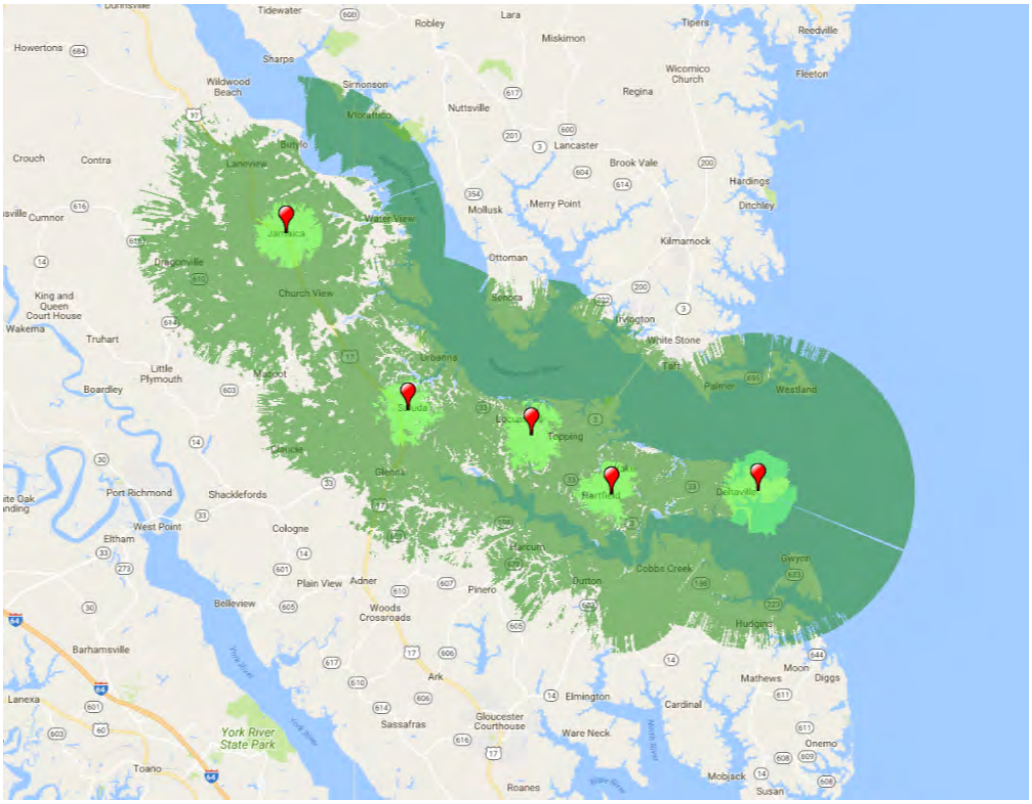
KING WILLIAM STUDY



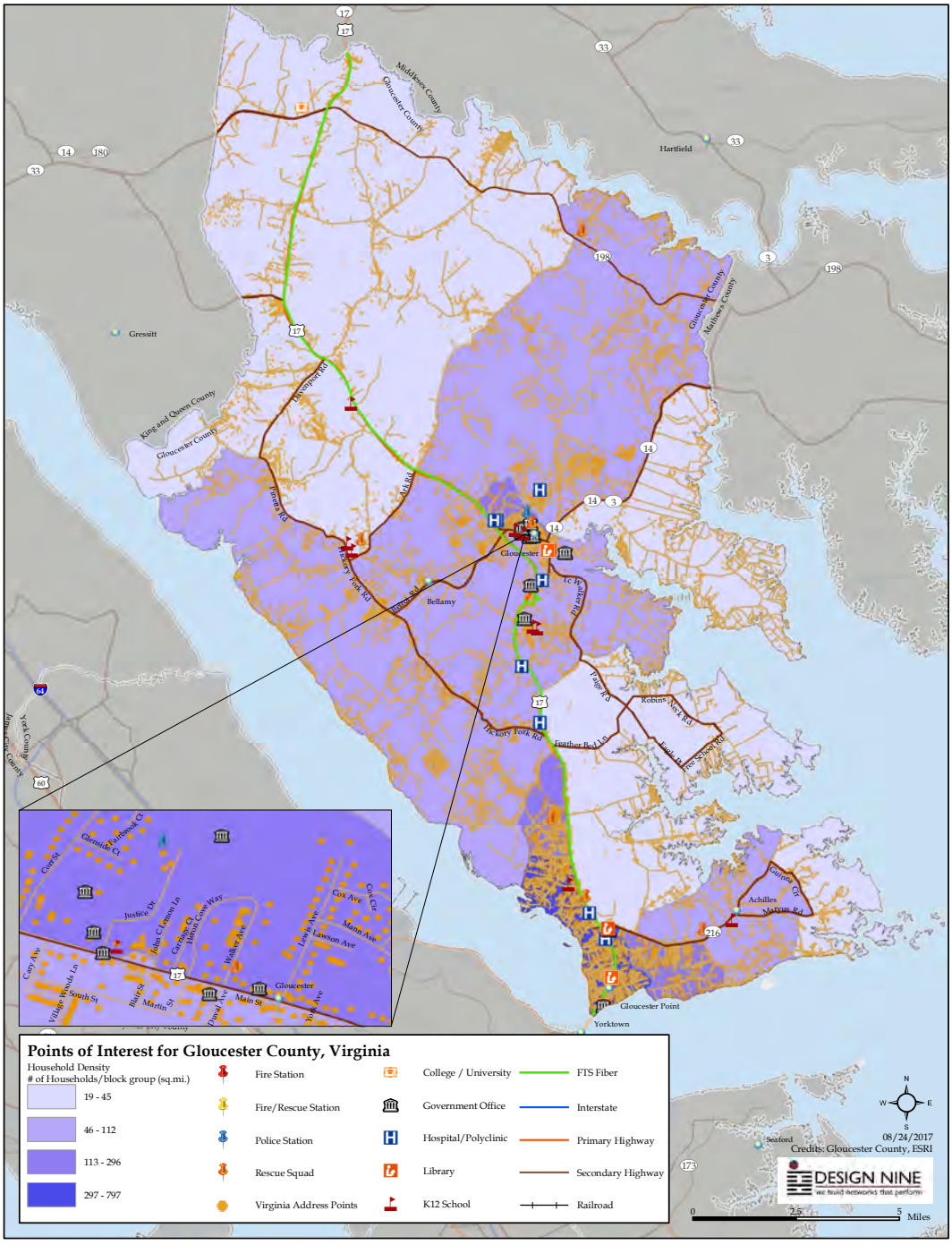
MATHEWS STUDY

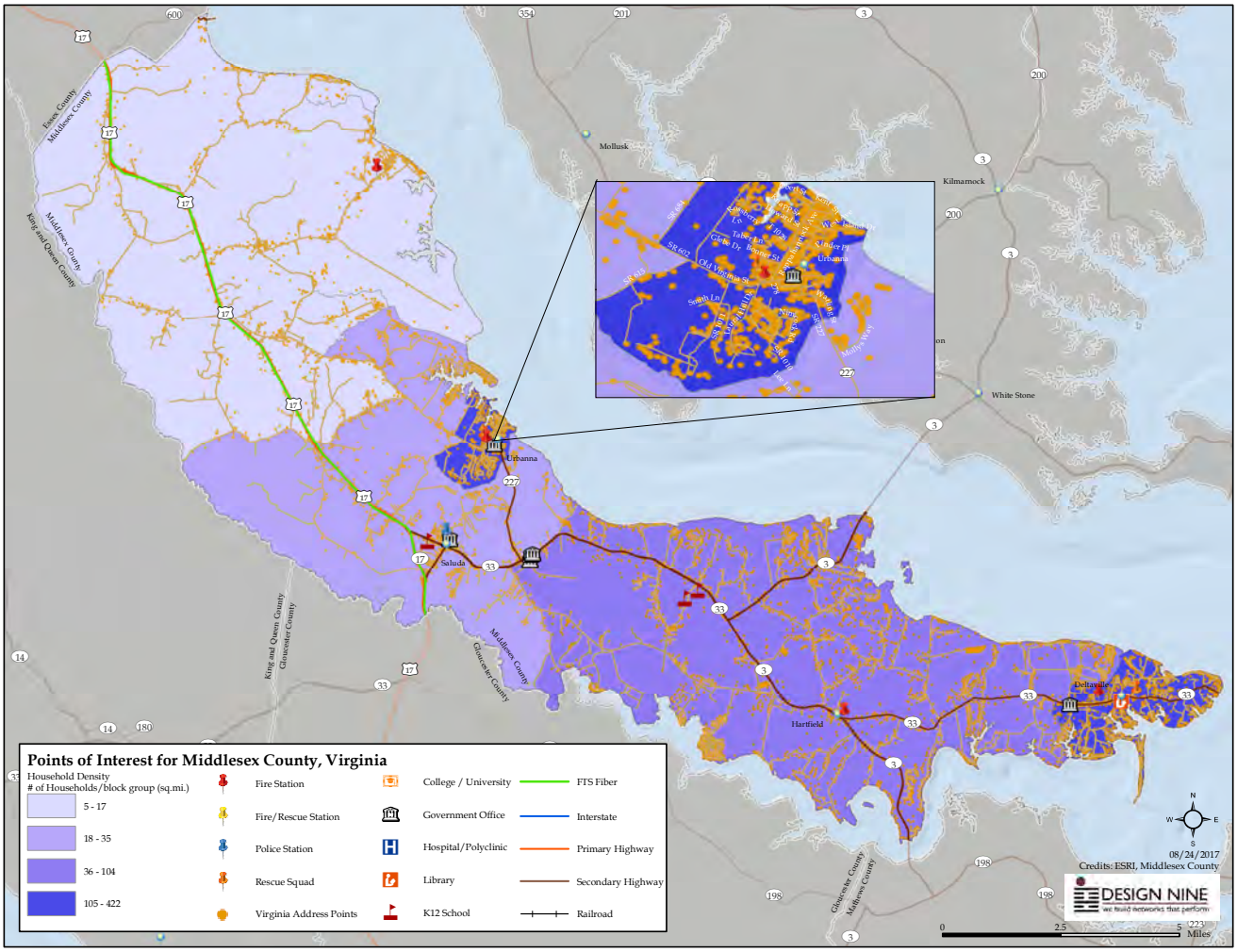


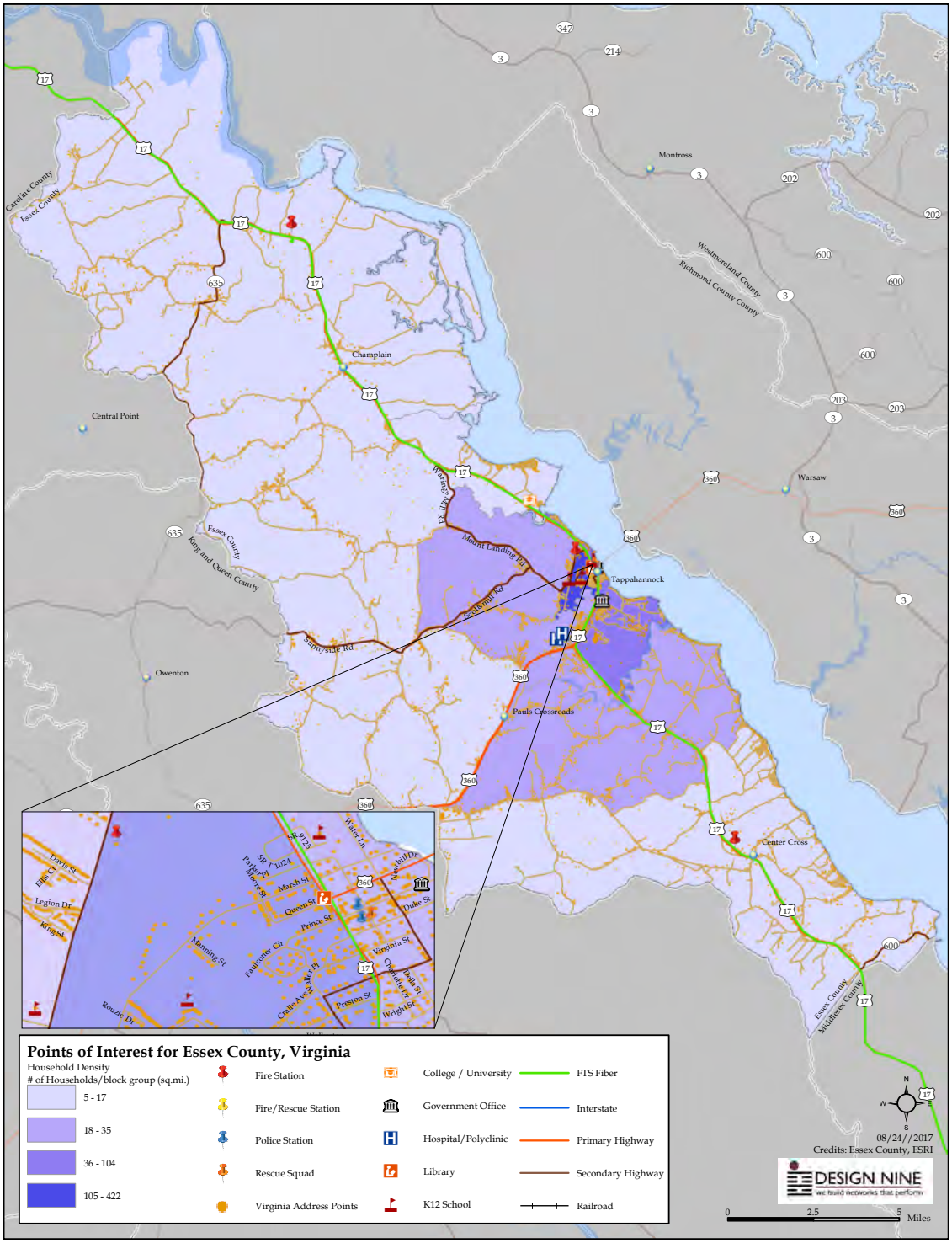
MIDDLESEX STUDY

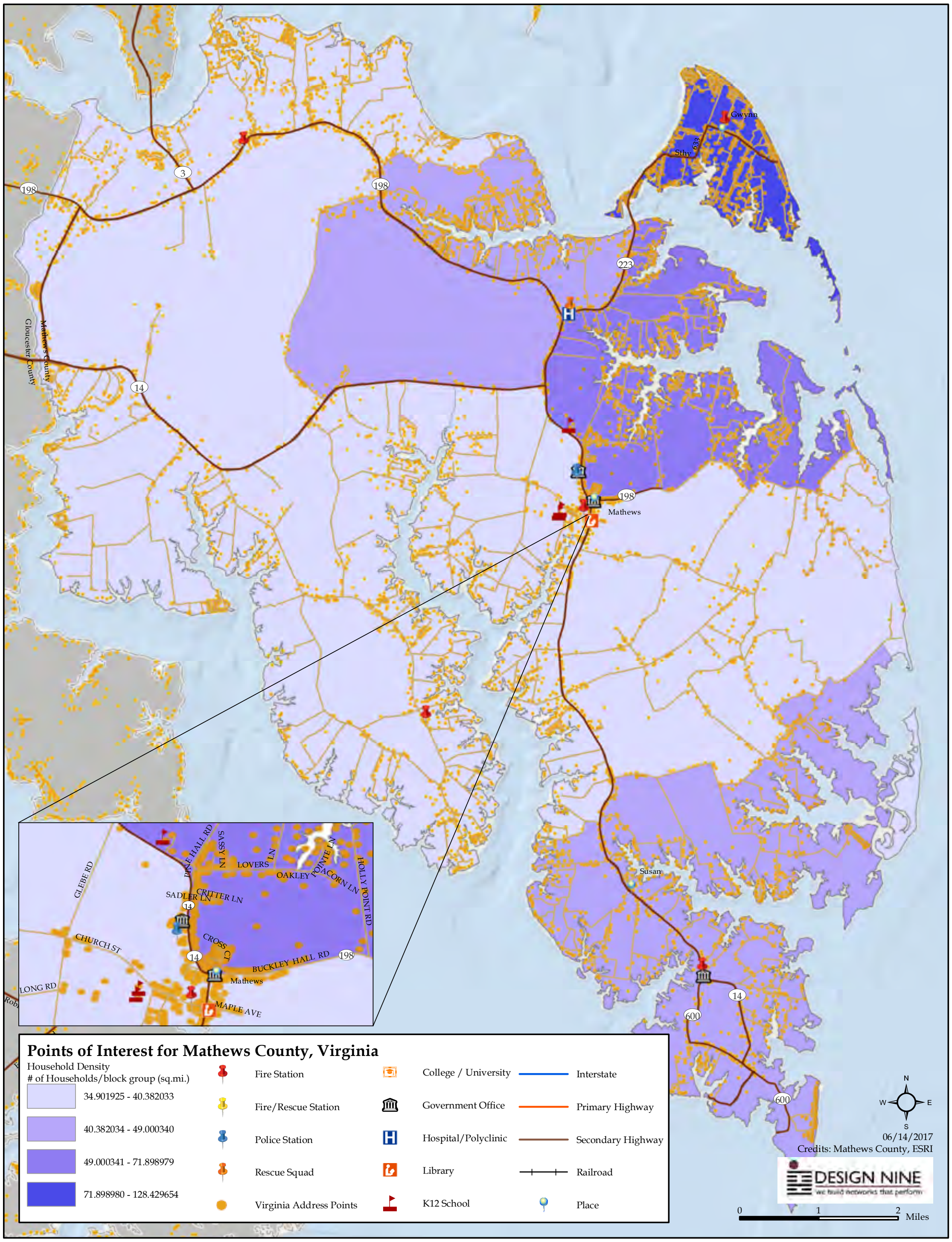


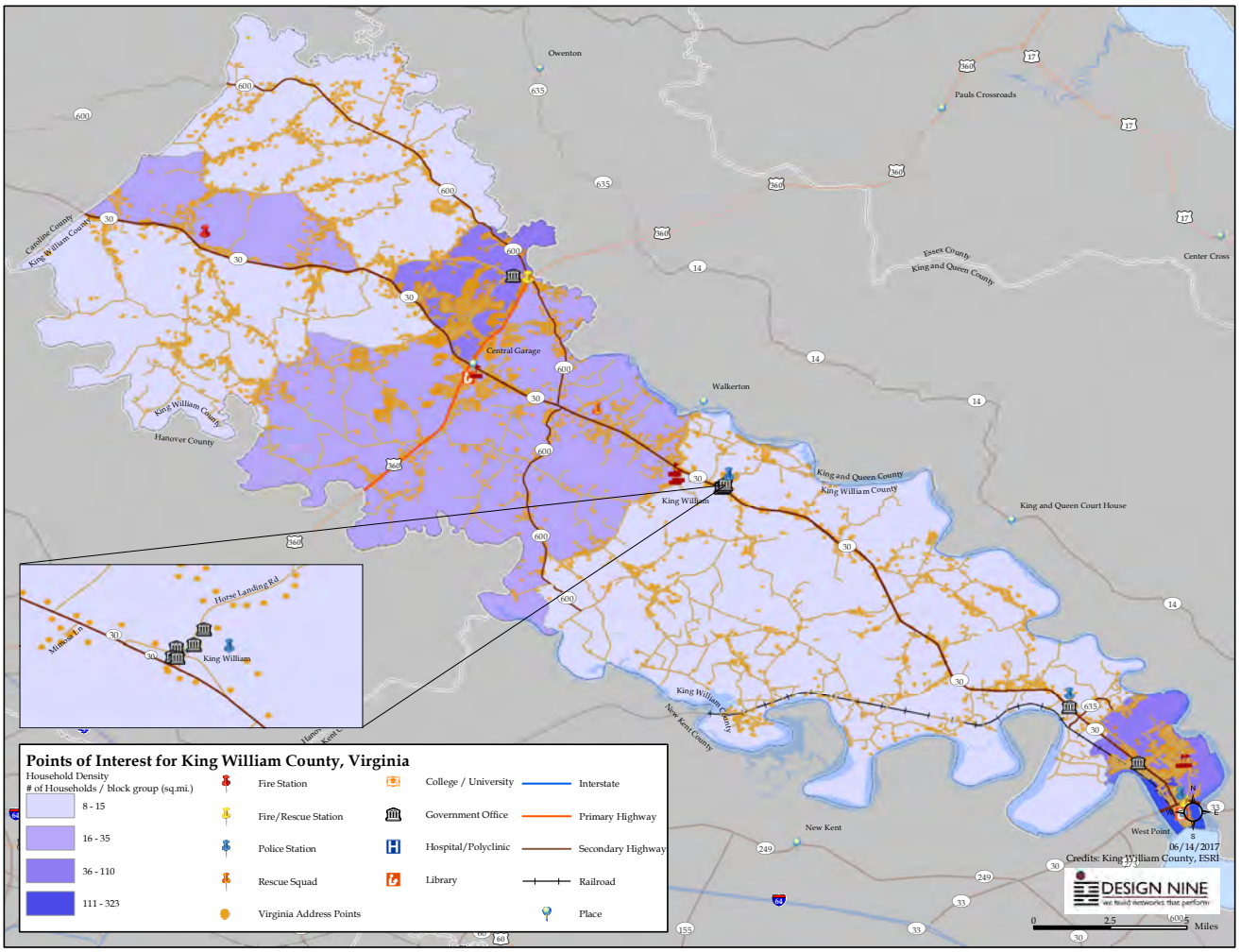
Appendix B: Area Maps

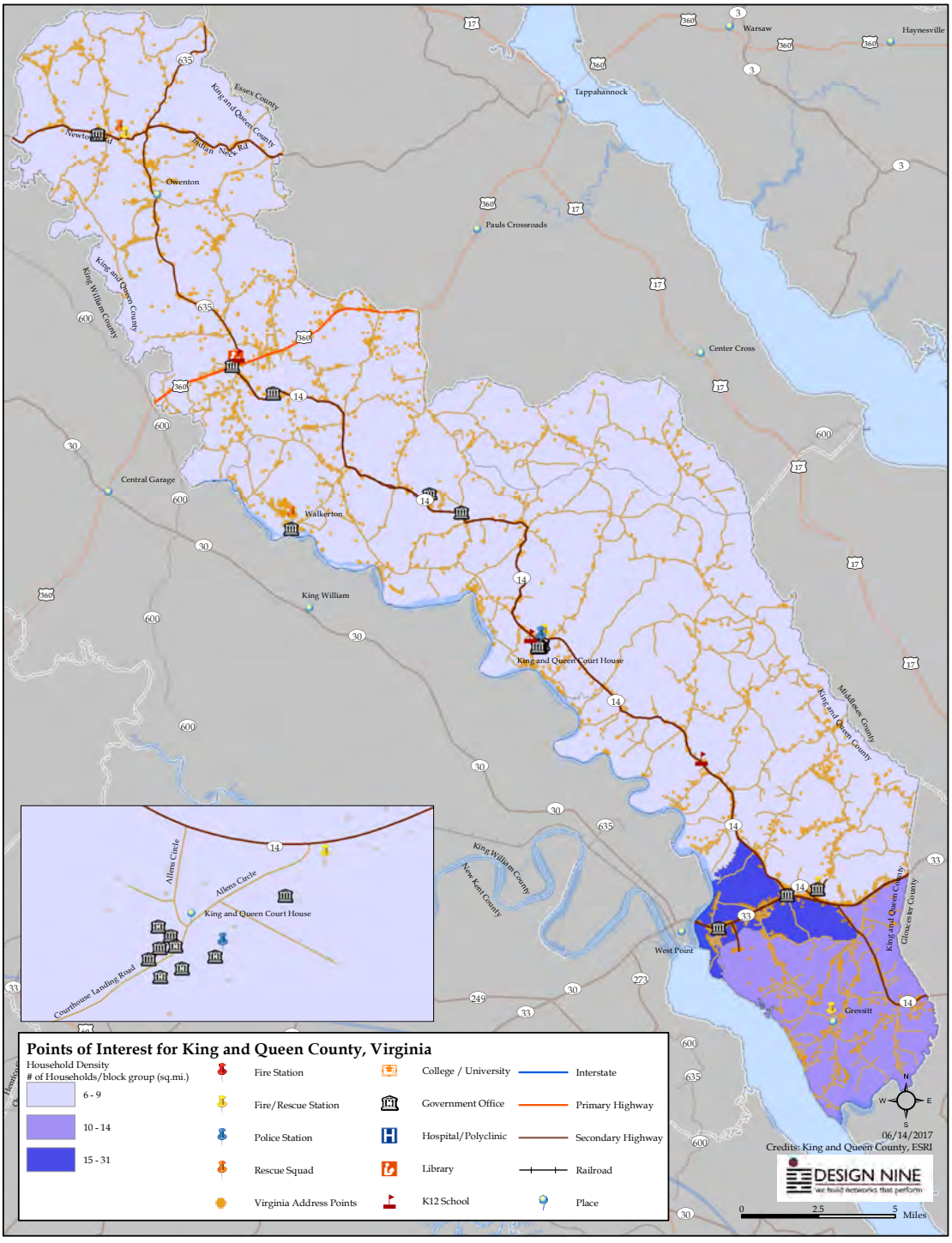


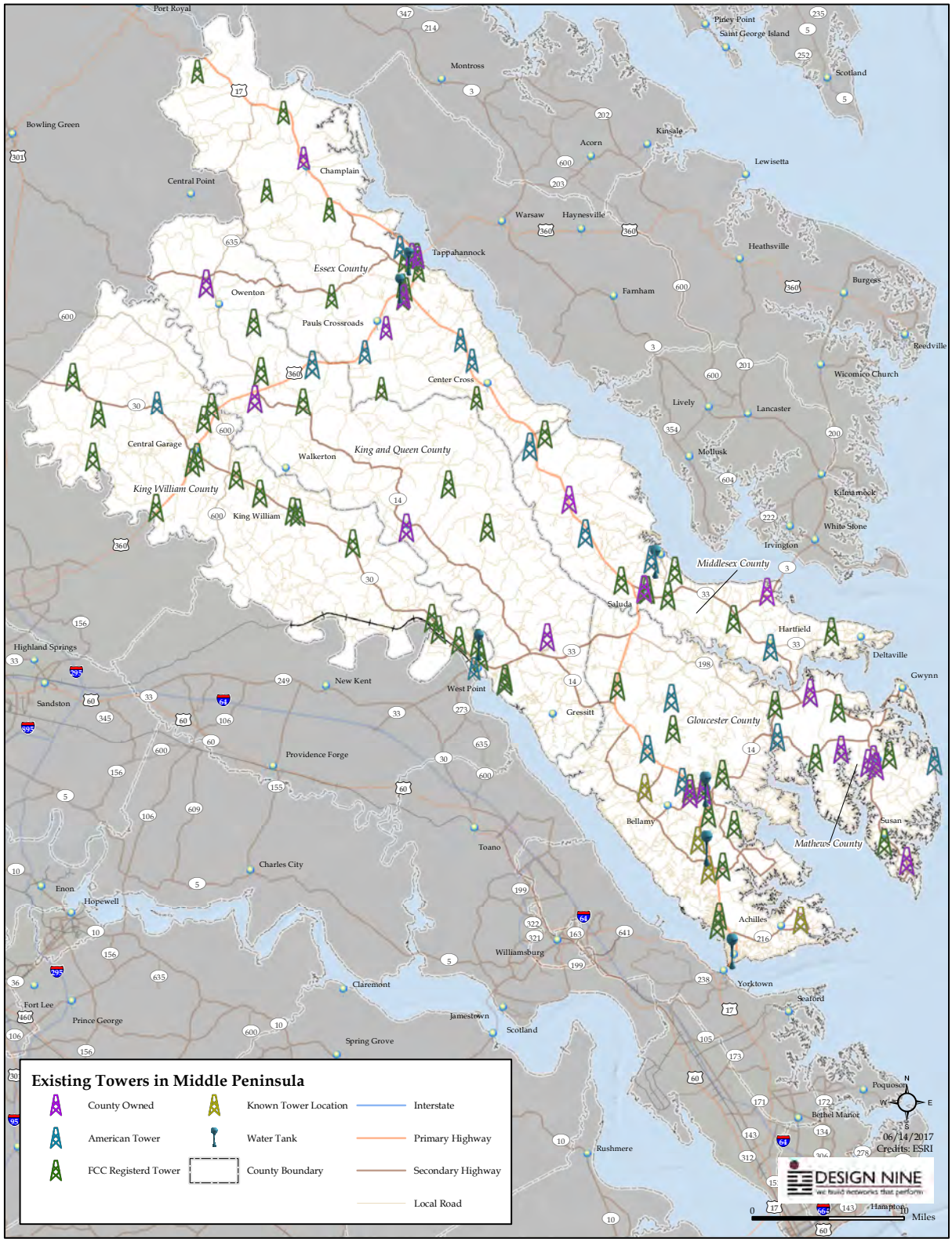

Points of Interest for Middlesex County, Virginia
Household Density
# of Households/block group (sq.mi.)
5 - 17
18 - 35
36 - 104
105 - 422
Fire Station
Fire/Rescue Station
Police Station
Rescue Squad
Virginia Address Points
College / University
Government Office
Hospital/Polyclinic
Library
K12 School
FTS Fiber
Interstate
Primary Highway
Secondary Highway
Railroad
Mollusk
Kilmarnock
White Stone
Urbanna
Saluda
Hartfield
Deltaville
King and Queen County
Middlesex County
Gloucester County
Essex County
08/24/2017
Credits: ESRI, Middlesex County
DESIGN NINE
we build networks that perform
0
2.5
5
Miles


Points of Interest for Essex County, Virginia
Household Density
# of Households/block group (sq.mi.)
5 - 17
18 - 35
36 - 104
105 - 422
Fire Station
Fire/Rescue Station
Police Station
Rescue Squad
Virginia Address Points
College / University
Government Office
Hospital/Polyclinic
Library
K12 School
FTS Fiber
Interstate
Primary Highway
Secondary Highway
Railroad
Montross
Champlain
Central Point
Warsaw
Tappahannock
Owenton
Pauls Crossroads
Center Cross
Carolina County
Essex County
Westmoreland County
Richmond County County
King and Queen County
Middlesex County
08/24//2017
Credits: Essex County, ESRI
DESIGN NINE
we build networks that perform
0
2.5
5
Miles


Points of Interest for Mathews County, Virginia
Household Density
# of Households/block group (sq.mi.)
34.901925 - 40.382033
40.382034 - 49.000340
49.000341 - 71.898979
71.898980 - 128.429654
Fire Station
Fire/Rescue Station
Police Station
Rescue Squad
Virginia Address Points
College / University
Government Office
Hospital/Polyclinic
Library
K12 School
Interstate
Primary Highway
Secondary Highway
Railroad
Place
06/14/2017
Credits: Mathews County, ESRI
DESIGN NINE
0 1 2 Miles
Mathews
Susan
Gwynn
Mathews County
Gloucester County
GLEBE RD
CHURCH ST
LONG RD
SADLER LN
CRITTER LN
LOVERS
OAKLEY
ACORN LN
HOLLY POINT RD
BUCKLEY HALL RD
MAPLE AVE
CROSS CT
SASSY LN


Points of Interest for King William County, Virginia
Household Density
# of Households / block group (sq.mi.)
8 - 15
16 - 35
36 - 110
111 - 323
Fire Station
Fire/Rescue Station
Police Station
Rescue Squad
Virginia Address Points
College / University
Government Office
Hospital/Polyclinic
Library
Interstate
Primary Highway
Secondary Highway
Railroad
Place
Owenton
Pauls Crossroads
Center Cross
Essex County
King and Queen County
Caroline County
King William County
Central Garage
Walkerton
Hanover County
King and Queen County
King William County
King William
King and Queen Court House
Horse Landing Rd
King William
King William County
New Kent County
New Kent
West Point
06/14/2017
Credits: King William County, ESRI
DESIGN NINE
we build networks that perform
0
2.5
5
Miles


Points of Interest for King and Queen County, Virginia
Household Density
# of Households/block group (sq.mi.)
6 - 9
10 - 14
15 - 31
Fire Station
Fire/Rescue Station
Police Station
Rescue Squad
Virginia Address Points
College / University
Government Office
Hospital/Polyclinic
Library
K12 School
Interstate
Primary Highway
Secondary Highway
Railroad
Place
Warsaw
Haynesville
Tappahannock
Owenton
Pauls Crossroads
Center Cross
Central Garage
Walkerton
King William
King and Queen Court House
West Point
Gressitt
Newtown
Indian Neck Rd
Allens Circle
Courthouse Landing Road
Essex County
King and Queen County
King William County
New Kent County
Middlesex County
Gloucester County
06/14/2017
Credits: King and Queen County, ESRI
DESIGN NINE
we build networks that perform
0
2.5
5
Miles


Existing Towers in Middle Peninsula
County Owned
American Tower
FCC Registerd Tower
Known Tower Location
Water Tank
County Boundary
Interstate
Primary Highway
Secondary Highway
Local Road
Essex County
King and Queen County
King William County
Middlesex County
Gloucester County
Mathews County
Port Royal
Bowling Green
Central Point
Champlain
Montross
Piney Point
Saint George Island
Scotland
Kinsale
Acorn
Lewisetta
Warsaw
Haynesville
Heathsville
Tappahannock
Owenton
Farnham
Burgess
Pauls Crossroads
Reedville
Center Cross
Wicomico Church
Lively
Lancaster
Central Garage
Walkerton
Mollusk
King William
Kilmarnock
White Stone
Irvington
Saluda
Hartfield
Deltaville
Highland Springs
Gwynn
New Kent
West Point
Sandston
Gressitt
Providence Forge
Bellamy
Susan
Toano
Charles City
Enon
Hopewell
Achilles
Williamsburg
Yorktown
Claremont
Seaford
Fort Lee
Prince George
Jamestown
Scotland
Spring Grove
Poquoson
Bethel Manor
Rushmere
Hampton
N
W
E
S
06/14/2017
Credits: ESRI
DESIGN NINE
we build networks that perform
0
10
Miles

Appendix C: Glossary

Active network: Typically a fiber network that has electronics (fiber switches and CPE) installed at each end of a fiber cable to provide "lit" service to a customer.

Passive network: Refers to infrastructure that does not have any powered equipment associated with it. Examples include wireless towers, conduit (plastic duct), handholes, and dark fiber.

Dark fiber: Dark fiber is fiber cable that does not have any electronics at the ends of the fiber cable, so no laser light is being transmitted down the cable.

Lit network: A "lit"network (or lit fiber) is the same as an active network. "Lit" refers to the fact that the fiber equipment at each end use small lasers transmitting very high frequency light to send the two way data traffic over the fiber.

FTTH/FTTP/FTTx: Fiber to the Home (FTTH), Fiber to the Premises (FTTP), and Fiber to the X (FTTx) all refer to Internet and other broadband services delivered over fiber cable to the home or business rather than the copper cables traditionally used by the telephone and cable companies.

Symmetric connection: The upload and download bandwidth (speed) is equal. This is important for businesses and for work from home/job from home opportunities.

Asymmetric connection: The upload and download bandwidth (speed) are not equal. Cable Internet and satellite Internet services are highly asymmetric, with upload speeds typically 1/10 of download speeds. Asymmetric services are problematic for home-based businesses and workers, as it is very difficult to use common business services like two way videoconferencing or to transfer large files to other locations.

IP video: Video in various forms, including traditional packages of TV programming, delivered over the Internet rather than by cable TV or satellite systems.

Latency: The time required for information to travel across the network from one point to another. Satellite Internet suffers from very high latency because the signals must travel a round trip to the satellite in stationary orbit (22,500 miles each way). High latency makes it very difficult to use services like videoconferencing.

Fiber switch: Network electronic equipment usually found in a cabinet or shelter

CPE: Customer Premises Equipment, or the box usually found in a home or business that provides the Internet connection. DSL modems and cable modems are examples of CPE, and in a fiber network, there is a similarly-sized fiber modem device.

Handhole: Handholes are open bottom boxes with removable lids that are installed in the ground with the lids at ground level. The handholes provide access to fiber cable and splice closures that are placed in the handhole. Handholes are also called pull boxes.

Pull boxes: Pull boxes (also called handholes) are used to provide access to fiber cable and splice closures. They are called pull boxes because they are also used during the fiber cable construction process to pull the fiber cable through conduit between two pull boxes.

Splice closures: Splice closures come in a variety of sizes and shapes and are used to provide access to fiber cable that has been cut open to give installers access to individual fiber strands. Splice closures are designed to be waterproof (to keep moisture out of the fiber cable) and can be mounted on aerial fiber cable or placed underground in handholes.

Splicing: The process of providing a transparent joint (connection) between two individual fiber strands so that laser light passes through. A common use of splicing is to connect a small "drop" cable of one or two fiber strands to a much larger (e.g. 144 fiber strand) cable to provide fiber services to a single home or business.

SCADA: Supervisory Control and Data Acquisition. Used by the electric utility industry and some other utilities (e.g. water/sewer) to manage their systems.

Colo facility: Colo is short for Colocation. Usually refers to a prefab concrete shelter or data center where network infrastructure converges. A colo or data center can also refer to a location where several service provider networks meet to exchange data and Internet traffic.

Backhaul: Typically refers to a high capacity Internet path out of a service area or locality that provides connectivity to the worldwide Internet.

Appendix D: Key Broadband Technologies

In the Middle Peninsula region, there is no one technology that is going to provide a "one size fits all" solution for homes, businesses and institutions. While wireless broadband will be a primary means of access for many if not most homes and businesses, fiber routes in key areas to support economic, community, public safety, and K12 use may be important complementary network assets.

Fiber Systems

Fiber is a future proof investment. The upper limit of fiber capacity has not yet been found, and off the shelf hardware can handle thousands of times the needs of an average home or business well into the future. Fiber has a life expectancy of thirty to forty years, and may last much longer than that; every year, the number goes up as fiber systems installed in the 1970s continue to perform adequately. A single fiber can carry all the traffic and services needed by a home or business, including voice telephone service, television programming, live videoconferencing, and HD television.

Fiber's primary drawback is its apparent high cost compared to other systems. Fiber is often unfairly compared to wireless, with the misleading conclusion that wireless is much cheaper. Regrettably, most fiber versus wireless studies compare the start up costs for wireless to the thirty year life cycle costs of fiber infrastructure. During a thirty year period, fiber is installed just once, while wireless systems will have to be replaced entirely several times. Properly costed over a thirty year period, fiber is actually less expensive than wireless, with many times the capacity.

Metro Ethernet is a point-to-point service provided over fiber. Metro Ethernet networks can deliver service as far as 50 miles from network element locations and provide speeds up to 10 Gigabits per second (10GB Metro Ethernet circuits are now commonly available from some providers).

Carrier Ethernet is the term used to describe Active or Metro Ethernet deployed to the premises. Carrier Ethernet is available in 100 Mbps and 1 Gbps utilizing a pair or a single fiber strand and speeds of 10 Gbps over a pair of fiber optic strands. Carrier Ethernet can be deployed at distances of up to 50 miles (80km) from the central office.

A Passive Optical Network, or PON, is a fiber optic network based upon a splitter technology. A single PON port can support up to 64 customers utilizing either daisy chained splitters or a central splitter location. For service providers PON is cost effective as it allows the service providers to create "fiber light" networks and fewer network elements. However, PON has many drawbacks including bandwidth limitations due to the shared nature of the feeder fibers as all customers fed from a splitter share bandwidth over a single fiber (or single pair in some networks). A major drawback of PON, if field splitters are used, is the upgradeability of the network which usually requires additional feeder fiber to be deployed which is costly as it is considered a "forklift upgrade."

CARRIER FIBER (ACTIVE) ETHERNET CHARACTERISTICS	
Bandwidth	1 Gbps standard
Line sharing	Each user has a dedicated 1Gbps between the premises and the core location.
Latency	Not latent
Symmetric/Asymmetric	Symmetric
Effective Distance	up to 50 miles (10km, 20km, 40km, and 80km optics available)
Services Support	Multiple services, multiple providers
Typical per subscriber build cost	$3250 - $3500

PON FIBER (PASSIVE) CHARACTERISTICS	
Bandwidth	2.4 Gbps/1.24 Gbps (shared between users on a port). A few 10Gig PON systems are now being deployed because the older PON systems are running out of bandwidth.
Line sharing	Each port is shared by a power of 2 premises (2, 4, 8, 16, 32, or 64) depending on how the network is configured.
Latency	Minimal latency.
Symmetric/Asymmetric	Asymmetric
Effective Distance	up to 25 miles (40km)
Services Support	Multiple services, multiple providers
Typical per subscriber build cost	$3250

We are now seeing even small and medium-sized businesses asking for fiber connections. Fiber is the only transmission system that will be able to deliver all the services businesses and residents will expect and demand in just a few years. Communities that choose to delay fiber infrastructure investments will be at a severe disadvantage in the next several years when trying to attract and retain businesses and workers.

In business areas of the region, fiber is an absolute requirement to retain existing businesses and to attract new ones. Many of subdivisions could have fiber within the neighborhood and wireless backhaul, and multiple services (e.g. video, Internet, voice, data backup) could be delivered within the neighborhood by fiber. In growth areas, retail and office space would become more valuable with high performance fiber availability.

Fixed Point Access Wireless

Fixed point wireless Internet access via private sector providers is already available in some areas of the region. This service introduces additional competition for Internet access customers, which can lower prices and create incentives to offer better customer service from the providers. Over time, most fixed point Internet users (five to seven years out) will want to migrate to fiber connections which will have the capacity to provide a much wider range of services, including HD TV, telemedicine, and tele-health, among other applications.

Fixed point wireless infrastructure investments (e.g. locations for towers, towers, fiber and duct backhaul connections) can be re-used over time to support mobile wireless services and long term public safety voice and data services.

The goal would be to identify existing tower sites that could be reached affordably with fiber. Fiber access to these towers will lower the cost of backhaul for local wireless broadband providers while simultaneously allowing them to increase bandwidth and overall performance.

Wireless broadband services will be important in rural parts of the region. And wireless is not going away; it will remain as an important component of a well-designed community broadband system--as a mobility solution. As we travel around the community, we want to be able to access the Web, check email, make phone calls, and do other sorts of things. Wireless services enable that, and in rural areas, wireless services are an important step up from dial-up.

WiMax and LTE capacities and distances are widely exaggerated. It is very common to see promises of "up to 80-100 megabits" of capacity and distances of "10 to 20 miles." With respect to bandwidth, that 100 megabits of capacity will be shared among all connected users, so if 100 households are trying to access the network via a single WiMax access point, the usable bandwidth may be more like 2-4 megabits per household or per user. Distances are limited by line of sight.

Both WiFi and WiMax signals will work over many miles, but only with narrow angle antennas and clear line of sight. While WiFi can easily reach ten miles or more with clear line of sight, and WiMax can reach twenty miles with clear line of sight, in practice these optimum distances are rarely achieved; it is more realistic to consider WiFi usable over 2-4 miles and WiMax over 4-8 miles. Tree cover is particularly problematic, and it is often necessary to remove tree limbs, an entire tree, or to relocate the antenna in order to get a good signal.

LTE and television "white space" systems are emerging standards that can provide connectivity at much longer distances (five to ten miles is possible under ideal circumstances) and the radio frequencies used are better able to penetrate at least some foliage. Bandwidth of several megabits are possible, and compare very favorably with copper-based systems like DSL. But even these systems will have a limited ability to handle TV programming, interactive videoconferencing, and other business class services.

FIXED POINT WIRELESS CHARACTERISTICS	
Bandwidth	5Mbps - 10Mbps on average for rural/residential service. Higher speeds available at higher cost.
Line sharing	In most Wireless ISP (WISP) architectures customers share a point to multi-point connection with an access point. Service can be affected when too many customers are on an access point.
Latency	Minimal latency issues
Symmetric/Asymmetric	Symmetric
Effective Distance	The effective range of an access point depends on the frequency chosen.
Services Support	Internet, VoIP, and streaming video can be supported by WISP architectures. A multi-provider environment can be configured on a WISP network, but is less commonly found compared to fiber networks.
Typical per subscriber build cost	$370 to $550, and costs could be much higher if a pole has to be installed ($2000 to $7000). High operating costs should be considered as a factor because of the high failure rate for wireless equipment.

Cellular Data Wireless

Wireless access to the Internet and other mobile services like cellular telephone providers is a long term need that will not be replaced by fiber access. In fact, over the next five to seven years, the most common use for wireless Internet access will be for mobility--casual business, personal, and government access away from the home or office. In the rural areas of the region, fixed point cellular data services (e.g. "air card") can provide substantial improvements over DSL, satellite, or dial up.

Mobile wireless access to voice and data services is already widely available from multiple providers in most of the U.S. Nationwide, Verizon, Sprint, and AT&T have already begun an aggressive expansion and upgrade to LTE (the so-called 4G/5G networks). However, the bandwidth caps and bandwidth overage charges make cellular data services too expensive as a primary residential or small business connection.

Perhaps more alarming, some telephone companies, including Verizon and AT&T, are abandoning their copper line plant in many rural areas of the country, and are only offering cellular-based dial tone for home and small business use.

Cellular data plans, because of the bandwidth caps and overcharges that are included with typical plans, can be a poor solution for rural residents who may be trying to use it for business purposes, for K12 school assignments, and/or personal use. Households with children report that it is very difficult (and/or expensive) to keep within data caps.

CELLULAR DATA SERVICE CHARACTERISTICS	
Bandwidth	2Mbps-12Mbps and up, but actual bandwidth can vary widely.
Line sharing	In a mobile wireless broadband network the access point is in a point to multi-point configuration, meaning access is shared.
Latency	Latency is generally not an issue
Symmetric/Asymmetric	Symmetric
Effective Distance	The effective range of an access point depends on the frequency chosen.
Services Support	Internet, VoIP, and streaming video can be supported but service may degrade at peak times.
Typical per subscriber build cost	$80 and up, depending on data plan, bandwidth caps and overage charges.

Emerging Wireless Technologies

MIMO Wireless

MIMO (Multiple Input, Multiple Output) describes a variety of technologies that can be summarized as using more than one receive and transmit antenna for wireless data applications. Wireless protocols that are using the MIMO concept include IEEE 802.11n (Wi-Fi), IEEE 802.11ac (Wi-Fi), 4G, LTE (Long Term Evolution), and WiMAX. Each of these protocols use the MIMO technology to increase the amount of available bandwidth in a given section of radio frequency spectrum.

New hardware is required to make effective use of MIMO. While the technology increases wireless bandwidth, the typical amount of bandwidth being used by wireless devices is also increasing rapidly. Some applications where MIMO is likely to provide noticeable improvements are in home wireless routers, where the effective throughput will be able to better handle the demanding bandwidth requirements of HD and 4K video streams. MIMO is slowly being developed for use with cellular smartphones, but both the phones and the cell tower radios have to be upgraded to support MIMO.

LTE/4G/5G

LTE (Long Term Evolution) is a set of protocols and technologies designed to improve the performance of voice/data smartphones. Like MIMO, both the user phone and the cell tower radios have to be upgraded to support LTE improvements. In 2013, only 19% of U.S. smartphone users were able to take advantage of LTE speeds, although that percentage has been increasing rapidly since then, and more than 85% of the U.S. cellular towers are expected to be upgraded to LTE in the next two years. As noted previously, the actual bandwidth available to a smartphone user is highly variable and depends on distance from the cell tower, the number of smartphones accessing the same tower simultaneously, and the kinds of services and content being accessed by those users.

The primary purpose of cellular bandwidth caps is to keep cellular users from using too much bandwidth and degrading the overall service. While LTE and MIMO improvements will improve overall cellular service, these technologies are not going to replace fiber to the home and fiber to the business.

The 5G technical standard is not scheduled for release until 2020, so any promises of 5G systems eliminating the need for fiber services is just marketing promises without any substance.