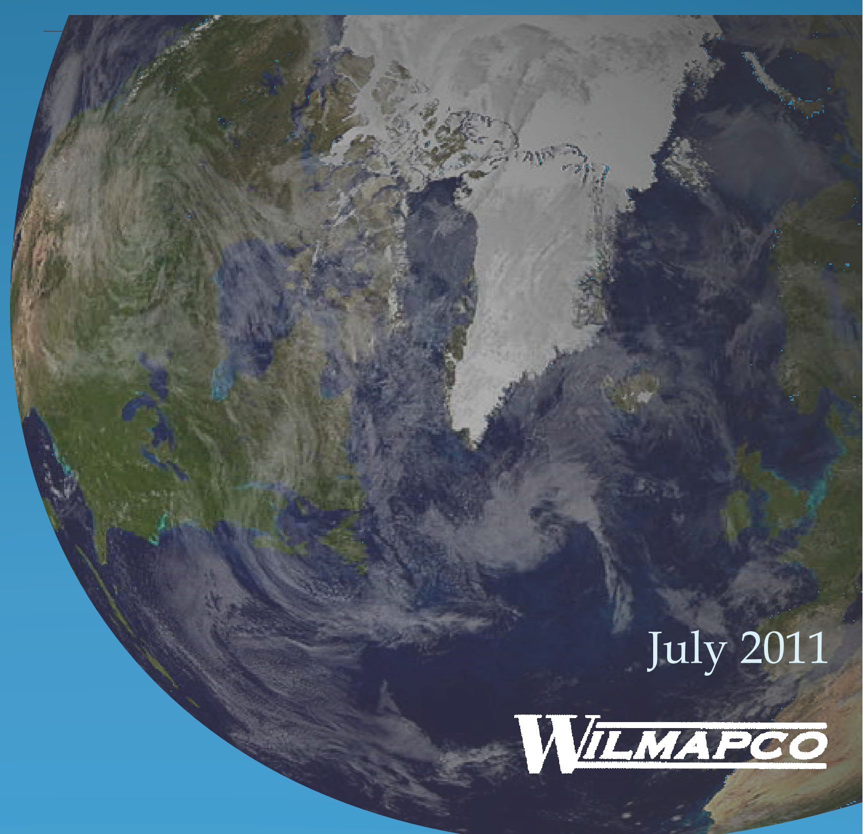
Sea-Level Rise

A Transportation Vulnerability Assessment of the

Wilmington, Delaware Region



July 2011

WILMAPCO

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Sea-level Rise

A Transportation Vulnerability Assessment of the Wilmington, Delaware Region

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RESOLUTION

BY THE WILMINGTON AREA PLANNING COUNCIL (WILMAPCO) TO ACCEPT SEA-LEVEL RISE: A TRANSPORTATION VULNERABILITY ASSESSMENT OF THE WILMAPCO REGION

WHEREAS, the Wilmington Area Planning Council (WILMAPCO) has been designated the Metropolitan Planning Organization (MPO) for Cecil County, Maryland and New Castle County, Delaware by the Governors of Maryland and Delaware, respectively; and

WHEREAS, the potential transportation impacts of climate change are a growing area of concern for regions across the globe; and

WHEREAS, sea-level rise adaptation planning processes have been initiated by the states of Delaware and Maryland; and

WHEREAS, *Sea-level Rise: A Transportation Vulnerability Assessment of the WILMAPCO Region* identifies at-risk existing and planned transportation infrastructure, carrying forward those adaptation planning processes; and

WHEREAS, *Sea-level Rise: A Transportation Vulnerability Assessment of the WILMAPCO Region* addresses climate change ahead of likely federal requirements; and

WHEREAS, *Sea-level Rise: A Transportation Vulnerability Assessment of the WILMAPCO Region* provides recommendations to better incorporate climate change adaptation and mitigation activities into WILMAPCO's planning process;

NOW, THEREFORE, BE IT RESOLVED that the Wilmington Area Planning Council does hereby accept *Sea-level Rise: A Transportation Vulnerability Assessment of the WILMAPCO Region*.

July 14, 2011
Date

Stephen Kingsberry, Chairperson
Wilmington Area Planning Council

WILMAPCO

Partners with you in transportation planning

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Introduction

The Wilmington Area Planning Council (WILMAPCO) is the Metropolitan Planning Organization (MPO) for Cecil County, Maryland and New Castle County, Delaware. We are charged with planning and coordinating transportation investments for the Wilmington region.

The Wilmington region is home to nearly 640,000 residents, most of whom (84%) live in New Castle County. Wilmington, a financial hub supporting a population of more than 70,000, serves as the principal city. Urbanized development stretches outside of Wilmington along the I-95 corridor, from the Town of Elkton to the Pennsylvania border. Natural and rural landscapes, sprawling suburbs, and small towns blanket the rest of the region.

WILMAPCO's mission is to create the best transportation Plan for the region, one that meets all the requirements mandated by the Federal Clean Air Act and its Amendments (CAAA) and the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU).

Executive Summary

Sea-level rise (SLR) is a well-documented, and potentially devastating, outcome of global warming. The present study aims to identify at-risk transportation infrastructure in the WILMAPCO region using locally-developed inundation scenarios. In doing so, it advances larger SLR adaptation planning efforts already well -underway in Delaware and Maryland, while firmly addressing a key aspect of climate change in anticipation of federal requirements.

Background

The Earth's seas have historically risen and fallen considerably during periods of warming and cooling. During the past century, seas rose about one-half foot. Scientists conservatively estimate a further rise of some two feet during the next century. Additionally, storms are expected to increase in intensity over the same period, bringing with them more flooding.

SLR presents key challenges to coastal lands and their transportation networks. Among others, these include:

- Coastal flooding
- Loss of wetlands
- Land inundation

Specific concerns to transportation may be:

- Road/railway inundation and erosion
- Loss of evacuation routes
- Sea channel navigation

Adaptation measures to address these concerns include:

- Elevation
- Relocation
- Shoreline defenses
- Eco-engineering
- Abandonment

The product of a complete SLR adaptation planning process would be the selection of one or more of these adaptation strategies to pursue at threatened areas. The present assessment hopes to inform these ultimate decisions.

Methods

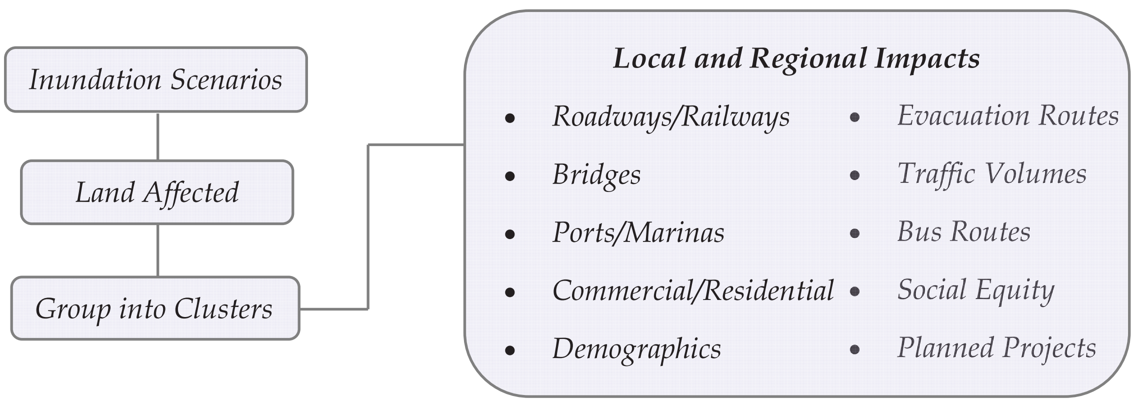
A steering committee comprised of staff from our member agencies and the public guided the development of this study. Gathering four times during 2010 and 2011, the group laid out the study's scope and provided technical feedback and direction.

The chart below details the study's approach. Analyses involving inundation scenarios are the cornerstone of the study. The scenarios used are shown below.

Cecil Co.	New Castle Co.
2 feet	0.5 meter (1.6 feet)
5 feet	1.0 meter (3.3 feet)
10 feet*	1.5 meter (4.9 feet)

* Surge scenario

Using Geographic Information Systems (GIS), we assessed SLR impacts to transportation both regionally and locally (within the clusters). Examples of different facilities and measures considered can be found in the balloon below.



Results

Geologic differences between the Chesapeake Bay and the Delaware River result in greater SLR impacts in New Castle County. Some 12% of land there may be exposed to inundation at a 1.5 meter rise; a shade over 1% of Cecil County's land would be tested in the same circumstance.

These SLR challenges include major population centers, home to crucial infrastructure, such as our region's principal city, Wilmington, the City of New Castle, Delaware City, and the towns of Elkton, Chesapeake City, and North East. More than 1,600 residential and commercial properties risk inundation at a 1.5 meter rise regionally, with an additional 1,000 plus properties impacted with a 10 foot surge in Cecil County. We found that neighborhoods with above average concentrations of blacks and low-income residents were more likely to face inundation.

SLR presents challenges to key facets of our transportation network. Segments of highways, such as SR 9 and US 13 hugging the Delaware River and SR 222 along the Susquehanna River, risk increased flooding or complete inundation.

More than seven miles of SR 9 may be inundated with a 1.5 meter rise, for example. A similar fate may befall segments of near-river railways such as the New Castle County Secondary and Norfolk Southern's Port Road Branch. Wilmington's train station risks inundation with a 1.0 meter rise, while Newport's planned station may be exposed at 1.5 meters. Structures at the Port of Wilmington may be tested with a rise of as little as 0.5 meters. Further, sixty funded and unfunded regional transportation projects at-risk of inundation were flagged, along with impacted fixed-route bus routes, evacuation routes, bridges and marinas.

Finally, a "Critical Roadway Impact Index" was developed to help identify the most crucial of the 30 miles of key roadway segments challenged by SLR. The index considers a road segment's inundation level, traffic characteristics and the surrounding area's demographics to begin to understand the segment's comparative importance within our regional system. Inundated stretches of US 40 in Elkton and Walnut Street in Wilmington received the highest scores.

Local Impacts

Sub-regional exposures to SLR were profiled within 20 "clusters." Clusters represent groupings of census block-groups that may experience SLR impacts to their infrastructure. Three maps are provided for each cluster. These maps analyze the area's present and future demographics, socio-economic data, locally-impacted transportation facilities (road, rail and bridges), and locally-impacted planned transportation projects. Cluster 6, South Wilmington, was found to have the most severe SLR impacts.

Policy

Four WILMAPCO policy adjustments are suggested as a result of the present study:

- Fully incorporate climate change policy into the Regional Transportation Plan, and track our performance in this area
- Continually monitor SLR impacts to planned projects
- Enhance climate change public outreach
- Support ongoing climate change efforts

Conclusion

Adaptation planning is necessary to begin addressing potential impacts of SLR. It is well beyond the ability of a single agency to tackle the impacts SLR poses to coastal areas. Coordination at all levels of government, and with the public and other private entities, is necessary to develop long-range response plans.

In our examination of potential SLR impacts to our transportation network, this report hopes to push forward the SLR adaptation efforts begun in Delaware and Maryland, and to assist with the decision-making process. Additionally, climate change planning efforts figure to factor into new planning requirements for MPOs with the upcoming federal transportation bill. The present study constitutes one of WILMAPCO's "new initiatives," in anticipation of new requirements.

Chapter 1

Background

Sea-level rise (SLR) is one of the most significant effects of climate change.[1] Shoreline erosion, inundation of wetlands, and damage to infrastructure are key consequences of SLR that may be experienced in the coming decades (DNREC Sea-level Rise Technical Workgroup, 2009).

Adaptation efforts to reduce impacts on low-lying areas, like the Wilmington region, are crucial. Planning efforts in Delaware and Maryland are emerging to evaluate the potential effects of SLR (Delaware Coastal Programs, 2010a).

What is Climate Change?

Climate change refers to a long-term shift in the Earth's weather pattern as a result of both natural variation and human-induced factors. These shifts include alterations in the averages, extremes, timing, and spatial distribution of weather (Holdren, 2008).

The past two decades have been the warmest period on record (NOAA, 2007). As a result, mitigation and adaptation efforts to reduce potential impacts of climate change (increases in temperature, precipitation, hurricane events, and rising sea-level) are being implemented. In the transport sector, mitigation efforts focus on reducing the system's contribution to warming through minimizing greenhouse gas emissions. Adaptation addresses the need for building infrastructure resilience and protection from impacts.

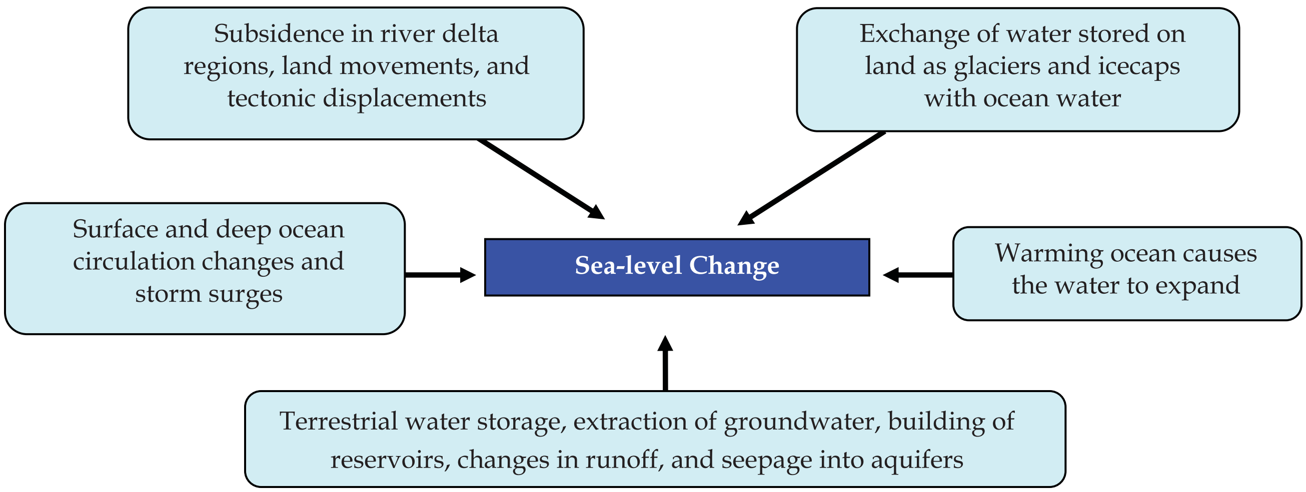
What is Sea-level Rise?

Sea-level rise along the Mid-Atlantic coast is the result of three global processes (Figure 1):

- Sinking land (subsidence) is occurring as a result of geologic changes (Delaware Coastal Programs, 2010b).
- Melting land reservoirs of ice and water cause increased drainage to the oceans (Titus et al., 2009).
- Warming ocean temperatures cause water expansion; leading to an increase in overall volume (Titus et al., 2009).

1. Other impacts of climate change include increases in very hot days and heat waves, increases in Arctic temperatures, increases in intense precipitation events, and increases in hurricane intensity (TRB, 2008).

Figure 1: Causes of Sea-level Change (Griggs, 2001)



Rates of Sea-Level Rise

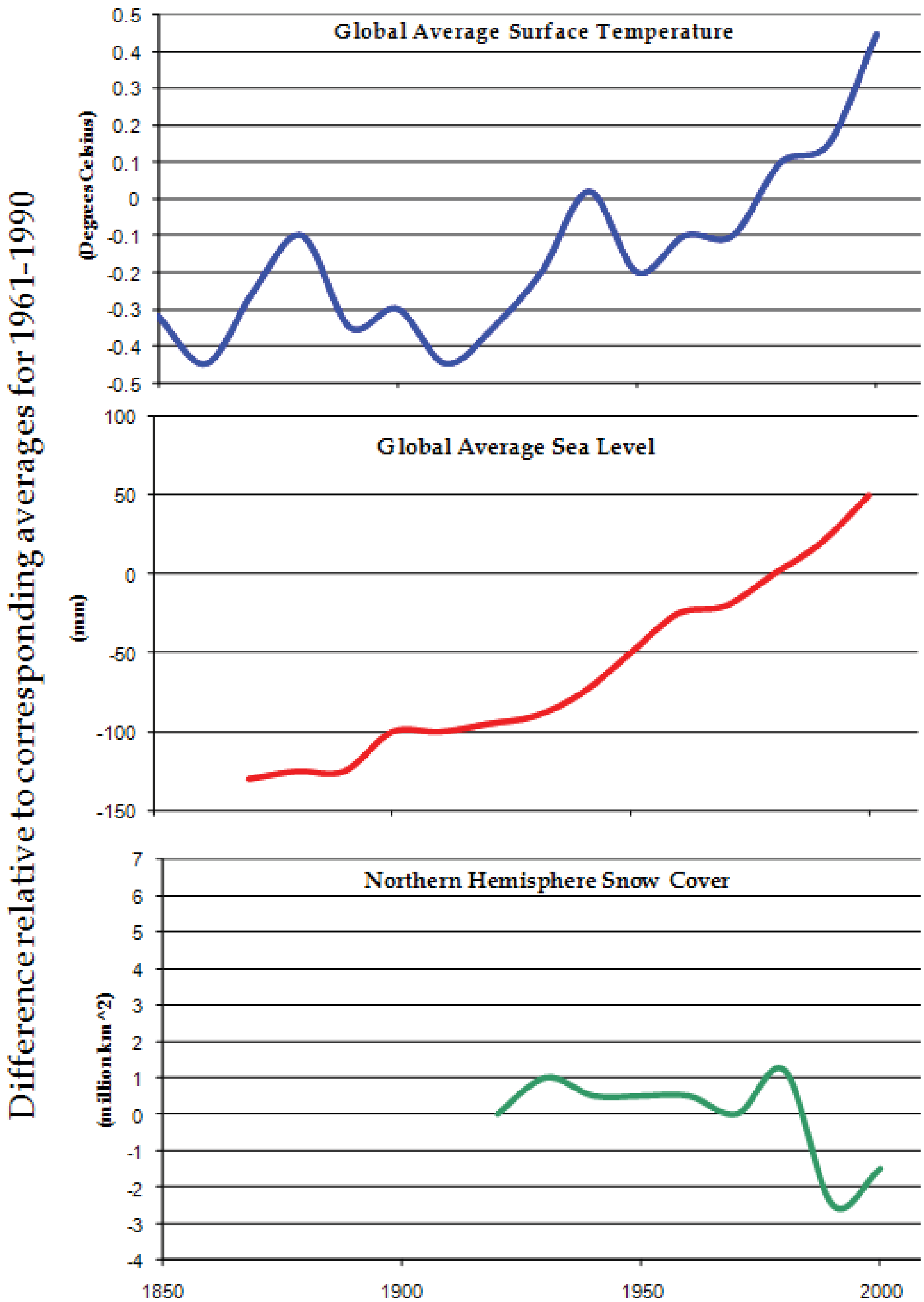
SLR is one of the most documented and accepted impacts of climate change (Savonis et al., 2008). The average global sea-level rose approximately 1.7 millimeters per year during the 20th century, and observations suggest this rate is accelerating (Titus et al., 2009). Similar to average surface temperature trends, the average SLR rate increased 1.8 millimeters per year between 1961 to 2003 (see Figure 2) (IPCC, 2007). According to the International Governmental Panel on Climate Change (2007), global sea-level will rise between 0.59 and 1.9 feet by the end of the 21st century (Delaware Coastal Programs, 2010b). However, if polar ice caps melt at a more accelerated rate than projected, global SLR could be more substantial. The uncertainty behind the causes of sea-level rise leads to a range of differing scenarios.

Global sea-levels have fallen and risen widely during the past half-million years. During periods of cooling, seas dip, and during periods of warming they rise. Seas were about 4 to 6 meters higher than the present during the last interglacial warming period, about 125,000 years ago, while the last Ice Age (some 21,000 years ago) witnessed seas 120 meters below present levels (Titus et al., 2009).

Rates of sea-level rise have historically been quite pronounced. Following the last Ice Age, seas rose at rates of anywhere from 10-50 mm per year, two to four times what is expected during the decades to come (Titus et al., 2009).

As the debate continues concerning the extent human activities have impacted this natural cycle (Legates, 2006), what is clear is that sea-levels are rising, and this poses serious adaptation challenges to coastal communities.

Figure 2: Change in Temperature, Sea-level and Northern Hemisphere Snow Cover (IPCC, 2007)



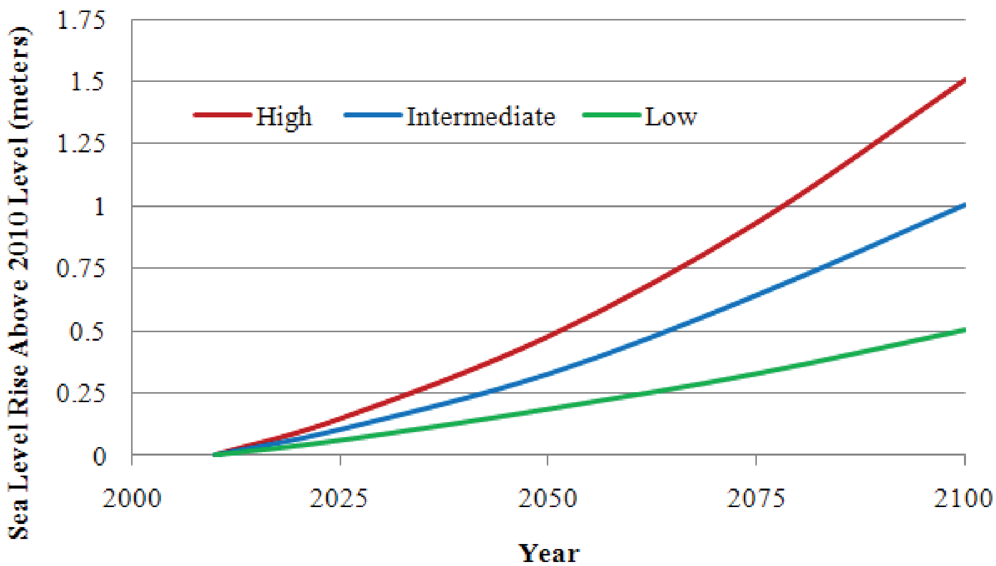
Delaware and Maryland's Vulnerability

Sea-levels rose more substantially off the U.S. Mid-Atlantic coast compared to the global average during the 20th century. The Mid-Atlantic SLR rate ranged between 2.4 and 4.4 millimeters per year, versus less than 2 millimeters per year globally. This is a rise of about 1 foot during the twentieth century in the Mid-Atlantic (see Figure 3) (Titus et al., 2009). This increased rate is primarily due to the low-lying landscape and slope grade in and around the Chesapeake and Delaware Bays and other geologic changes resulting from postglacial rebound (Maryland Commission on Climate Change, 2008). Postglacial rebound is the readjustment (or sinking) of land elevations since the retreat of the glaciers at the end of the last Ice Age (Maryland Commission on Climate Change, 2008).

***Figure 3: Rates of SLR in Chesapeake and Delaware Bays Region** (Maryland Commission on Climate Change, 2008)*

Using projections to effectively predict and prepare for future events is essential. The Delaware Department of Natural Resources and Environmental Control (DNREC) has determined three pathways for SLR in Delaware within the next century: low (0.5 m), intermediate (1.0 m), and high (1.5 m) (see Figure 4).

***Figure 4: Delaware SLR Scenarios** (DNREC Sea-level Rise Technical Workgroup, 2009)*



Similarly, the Maryland Commission on Climate Change has determined SLR scenarios that incorporate not only the IPCC scenarios but also the possibility of accelerated melting. Based on this, Maryland's coast may experience a rise of 0.6 feet (0.18 meters) to 1-1.3 feet (0.3-0.4 meters) by the end of the twenty-first century.

Potential Impacts of Sea-Level Rise

Sea-level rise has the potential to significantly impact coastal regions. These areas in Delaware and Maryland are vulnerable to "episodic" and "chronic" SLR events (Maryland Commission on Climate Change, 2008).

Episodic events include extreme weather incidences such as:

- Hurricanes
- Nor'easters

Chronic events include:

- Shoreline erosion
- Coastal flooding
- Storm surge (intense flooding associated with storms as a result of wind stress)
- Inundation

Impacts from these events may include (Maryland Commission on Climate Change, 2008):

- *Shoreline Erosion*- reduced land area leads to devalued property and undermining of roadways.
- *Coastal Flooding*- increased height of storm waves leads to increased flood waters, which cause property and infrastructure damage.
- *Loss of Wetlands*- rising seas cause wetlands to become stressed leading to a loss of wildlife and habitat.
- *Inundation of Low-Lying Lands*- areas with minimal elevation change are vulnerable to gradual submergence.
- *Reshaping of Barrier and Bay Islands- wave, wind, and ocean currents, coupled with SLR, reshape barrier and bay islands.*
- *Higher Water Tables*- rising seas lead to rising groundwater tables, which cause salt-water intrusion, septic system failure, and infrastructure instability.

SLR poses a threat to infrastructure, such as housing, utilities, and sewage treatment facilities. Transportation systems, including roadways, railways, ports, airports, and non-motorized networks are also at-risk.

Roadways

Sea-level rise directly affects travel on roadways as a result of flooding, inundation, erosion of road bases, removal of sediment around bridge abutments or piers, and reduced bridge clearance (TRB, 2008).

Roadways are often lower in elevation than surrounding lands to maximize the storm water drainage. As flooding increases, roads can become inundated, as shown below.

A Flooded Roadway on Route 9 at Appoquinimink River Bridge (Source: Delaware Coastal Programs)

An indirect effect of flooded roadways is the loss of evacuation routes. Loss of these routes leads to increased risk to life during flood events (Titus, 2002).

Another significant issue is the impact of coastal erosion on roadways. The effects of increased wave action, tidal currents and extreme storm surges can cause the removal of sediment in and around roadways, making them inaccessible.

Railways and Tunnels

Railways are vulnerable to many of the same impacts as roadways including inundation of rail lines in coastal areas, severe flooding of underground tunnels and low-lying rail tracks, erosion of rail base, and reduced clearance under bridges (TRB, 2008).

Similar to roadways, rail tracks are often found in low-lying areas, and therefore, are at-risk for interruptions in service due to flooding (TRB, 2008). In addition, railroads often run through marsh areas in coastal zones and as the low-lying tracks become flooded, the marsh beds become vulnerable to sinking from the compaction of marsh peat (Titus, 2002).

Tunnels are highly vulnerable to the impacts of SLR as a result of two factors. First, the risk of flooding to entrances and vents increases, and second, the hydraulic pressure on the walls of the tunnel increases as the water table rises (Titus, 2002).

Sea Navigation

As sea-levels rise the water depth increases, which directly affects port infrastructure and operations. Specifically, there are impacts on channel navigability. Some channels may become more accessible due to deeper waters, while others may become more restricted due to changes in sedimentation, which is the accumulation of sediment particles (TRB, 2008). The changes in sedimentation result from saltwater advancing upstream, which can alter the point at which sediment clusters form, leading to sedimentation and the creation of shoals (Titus, 2002).

As a result of higher tides, harbor and port facilities will have to be altered. For example, higher tides lead to reduced clearance under bridges. In specific cases where the clearance is low, this impact could reduce the ability of ships to pass underneath bridges (Titus, 2002). Another impact is that docks, jetties and other port facilities are set at an optimal elevation in relation to the current sea-level. As sea-levels rise, these facilities are then at a suboptimal elevation (Titus, 2002).

Aviation

Sea-level rise is less likely to have a significant impact on aviation. However, specific airports that are located along tidal waters are at-risk for runway inundation.

Adaptation Planning Efforts

Adaptation in the context of climate change refers to the ability of a system to adjust to variability with the goal of reducing potential damage from impacts (IPCC, 2007). As a result of the uncertainties associated with SLR (such as the magnitude, range, and timeframe) a comprehensive adaptation plan is necessary to address all areas affected. In order to address potential impacts on transportation facilities, changes in implementation as well as design and materials are required. Some adaptation considerations to transportation facilities include the following:

- Elevating streets, bridges, runways, and rail lines
- Relocating sections of roads and rails inland
- Strengthening and heightening levees, seawalls and dikes to protect existing development
- Restricting further development of vulnerable coastal areas
- Using natural ecosystems for protection (eco-engineering) such as forests and wetlands to manage flooding, erosion, and slope stability impacts

Finding proactive ways to reduce potential impacts of SLR can lead to environmental, economic, and social benefits in the short and long term. Integrated adaptation planning that implements planning, management and regulatory strategies throughout state and local programs is a promising method for responding to the potential impact of SLR (see Figure 5). In both Delaware and Maryland, programs and strategies are being developed in response to climate change adaptation.

Delaware

The state of Delaware's Department of Natural Resources and Environmental Control (DNREC) has developed a SLR Technical Workgroup as well as a SLR Initiative to prepare coastal communities and habitats. The initiative includes four objectives (Delaware Coastal Programs, 2010a):

1. Provide data necessary for projects to assess vulnerability
2. Utilize pilot implementation projects as a learning opportunity
3. Provide tools, methods, and training to stakeholders
4. Use initiative to inform policy development through the Statewide SLR Adaptation Plan

Maryland

The state of Maryland is developing an adaptation and response plan to reduce the impacts of climate change. The Maryland Commission on Climate Change established the Adaptation and Response Working Group to develop a "Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change" (2008). The intent is to provide recommendations to:

1. Promote programs aimed at reducing impacts to existing-built environment
2. Shift to sustainable economies and investments
3. Enhance preparedness and planning efforts
4. Protect and restore the state's natural shoreline and resources

Maryland's State Highway Administration has taken this work a step further, analyzing impacts of SLR on their facilities. Using three inundation scenarios developed by Towson University's Center for Geographic Information Systems (GIS), an automated process has been developed to determine which pieces of infrastructure are at risk. The three scenarios are: 2 foot rise; 2-5 feet rise; and 5-10 feet rise.

Figure 5: Integrated SLR Adaptation and Response *(Maryland Commission on Climate Change, 2008)*

Path Forward

Adaptation planning by agencies is necessary to begin addressing potential impacts of SLR. It is well beyond the ability of a single agency to tackle the impacts SLR poses to coastal areas. Coordination at all levels of government, and with the public and other private entities, is necessary to develop response plans.

Which land and infrastructures should be preserved through implementing dikes or raising existing elevations? Which land and infrastructures should be abandoned to the waters? The present report does not seek to answer these difficult questions, which must be answered in the coming decades for the public good.

Undermined Seawall along Delaware Bay In Fairfield Township, NJ (Press of Atlantic City)

Instead, this report aims to assess the potential impacts of SLR on one key sector in the Wilmington region: transportation. In so doing, it hopes to influence decision-making in the transportation planning process, and push forward the SLR adaptation efforts begun in Delaware and Maryland. Additionally, climate change planning efforts figure to factor into new planning requirements for MPOs with the upcoming federal transportation bill. The present study constitutes one of WILMAPCO's "new initiatives," to anticipate the new requirements. This assessment uses inundation layers to identify vulnerable transportation infrastructure, then discusses the transportation impacts of SLR both regionally and locally, and provides recommendations based on the findings.

Chapter 2

Methodology

This chapter explores the methods used to carry out the present assessment. It provides an overview of the formation and work of a steering committee, before turning to the data and analysis techniques used.

Steering Committee

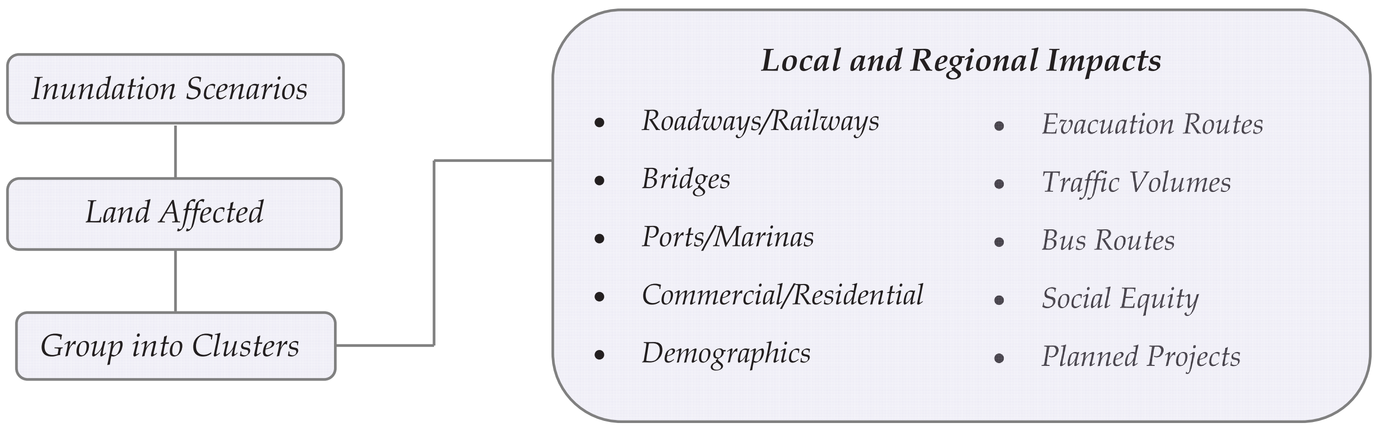
A steering committee, comprised of staff from the agencies listed below, guided the development of the study. Membership was specifically solicited from the WILMAPCO Technical Advisory Committee, but was open to anyone, including the general public. Meeting four times in total, the committee formed the study's scope, discussed its direction and provided critical feedback.

The following agencies participated:

- Cecil County Planning Department
- Delaware Department of Natural Resources and Environmental Control (DNREC)
- Delaware Department of Transportation (DelDOT)
- League of Women Voters of New Castle County
- Maryland Department of Natural Resources (DNR)
- Maryland State Highway Administration (SHA)
- New Castle County Department of Land Use
- University of Delaware

Base Data

The chart below illustrates our methodology. Using Geographic Information Systems (GIS) analysis, we identified which land (census blockgroup) was affected under inundation scenarios. These census blockgroups were grouped into clusters, based on spatial proximity to one another. Each cluster was then assessed for sea-level rise impacts. Submerged roadway segments within a given cluster were noted, for example, along with their key attributes, such as evacuation route designation, traffic volumes, etc. Once all of the cluster-level assessments were completed, a regional assessment was also generated. This assessment details SLR impacts across the region, such as total infrastructure and planned project affected, and social justice implications.



<u>Inundation Scenarios</u>

Six inundation scenarios, three for each county, were supplied by DNREC and Maryland's State Highway Administration (SHA) (from a Towson University analysis). The data from Delaware showed land submerged at 0.5 meter, 1.0 meter and 1.5 meter rises, while the Maryland data used a 2 and 5 foot rise, and a 10 foot surge, respectively. More details on the development of the Delaware inundation scenarios can be found in the appendix.

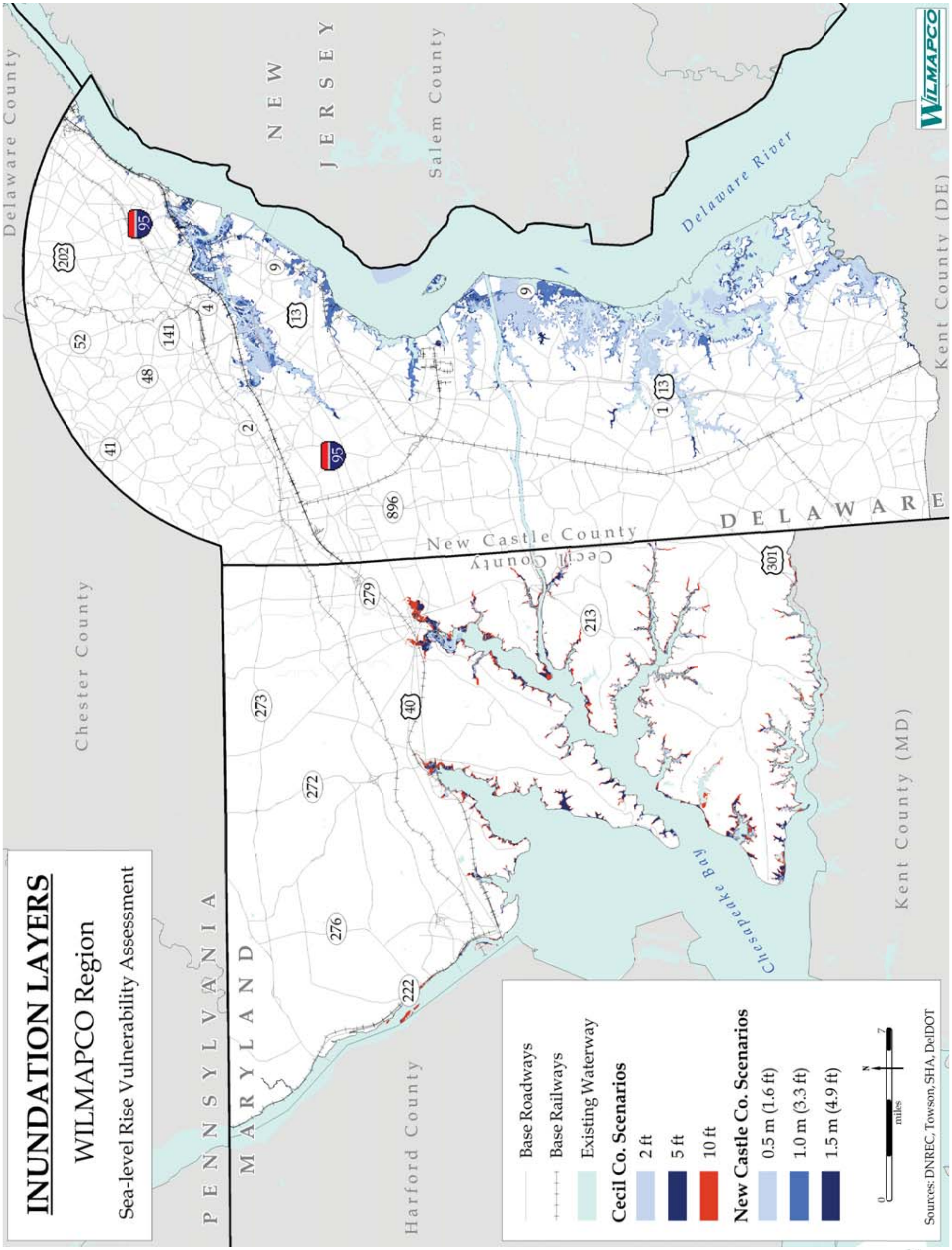
Table 1: Inundation Scenarios

Maryland	Delaware
2 feet	0.5 meter (1.6 feet)
5 feet	1.0 meter (3.3 feet)
10 feet*	1.5 meter (4.9 feet)

* Surge scenario

Map 1 shows the inundation scenarios used in the analysis. We can expect far greater sea-level rise impacts on the New Castle County side of the region, as the Delaware River and its tributaries flood their banks. In Cecil County, only a handful of spots show noteworthy penetration. Geologic differences between the Delaware River and the Chesapeake Bay accounts for this discrepancy. The Delaware River has a shallow slope while the Chesapeake Bay is a sunken river valley with a steep shoreline.

Map 1: Inundation Levels



Land Clusters Affected

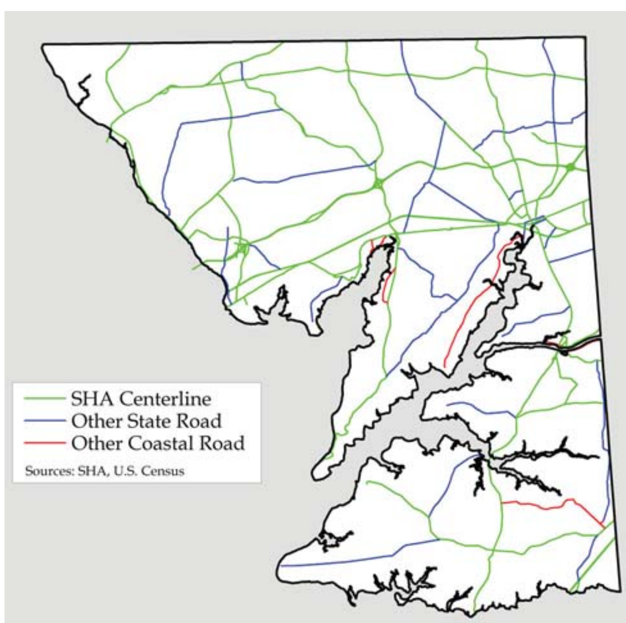
Census blockgroups (from 2000) that experienced inundation in the 10 feet and 1.5 meter scenarios, with associated infrastructure impacts (measured via a scan of air photos) were flagged. Identified blockgroups were then grouped into "clusters," based on spatial proximity. Twenty clusters were identified for closer examination, thirteen in New Castle County and seven in Cecil County. As shown in Map 2, the clusters vary in size considerably, a result of variable blockgroup size. Areas with higher population density are home to smaller blockgroups, while those with fewer persons per square mile are larger. Census blockgroups were slected as the base layer due to the plethora of demographic and socio-economic data available at that level, which allows for more informed cluster profiles.

Base Road and Rail Networks

The road and railway networks used in the vulnerability assessment are displayed on Map 1. These base files capture all major road and rail links in the WILMAPCO region, and include many local links as well. Though possible, time constraints prohibited the analysis from considering all local roads and railway spurs.

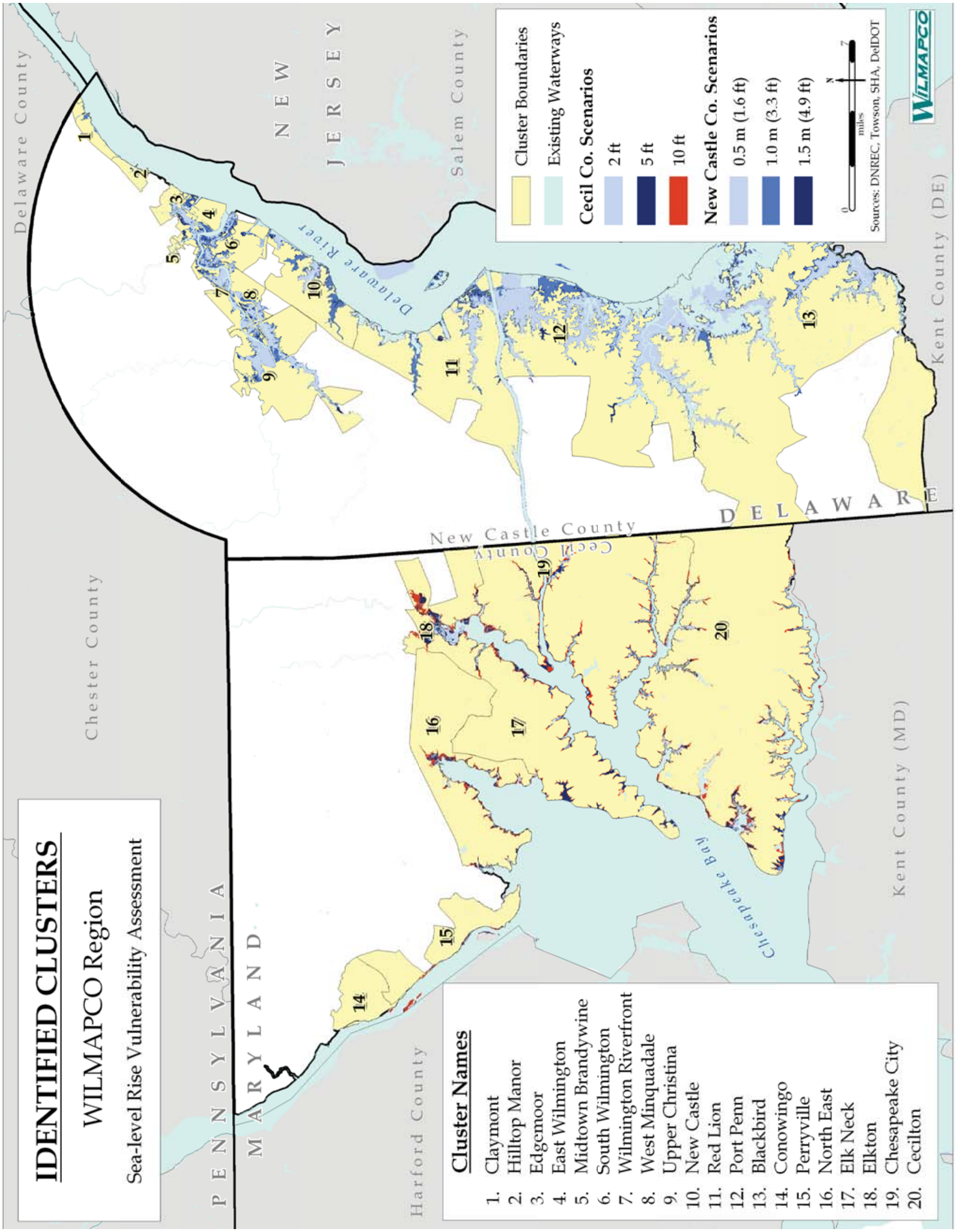
New Castle County's roadway file was obtained from DelDOT. It contains those major, minor and local roadways with associated traffic data. The roadway file for Cecil County is a hybrid. It includes the highways used as a base file for SHA's SLR analysis, and all state roads, plus other collectors that operate along the coast. Map 3 below shows the breakdown.

Map 3: Cecil County Base Roads



The rail files used for this assessment were obtained from DelDOT and MDOT. Only the major operational freight and commuter rail corridors were included. Places where more than one track fell were simplified to one.

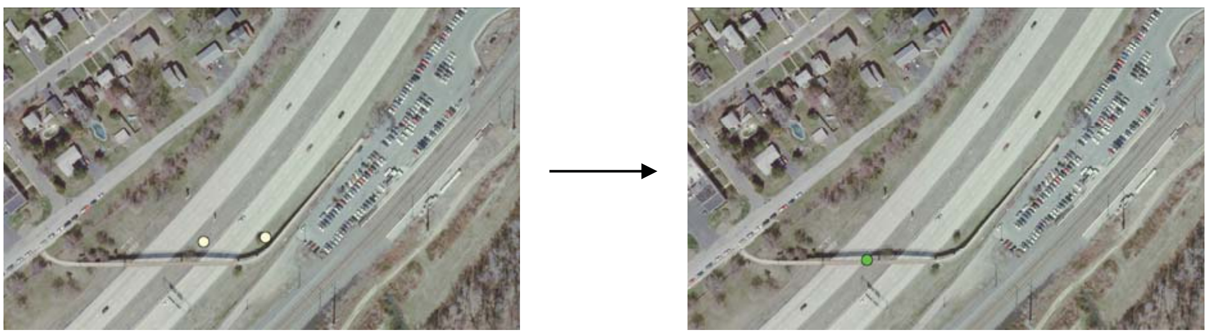
Map 2: Identified Clusters



Base Bridge Network

Like a road and rail network, a base bridge network was established. In New Castle County, DelDOT's bridge/overpass file was used. For the purposes of this assessment, only bridges and overpasses within identified clusters were considered, and the file was simplified to include only one feature per crossing. Illustrated by Figure 6, the original file often contains multiple features for each crossing, related to unique direction and lanes. Here, a pedestrian bridge adjacent to the Claymont Train Station displays two features, one for each direction of the I-495 overpass. This was simplified to one geo-rectified feature. Rail crossings were added to these data after air photo analysis.

Figure 6: Simplification of DelDOT Bridge Data



For Cecil County, a bridge file was obtained from SHA, which contained only those structures maintained by the agency. Using air photos, we supplemented these data with other bridges apparent along inundated road and rail segments. While far from comprehensive, it can be asserted that the base bridge files do capture all major road and rail crossings that may be challenged by SLR in the coming decades.

Other Base Data

Beyond roadways, railways and bridges, the present assessment also reviewed possible SLR impacts to other infrastructure. These include marinas, airports, residential and commercial units, bus routes and bus stops. Marinas and airports were identified from available data and web searches. Point-level residential and commercial data in New Castle County were supplied by the University of Delaware; similar parcel polygon data were obtained for Cecil County from the county's Planning Department. Public transit data from New Castle County were gathered from the Delaware Transit Corporation, while Cecil County transit data are developed and maintained by WILMAPCO.

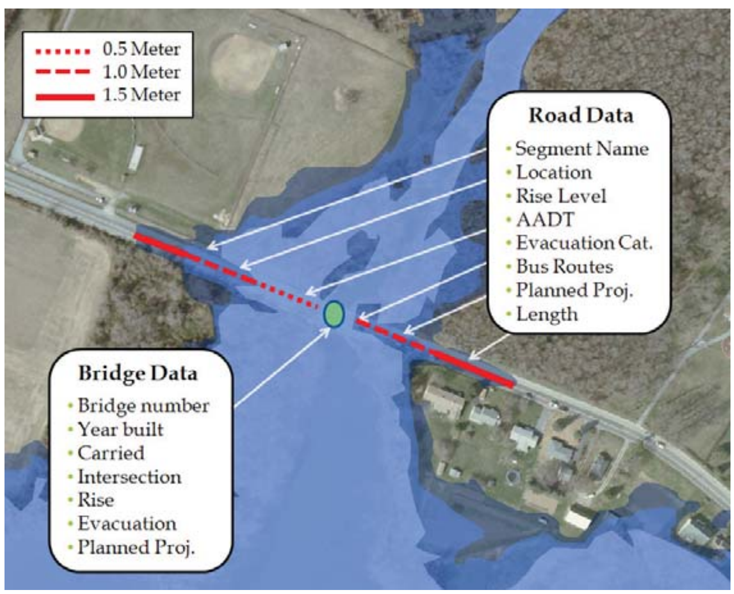
Planned projects were also reviewed. These data represent those financially-reasonable and aspiration projects listed in the WILMAPCO 2040 Regional Transportation Plan.

Data Analysis

Once the base networks were fully developed, they were overlaid with our inundation scenarios. Impacts at the various SLR scenarios were noted for each piece of infrastructure—road segment, bridge, commercial unit, etc. While some of this work was automated within GIS, much of it was done, or at least cross-checked, manually. After the creation of unique features for impacted segments and points, attribute data (traffic volume, operating bus routes, evacuation route designation, etc.) were added where possible and appropriate.

Figure 7 below illustrates the process for a typical road segment and bridge. Here inundated segments of SR 9 near a flooded Dragon Creek in Delaware City are traced; these are represented by the three different red hatched lines, which correspond to rises of 0.5 meter (light blue), 1.0 meter (medium blue), and 1.5 meter (dark blue). The dot represents the bridge (306A) which separates these road segments. It is impacted at level 1. The white boxes list attribute data associated with these seven features. An identical process was applied to rail segments and crossings.

Figure 7: Segment and Bridge Analysis Example



In Cecil County, much of the roadway segment identification was completed by SHA through their parallel SLR analysis. However, this work was only done on SHA-identified highways (see discussion in the previous section) and, because it was automated, was not as refined as the manual analysis we completed for New Castle County. SHA also did not account for bridges separately in their methodology; instead the agency elected to include the highway segments on bridges within the larger segment identification. Using the SHA data as a base, we fine-tuned it, then accounted for bridges separately, before moving into an analysis of inundated segments on roadways/railways not considered in the SHA study.

Impacts to residential and commercial units and bus stops were measured using an automated GIS process, while planned project, marina, train station, seaport, airport and toll facility impacts were measured manually via air photo analysis.

Complete Inundation versus Subsurface Inundation

Our study uses two approaches to identifying which facilitates face SLR challenges. While most are flagged only if "complete inundation" is a possibility, "subsurface inundation" triggers the inclusion of others. Complete inundation refers to the overtopping of a roadway, railway, or other feature with water. Subsurface inundation, illustrated by the flooding of a Florida railway and highway below, involves increases in water volumes at the base of a bridge or other structure. These structures may not have been built to withstand long periods of increased water volumes or wave action, and so may be said to have a potential SLR impact.

Table 2 provides a breakdown of the facilities for which the complete inundation approach was used, versus subsurface inundation.

Flooding of State Route 141 due to Suwanee River Flood, Florida (Source: USGS)

Table 2: Inundation Measure Used by Facility

Facility	Inundation Type
Roadways	Complete
Toll Facilities	Complete
Bus Routes and Stops	Complete
Evacuation Routes	Complete
Railways	Complete
Train Stations	Complete
Bridges	Subsurface
Port and Marinas	Complete
Airports	Complete
Commercial and Residential	Complete
Planned Projects	Subsurface

Critical Roadway Impact Index

Carrying forward the inundation analysis, an index was developed to identify the most critical impacts to our roadways. The index scores inundated road segments on their rise scenario, surrounding demographics, and traffic characteristics. Index measures (grouped into these local categories) are shown in Table 3, along with the weighting structure.

Figure 8: Measures found in the Critical Roadway Impact Index

Demographics

- *2010 Population/Employment*
- *2030 Population/Employment*
- *Environmental Justice*

Inundation Scenarios

Traffic Characteristics

- *Traffic Volume*
- *Transit Route*
- *Evacuation Route*

Sixteen points are available within each of the three local categories (scenarios, demographic characteristics and forecasts and traffic characteristics) bringing the index total to 48. The measure with the heaviest single weight (33% of global points) belongs to the inundation scenario. While the rise scenarios vary between our counties, it was still decided to maintain identical scoring for ease of use, and because investment decisions are distinct across state lines.

A segment's demographic makeup is scored within three measures: 2010 population and employment density (P&E density), forecasted 2030 P&E density and whether the segment fell within an identified Environmental Justice (EJ) neighborhood. Population and employment density data are based on Traffic Analysis Zone (TAZ) data. The measure sums population and employment figures, before dividing them by the TAZ's area. EJ neighborhoods represent significant and moderate concentrations of low-income and minority communities at the census blockgroup level. They are as identified in our *2009 Transportation Equity Report*.

Traffic characteristics considered include: traffic volume of a segment, whether it falls on a fixed-route bus route, and whether the segment forms part of the region's evacuation network. Traffic volume data are based on 2008 figures from DelDOT and MDOT. The single exception is Howard Street in the Town of Elkton, whose volume came from a 2009 WILMAPCO count. Transit route data were obtained from the Delaware Transit Corporation for New Castle County, and WILMAPCO for Cecil County. Evacuation route designations were collected from the two state DOTs.

Each of our 566 identified inundated segments were scored based on their spatial relationship to index measures. Points were awarded for each measure, then summed to produce a final score. Final scores ranged from 2 to 25, with the median resting at 5. Due to a lack of significant EJ neighborhoods in Cecil County, segments within moderate EJ neighborhoods there received a full 4 points. This was the only scoring discrepancy between the counties.

Table 3: Critical Roadway Impact Index Measures

Measure	Points	Local Weight	Global Weight	
Scenario				Scenarios
0.5 m (New Castle Co.) & 2 ft (Cecil Co.)	8	50%	17%	
1.0 m (New Castle Co.) & 5 ft (Cecil Co.)	5	31%	10%	
1.5 m (New Castle Co.) & 10 ft (Cecil Co.)	3	19%	6%	
2010 P&E Density				Demographic Characteristics & Forecasts
3x median	3	19%	6%	
2x median	2	13%	4%	
> median	1	6%	2%	
2030 P&E Density				
3x median	3	19%	6%	
2x median	2	13%	4%	
> median	1	6%	2%	
***EJ Neighborhood** (New Castle Co.)*				
Significant	3	19%	6%	
Moderate	1	6%	2%	
***EJ Neighborhood** (Cecil Co.)*				
Significant	0 (n/a)	0%	0%	
Moderate	4	25%	8%	
Traffic Volume				Traffic Characteristics
3x median	6	38%	13%	
2x median	4	25%	8%	
> median	2	13%	4%	
Transit Route				
Yes	2	13%	4%	
No	0	0%	0%	
Evacuation Route				
Yes	2	13%	4%	
No	0	0%	0%	

It should be noted that DelDOT and the University of Delaware are working together to better understand the impact of flooding on Delaware's roadways. This work, when available, could contribute to a more nuanced process of critical infrastructure identification, and a strengthening of this index.

Chapter 3

Regional Impacts

This chapter assesses broadly the transportation infrastructure impacts of SLR in the Wilmington region—New Castle County, Delaware and Cecil County, Maryland—under our inundation scenarios. We will first consider potential impacts to our highways (including identified evacuation routes, tolling facilities and bus routes and stops), then turn to our railways (including a detailed profile for Wilmington's Train Station), marinas and seaport, our airports, residential and commercial impacts (along with a social equity analysis), impacts to projects planned through 2040, and finally, an assessment of the most critical roadways impacted. The following chapter, Cluster Profiles, paints a more complete, neighborhood-level, picture of the challenges sketched below.

The impacts to facilities we identify in this and the next chapter represent only broad potential exposures to SLR using the best data at hand. This is a planning-level exercise; the definite behavior of individual infrastructures during inundation is variable and is not considered here.

General Observations

Major population centers, home to crucial infrastructure, may be challenged by SLR in the decades to come. These include our region's principal city, Wilmington, the City of New Castle, Delaware City, and the towns of Elkton, Chesapeake City, and North East. Segments of highways, such as SR 9 and US 13 hugging the Delaware River and SR 222 along the Susquehanna River, risk increased flooding or complete inundation if no action is taken. A similar fate may befall near-river railways such as the New Castle County Secondary and Norfolk Southern's Port Road Branch, along with stations near waterways.

As noted in the previous chapter, the analysis in this assessment is centered upon six inundation scenarios (three for each county), developed by DNREC and Towson University, respectively (see Table 1).Though the third rise level in Cecil County is twice as aggressive as in New Castle County (ten feet versus five feet), a mere glance at Map 1 reveals that SLR poses a much greater threat to New Castle County.

Table 4 details the land impacted at each county's scenarios. Some 55 square miles would face inundation at 1.5 meter (5 feet), or 7.1% of our region's land area. All but four square miles of that inundated land would be found in New Castle County, where 11.9% of land risks inundation in a 1.5 meter rise scenario. A 10 foot storm surge would threaten an additional 0.6 square mile in Cecil County.

Table 4: Impacted Land

New Castle County			*Cecil County*		
Scenario	**Sq. Miles**	**% of Land**	**Scenario**	**Sq. Miles**	**% of Land**
0.5 m	38.9	9.0%	2 ft	3.5	1.0%
1.0 m	45.7	10.6%	5 ft	4.0	1.2%
1.5 m	51.5	11.9%	10 ft	4.6	1.3%

Roadway Impacts

Roadway segments across our region risk inundation under the six scenarios. Shown below in Table 5, this represents more than 30 miles of road within our base road file, 2.7% of the total. Note that the figures shown below are cumulative. That is, 1.0 meter impacts include mileage impacted in 0.5 meter and 1.5 meter includes 0.5 meter and 1.0 meter.

Table 5: Impacted Roadways

Scenario	New Castle *(in miles)*	Scenario	Cecil *(in miles)*
0.5 m	8.9	2 ft	0.1
1.0 m	19.6	5 ft	0.6
1.5 m	27.9	10 ft	3.5

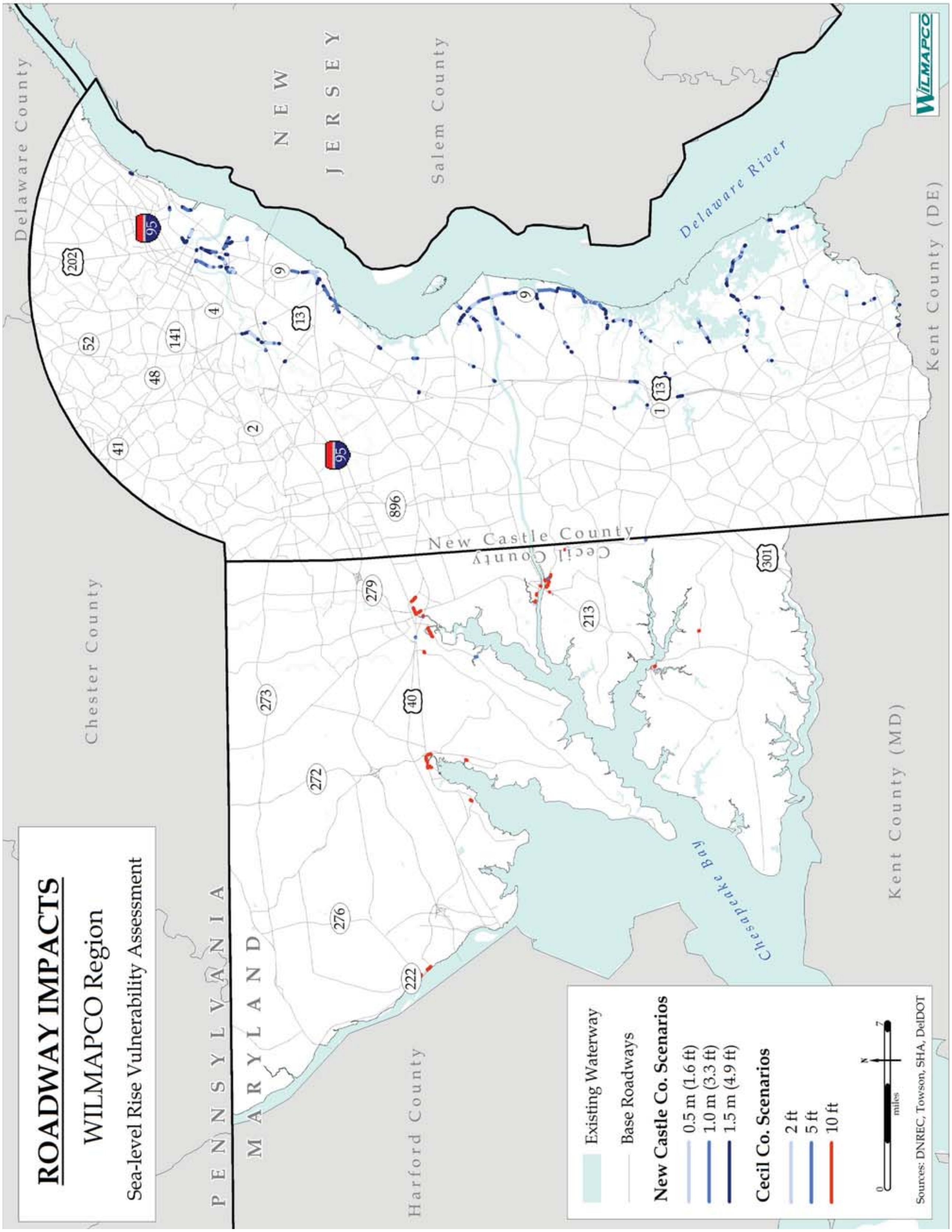
Illustrated in Map 4, these segments are principally found along the Delaware River in the east of the region. With more than seven miles of potentially impacted segments, SR 9 faces the most widespread challenges. Other roadways at risk include US 13, Walnut Street, and Old Airport Road in northern New Castle County. Cedar Swamp Road, Reedy Point Road and Staves Landing Road are notables in Southern New Castle County. Bethel Road, SR 7 and Old Field Point Road are key roadways facing SLR impacts in Cecil County. A listing of the most impacted roadways can be found in Table 6 below.

Table 6: Roadways with Greatest Impacts

Roadway	0.5 m	1.0 m *(in miles)*	1.5 m
New Castle County			
SR 9	1.60	5.83	7.54
Cedar Swamp Road	0.60	1.16	2.01
US 13	0.41	0.89	1.96
Walnut Street	0.18	0.93	1.02
Polktown Place	0.41	0.68	0.91
Staves Landing Road	0.38	0.51	0.89
Dutch Neck Road	0.46	0.58	0.86
Old Airport Road	0.41	0.47	0.81
Reedy Point Road	0.52	0.65	0.75
River Road	-	0.73	0.75

	2 ft	5 ft *(in miles)*	10 ft
Cecil County			
SR 7	-	0.01	0.57
Old Field Point Road	-	0.07	0.46
SR 222	-	-	0.41
Howard Street	-	-	0.30

Map 4: Roadway Impacts



Toll Facilities

Four facilities collect tolls along the Wilmington region's highway network. They are: I-95 and US 40 at the Susquehanna River, I-95 at the Delaware/Maryland border, and SR 1 at the Chesapeake and Delaware (C&D) Canal. None of these facilities faces a direct threat under the SLR rise scenarios considered here.

Tolling facility at the Hatem Bridge on US 40 (Source: Bing Maps)

Bus Routes and Stops

Forty-three fixed-route bus lines operate in New Castle and Cecil Counties. As shown in Table 7 below, 31 (or 70%) of those routes travel along roadways impacted at a 1.5 meter (or 5 foot) rise. Forty-five bus stops, all in New Castle County, would be impacted under our scenarios. Illustrated by Map 5 the majority of inundated bus route segments lie along roadways on the eastern and southern side of Wilmington.

Table 7: Fixed-route Bus Impacts

Scenario	New Castle	Scenario	Cecil
0.5 m	6	2 ft	-
1.0 m	28	5 ft	2
1.5 m	29	10 ft	2

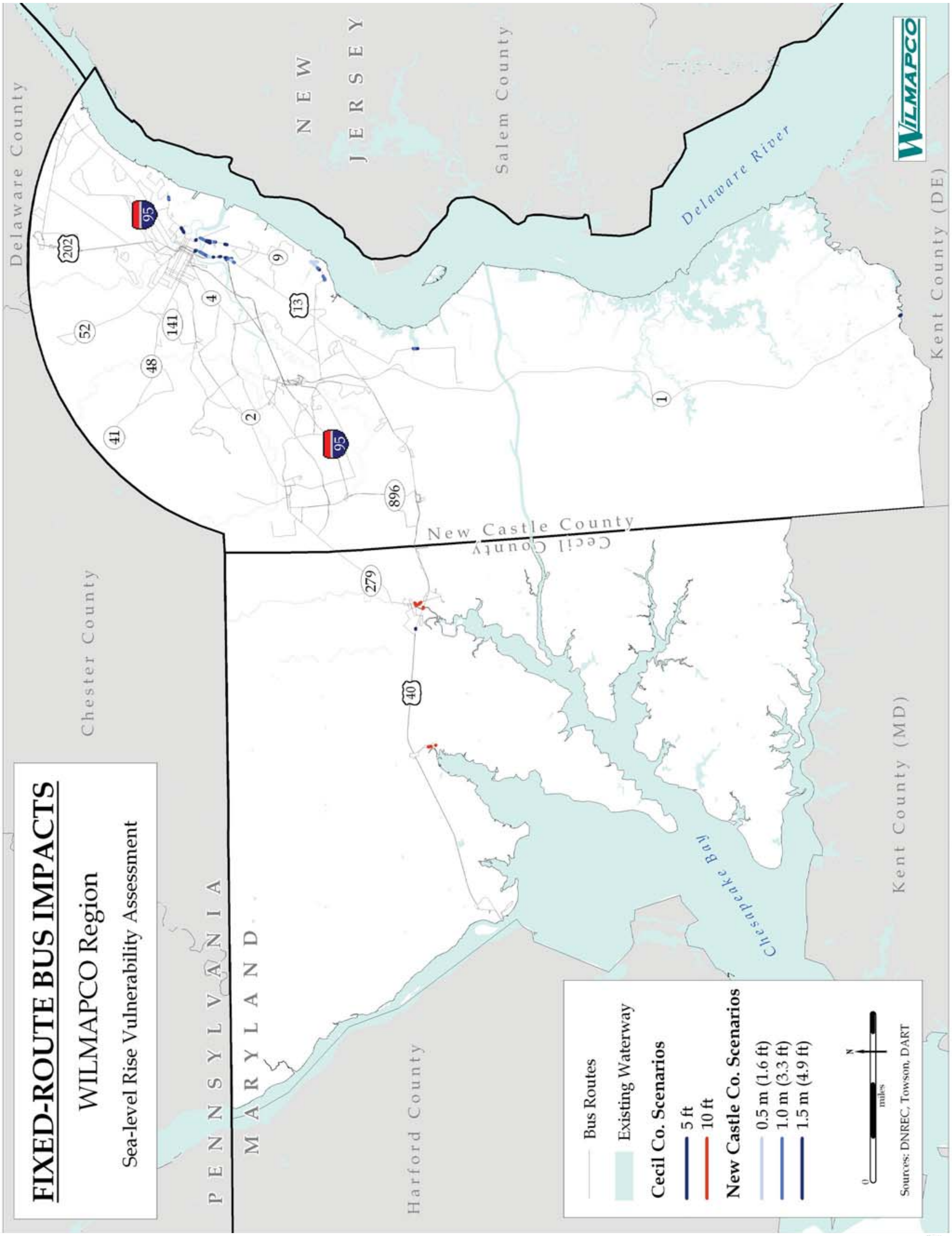
Table 8: Bus Stop Impacts

Scenario	New Castle	Scenario	Cecil
0.5 m	10	2 ft	-
1.0 m	21	5 ft	-
1.5 m	45	10 ft	-

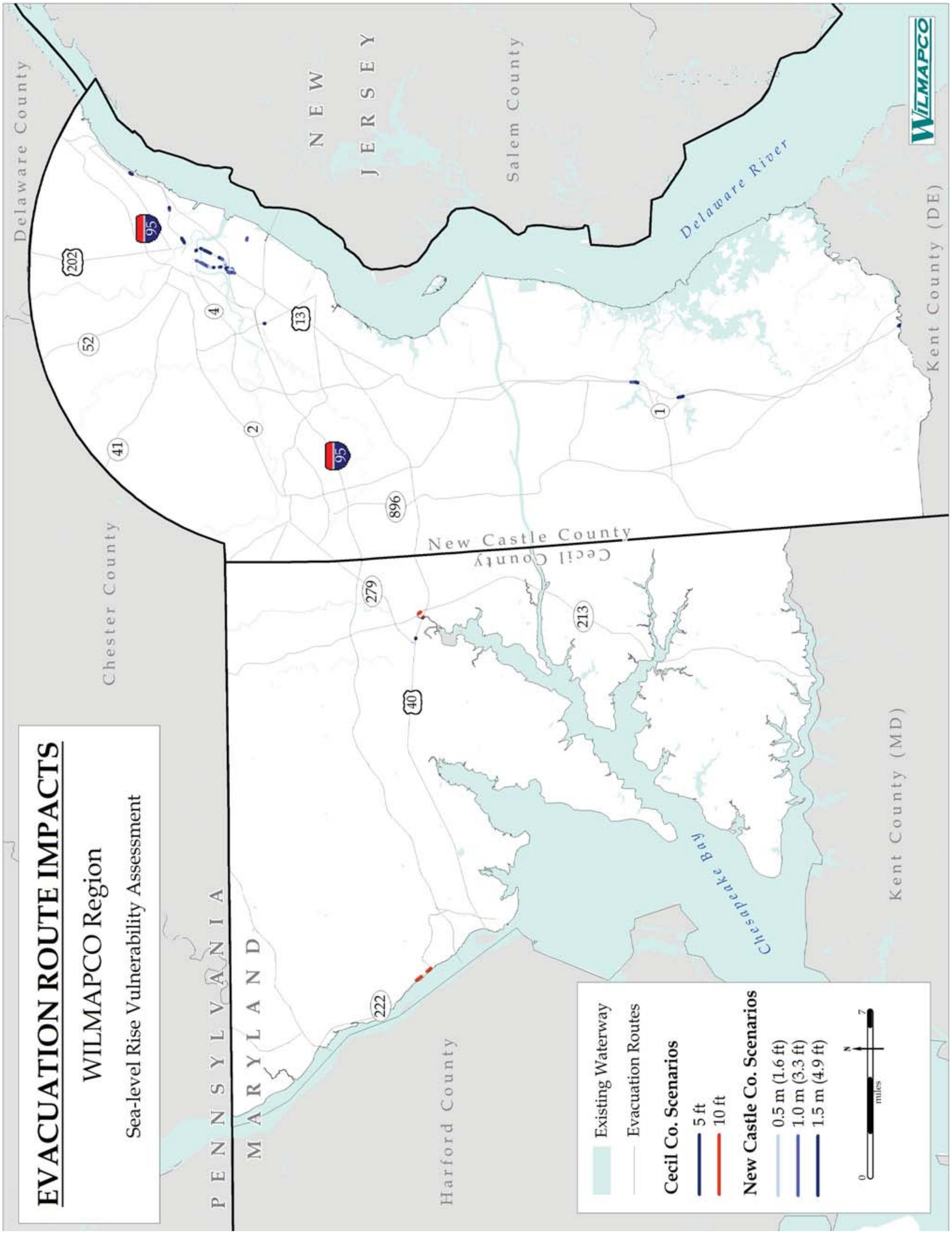
Evacuation Routes

Many of the region's highways serve as evacuation routes, capable of handling the heavy movement of traffic in the event of an emergency. Some four miles of this evacuation system (1.4%) is at-risk by SLR. Map 6 details which segments of these routes risk inundation under our SLR scenarios. US 13 and Business US 13 in South Wilmington face the greatest risk for impact.

Map 5: Fixed-route Bus Impacts



Map 6: Evacuation Route Impacts



Railway Impacts

Like roadways, low-lying rail infrastructure will be challenged by rising seas. Almost nine miles of rail are at risk in a 1.5 meter (5 foot) rise, about 5% of the total. The figures shown below are again cumulative.

Table 9: Impacted Railways

Scenario	New Castle (in miles)	Scenario	Cecil (in miles)
0.5 m	4.1	2 ft	-
1.0 m	6.6	5 ft	-
1.5 m	8.7	10 ft	0.5

Three rail lines risk inundation under our SLR scenarios: the Northeast Corridor and Norfolk Southern's (NS) New Castle County (NCC) Secondary and Port Road Branch lines. As explored below in Table 10 and Map 7 the NCC Secondary, a freight line along the Delaware River, faces the most extensive SLR impacts. Amtrak's Northeast Corridor, supporting both passenger and freight movement and serving as our principal rail link to neighboring metropolitan areas, also risks significant impacts. Along the Susquehanna River in the west, the Port Road Branch freight line is challenged under a 10 foot surge.

Table 10: Railways with Greatest Impacts

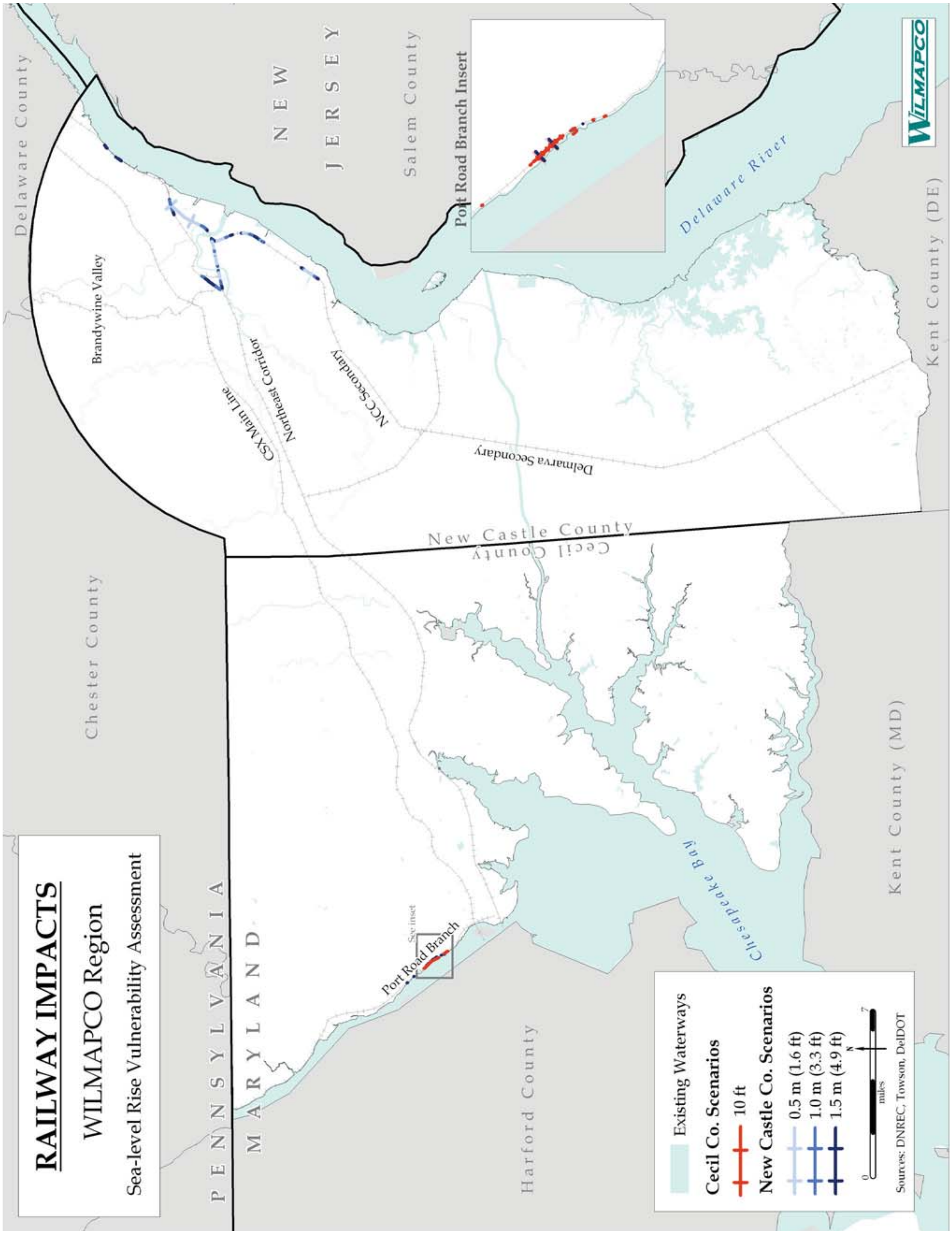
Railway	0.5 m	1.0 m (in miles)	1.5 m
New Castle County			
NS - NCC Secondary	2.6	3.7	4.7
Northeast Corridor (NEC)	1.6	2.5	3.0
NEC - Conrail West Yards	-	0.4	1.0
	2 ft	**5 ft** (in miles)	**10 ft**
Cecil County			
NS - Port Road Branch	-	-	0.5

Train Stations

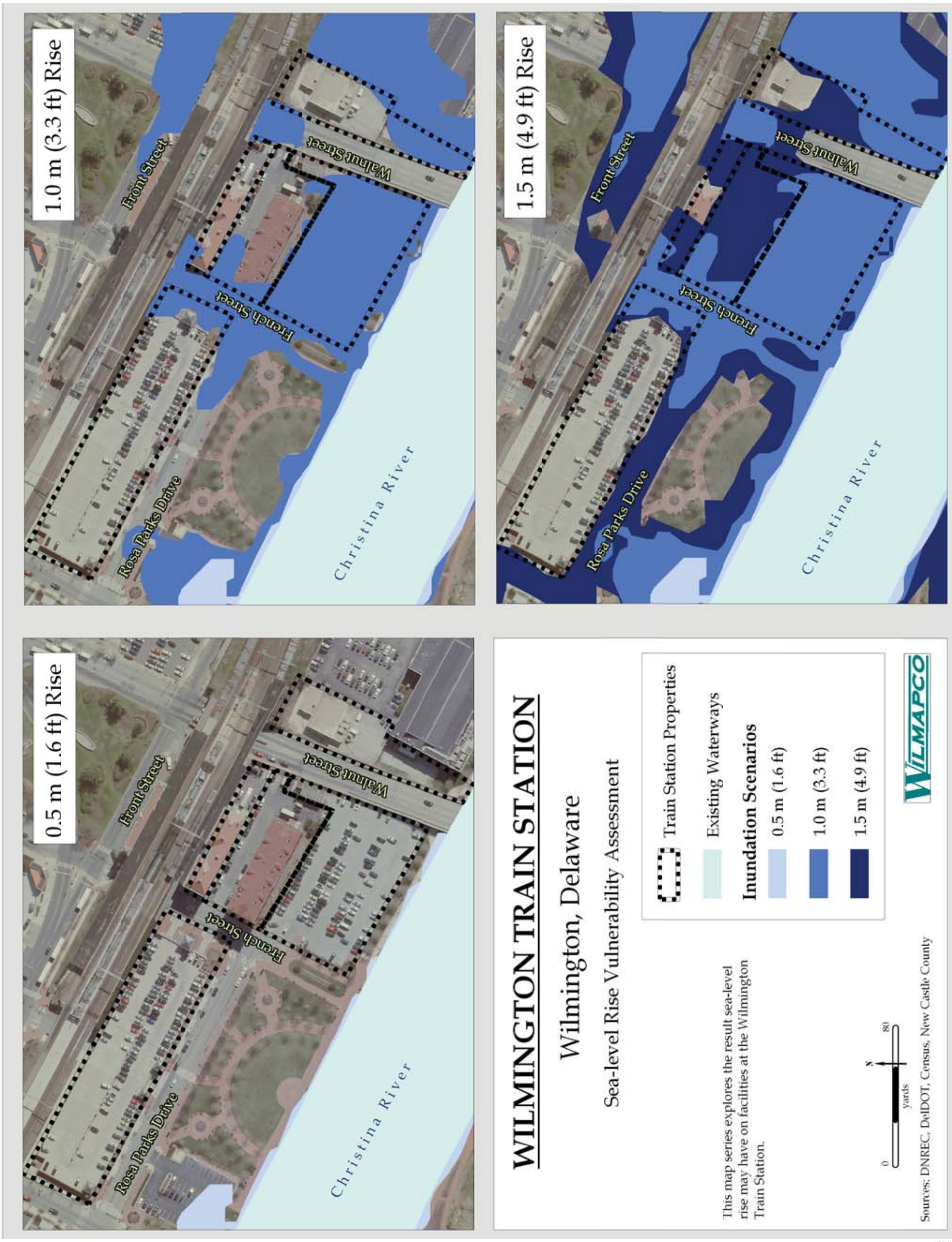
Five commuter rail stations serve passengers along the Northeast Corridor in the region. The most important of these, Wilmington's Train Station and surrounding properties, today, risks inundation during a 1.0 meter rise scenario. Potential SLR impacts to the Wilmington Station are illustrated in Map 8.

Beyond existing stations, abandoned train stations in the towns of Elkton and Newport hope to again welcome rail commuters during the coming decade. While the Elkton station is far from SLR impacts, the planned Newport station risks inundation if it is constructed on the southern side of the NEC.

Map 7: Railway Impacts



Map 8: Wilmington Train Station Impacts



Bridge Impacts

Bridges, especially those over waterways, are vulnerable to SLR. Our SLR analysis favored a liberal approach to bridge/overpass impacts. It flagged those features over waterways experiencing a rise in a SLR scenario, regardless of whether complete road or rail inundation was expected. Working from our base bridge networks described in the previous chapter, 117 bridges and overpasses were identified with possible SLR impacts in a 0.5 meter (2 foot) scenario (see Table 11 below). Their locations may be found throughout the following chapters.

Table 11: Impacted Bridges and Overpasses

Scenario	New Castle	Scenario	Cecil
0.5 m	104	2 ft	13
1.0 m	126	5 ft	17
1.5 m	143	10 ft	36

Marina and Port Impacts

Located alongside waterways, marinas and ports are naturally more vulnerable to SLR than any other piece of infrastructure. Thirty-three marinas were indentified across the Wilmington region. All were challenged by SLR under a 0.5 meter (2 foot) scenario. Figure 9 below illustrates potential inundation of the Old Seventh Street Boat Yard on the Brandywine Creek in Wilmington. The light blue in the picture on the right corresponds to the 0.5 meter scenario, the medium blue 1.0 meter and the darkest blue 1.5 meter. The lightest blue is existing water.

Figure 9: SLR Impacts to the Old Seventh Street Boat Yard

Illustrated by Map 9 the Port of Wilmington faces considerable SLR challenges, even in a 0.5 meter rise scenario. Buildings, roads, and rail associated with the port would be significantly impacted.

Airport Impacts

Three public use airports operate in the region. These are: New Castle County Airport, Summit Airport and Raintree Airpark. None are threatened by our SLR scenarios.

Map 9: Port of Wilmington Impacts

Commercial and Residential Impacts

Beyond transportation infrastructure, SLR also threatens shops, industries and homes. In reviewing impacts to commercial properties, the present analysis considered commercially-zoned parcels in Cecil County and similar units in New Castle County. As indicated in Table 12 more than 700 properties across the region face inundation at a 1.5 meter (5 foot) rise, 2.2% of the total. One-hundred and forty additional properties would be impacted at a 10 foot surge in Cecil County. Again, the figures below are cumulative.

Table 12: Impacted Commercial Properties

Scenario	New Castle	Scenario	Cecil
0.5 m	121	2 ft	16
1.0 m	332	5 ft	59
1.5 m	670	10 ft	199

Map 10 illustrates these impacts to commercially-zoned properties. Most affected properties are located in Wilmington: along the Riverfront, shops and public housing in Southbridge, and east of US 13 in the city's northeast. Properties in the City of New Castle and in Delaware City would also be impacted, especially the businesses along Clinton Street and Delaware City's Mobile Home Park. In Cecil County, commercial properties in Elkton's downtown would be impacted, as well as North East, and expanses of commercially-exempt parkland south of North East.

Delaware City's Mobile Home Park (Source: Bing Maps)

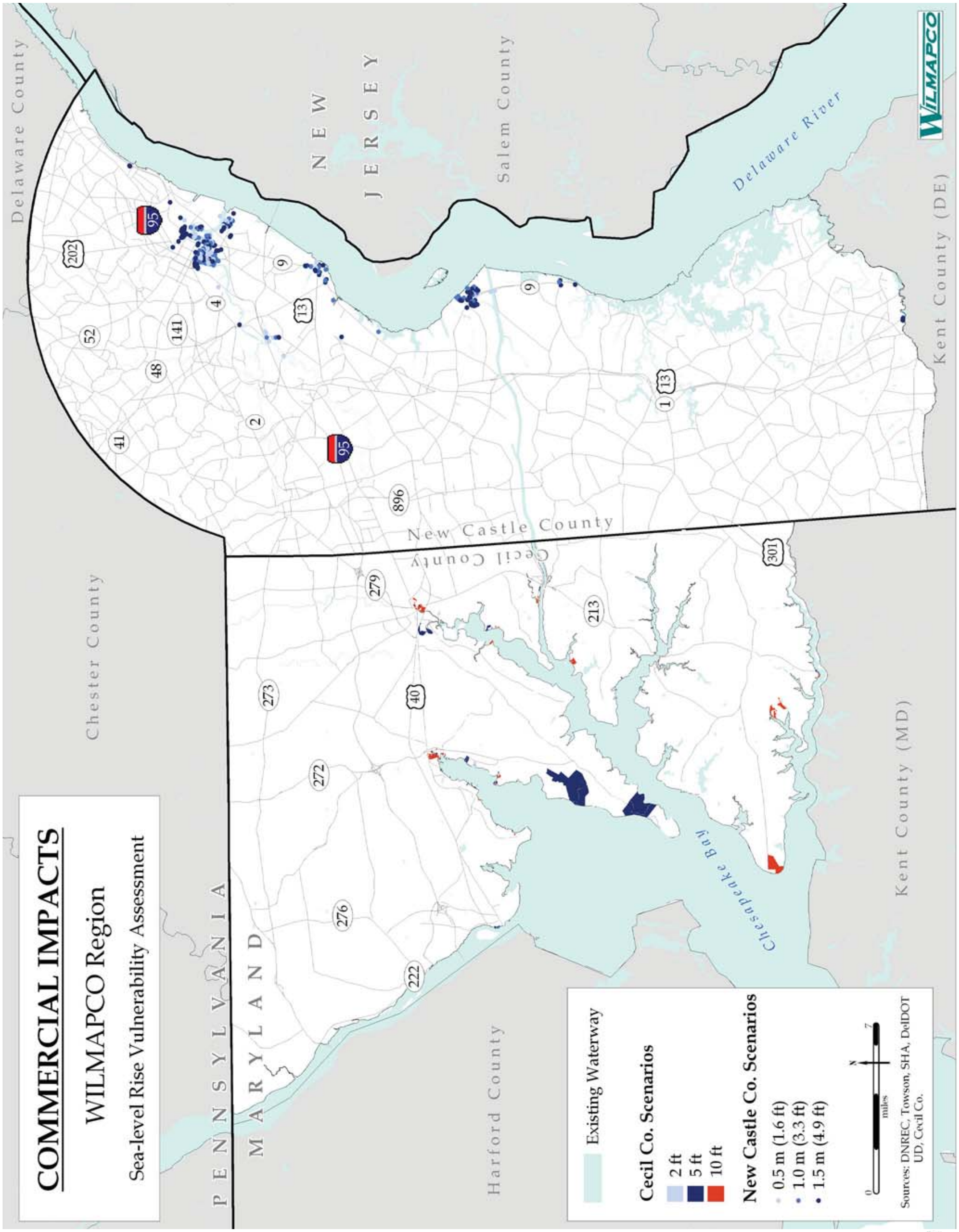
As shown in Table 13 below, almost 900 residentially-zoned units were found to be impacted at a 1.5 meter (5 foot) rise, 0.4% of the total. Over 670 additional residential units would be impacted during a 10 foot surge in Cecil County. These figures do not include housing on commercial properties.

Table 13: Impacted Residential Properties

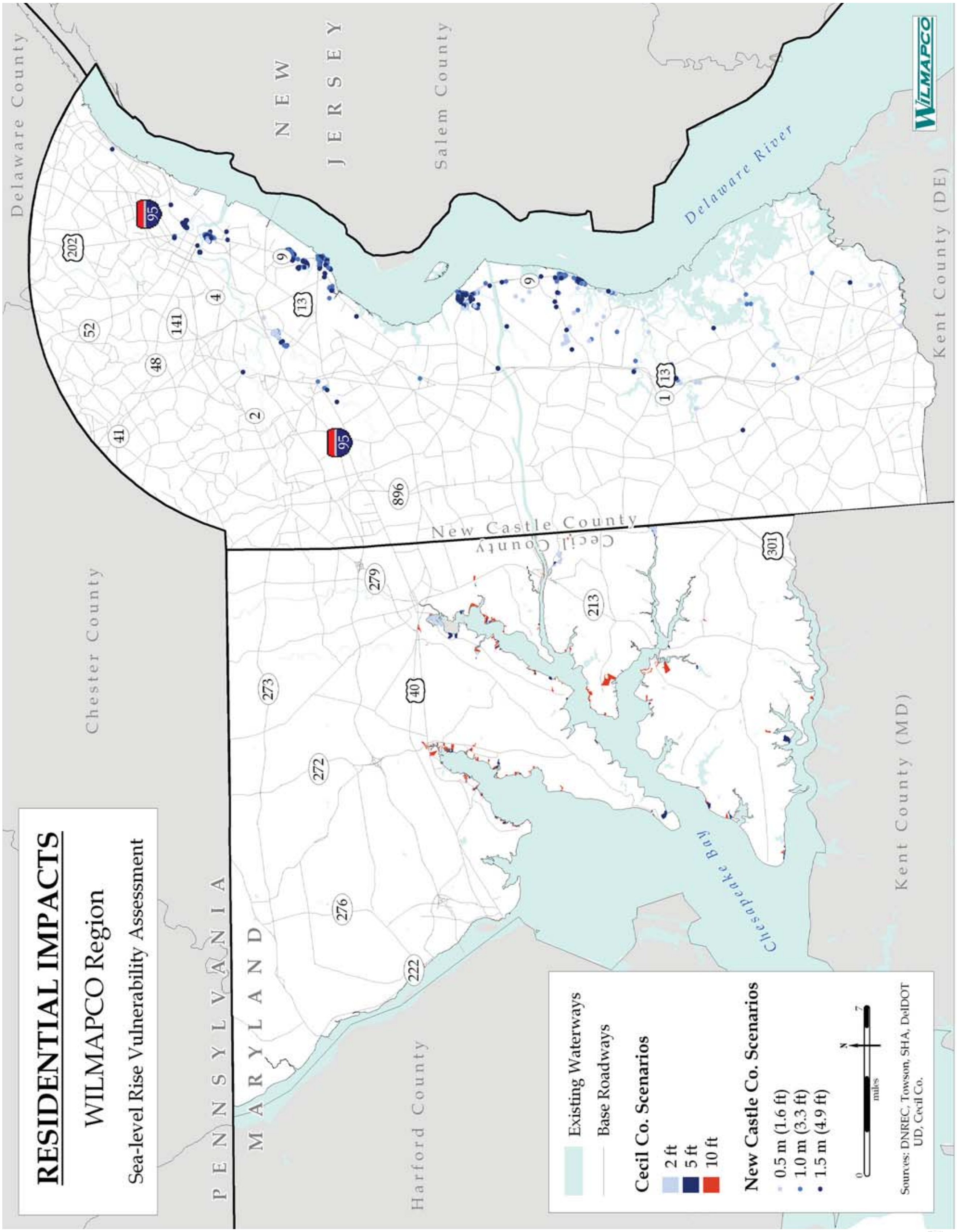
Scenario	New Castle	Scenario	Cecil
0.5 m	190	2 ft	23
1.0 m	453	5 ft	158
1.5 m	733	10 ft	831

Map 11 depicts the location of these impacts. Compared to commercial impacts, residential areas affected by SLR are far less concentrated in Wilmington. Properties all along SR 9 are impacted, with heavier pockets in Southbridge, the City of New Castle, Delaware City, and Port Penn.

Map 10: Commercial Impacts



Map 11: Residential Impacts

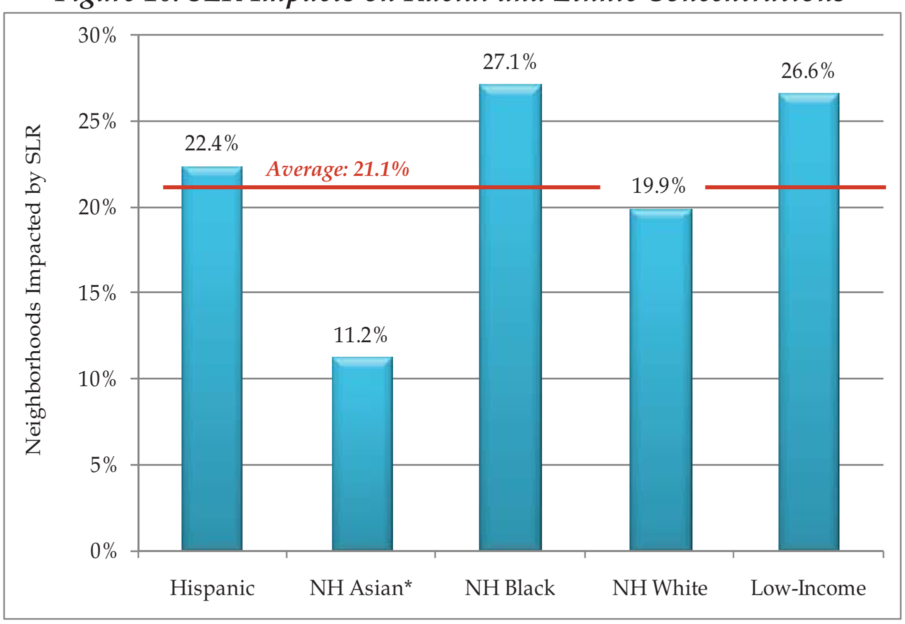


Social Equity Analysis

Recent WILMAPCO studies have shown that low-income and minority neighborhoods in the Wilmington region do not receive their fair share of transportation investment, and, with elevated exposure to mobile-source emissions, indeed carry more than their fair share of the transportation system's burden. Breaking the barriers that led to the ugly aftermath of Hurricane Katrina along the Gulf Coast, and fully lifting the transportation burdens carried by low-income and minority groups will be a long-term process. As we plan for sea-level rise and the increase of severe weather events associated with climate change, along with other initiatives, we must be particularly aware of the impacts to our low-income and minority neighborhoods.

Overall, 21.1% of the region's 403 census block-groups were impacted by a 1.5 meter rise in New Castle County, or a 10 foot surge in Cecil County. About the same percentage (21.8%) of block-groups that we formally classify as Environmental Justice neighborhoods[2] were similarly impacted. Disparities emerge when considering block-groups with concentrations[3] of specific groups. As shown in the figure below, non-Hispanic Black and low-income neighborhoods are more likely to be impacted by one of our SLR scenarios than the average neighborhood. As shown in Maps 12 and 13 these communities are found predominately along the Delaware River in the northeast of the region.

Figure 10: SLR Impacts on Racial and Ethnic Concentrations

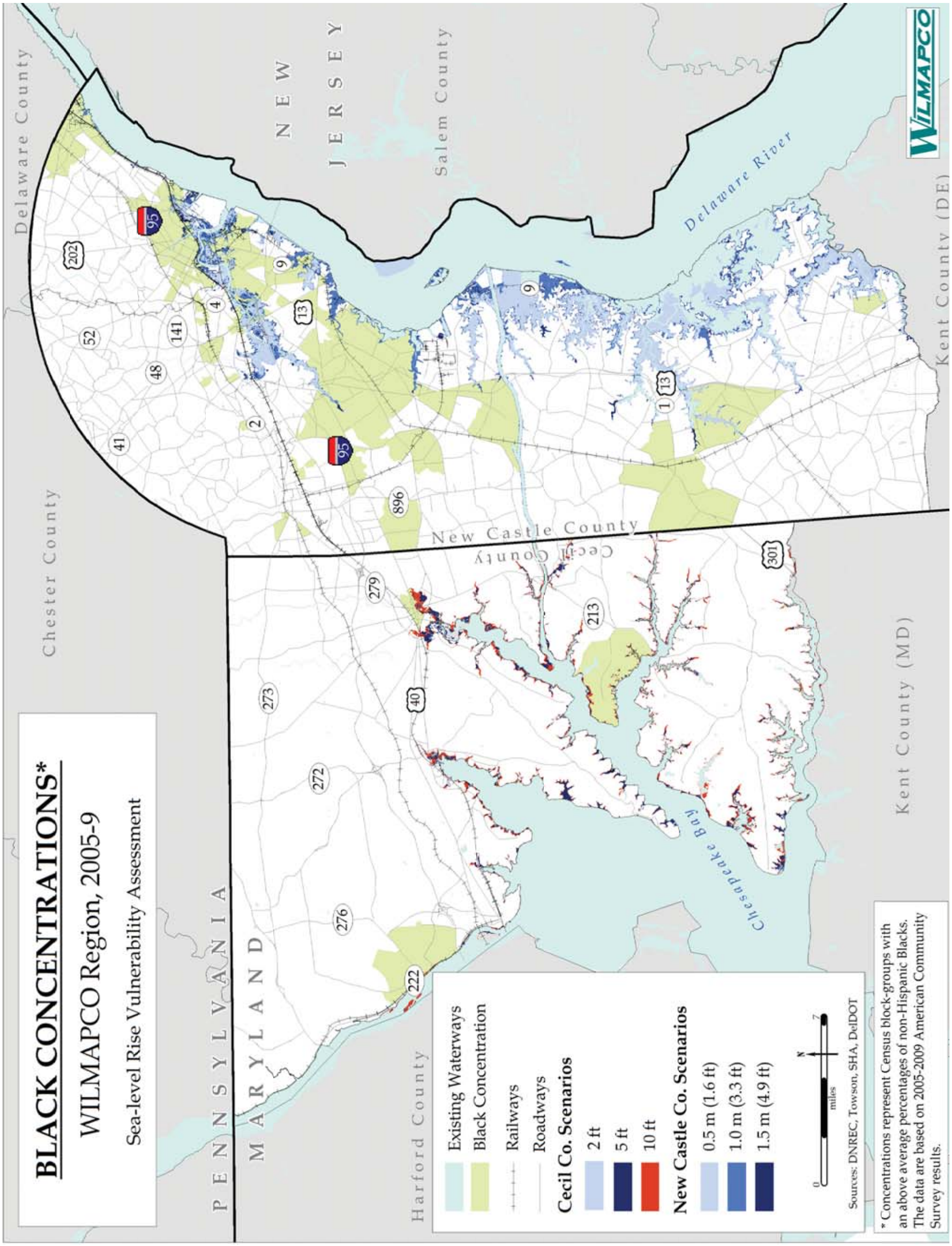


* NH = Non-Hispanic

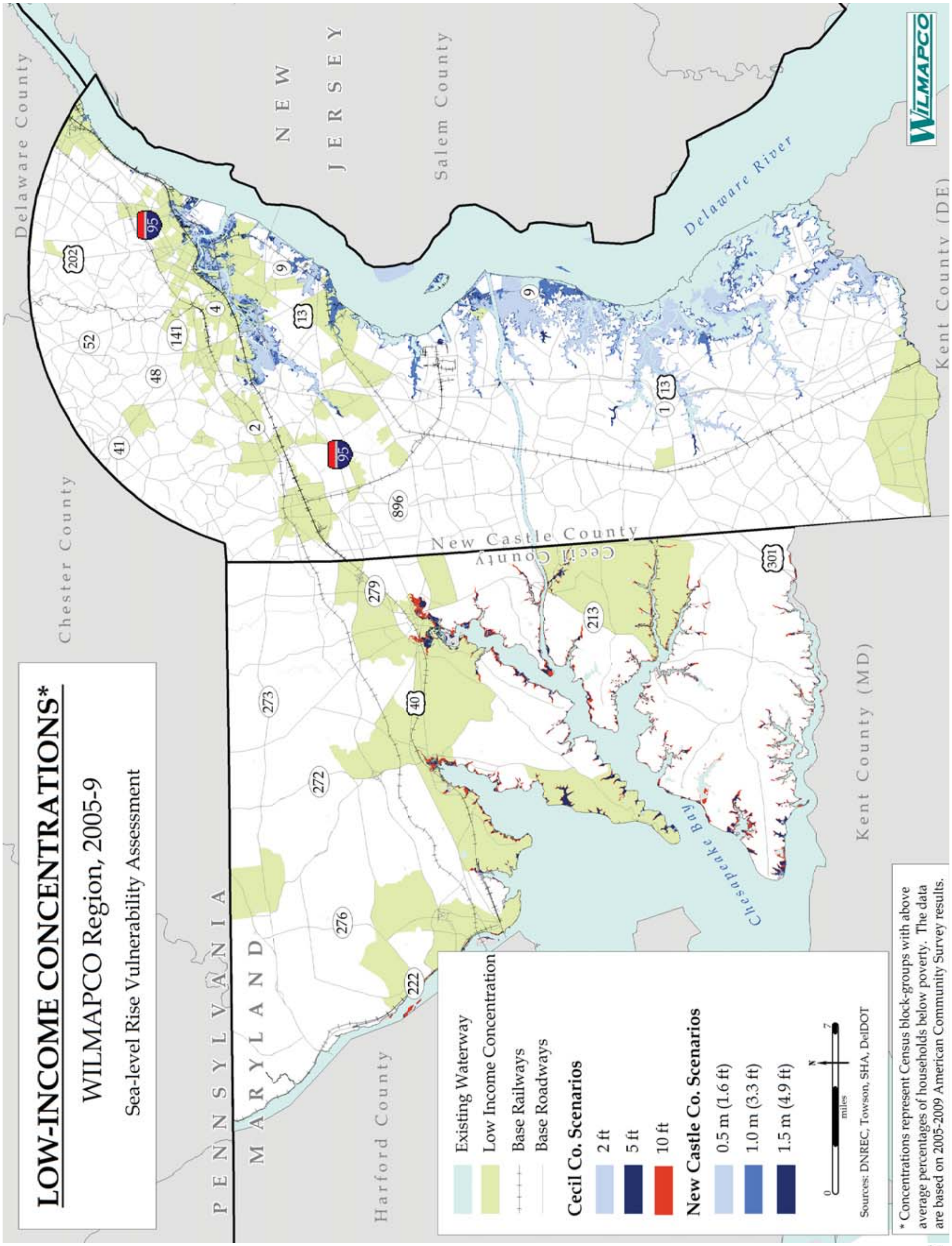
2. Environmental Justice neighborhoods are as defined in the *2009 Transportation Equity Report* (wilmapco.org/ej). They represent census block-groups from the 2000 Census with heavy concentrations of low-income and minority populations.

3. Racial and ethnic concentrations represent block-groups with above the regional average percentage of the five groups estimated in the 2005-2009 American Community Survey. Low-income is defined as households below poverty.

Map 12: Impacts to Non-Hispanic Black Neighborhoods



Map 13: Impacts to Low-income Neighborhoods



Planned Projects

More than 260 transportation projects are planned for the Wilmington region through 2040. Identifying which of these projects may be challenged by SLR allows us to reconsider those projects to include one or more SLR adaptation strategies, discussed in Chapter 1. Perhaps the scope of an at-risk project could be modified to include road/railway elevation. Or perhaps the wisdom of moving forward with a particular project should be reconsidered, if a projected scenario became more definite.

A shade over 16% of our planned projects have the funding necessary to move forward. These are known as "financially-reasonable" projects in our *2040 Regional Transportation Plan*. Table 14 below lists those financially-reasonable projects threatened by SLR. The eleven projects listed vary considerably in their expected in-service year, and total cost. Eight of the eleven would be impacted first at 0.5 meter (2 foot) rises.

Table 14: Impacts to Financially-Reasonable Planned Projects

Project	In-service	Cost	Level Impact
Cecil Transit Bus Connection to Harford County	2011	$1 M	2 ft
Elkton Bus Service Circulator	2012	$60 K	2 ft
Washington Street, New Castle & Frenchtown Road at DE 9	2013	$7.5 M	0.5 m
I-295: Westbound from I-95 to US 13	2014	$5.2 M	0.5 m
I-95: Susquehanna River to DE Line (highway/bridge expansion)	2040	$505 M	2 ft
City of New Castle Improvements (SR9/3rd and SR9/6th)	2016	$1.4 M	0.5 m
Christina River Bridge	2020	$21.7 M	0.5 m
Southern New Castle County Improvements	2020	$46.2 M	0.5 m
Southbridge Streetscape Improvements Phase I (TE)	2012	$1.2 M	1.0 m
SR 9, River Rd. Area, Dobbinsville (viaduct)	2020	$12.7 M	1.0 m
City of New Castle Improvements (SR9/Delaware St)	2016	$3.1 M	1.5 m

Projects in areas with SLR challenges should have their scopes revisited. (Photo: P. Schultz)

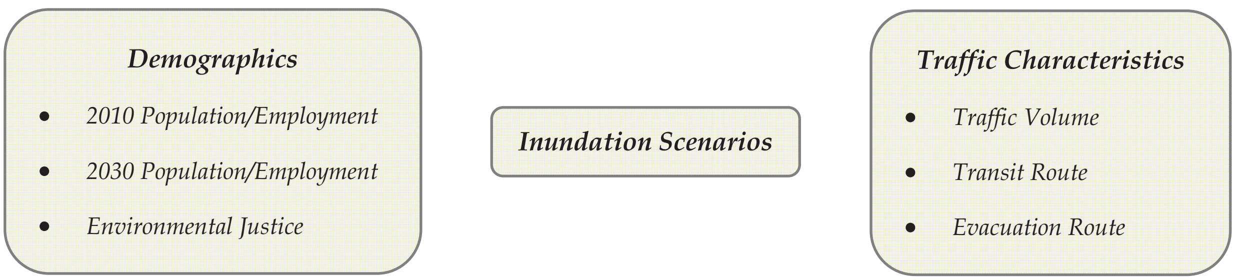
The more than 220 remaining planned projects do not yet have funding. Of these "aspiration" projects, 49 (22%) would be challenged by a 1.5 meter rise in New Castle County, or a 10 foot surge in Cecil County. Maps of both financially-reasonable and aspiration projects impacted under our rise scenarios can be found throughout the following chapter.

Critical Roadway Impacts

Beyond an awareness of which planned projects may be impacted by SLR, it is important to assess which infrastructure under threat is most critical. While a longer stretch of one road may be more impacted by SLR than another, the relative importance of the second facility should earn it a higher priority for adaptation measures. To take an initial step in this direction, an index was developed to identify the most critical of the 30 miles of roadway challenged by one of our scenarios.

Shown on Figure 11, the critical roadway impact index considers a road segment's inundation impact, traffic characteristics, and the surrounding area's demographics to better understand the facility's comparative importance. Details about the index can be found in Chapter 2.

Figure 11: Measures found in the Critical Roadway Impact Index

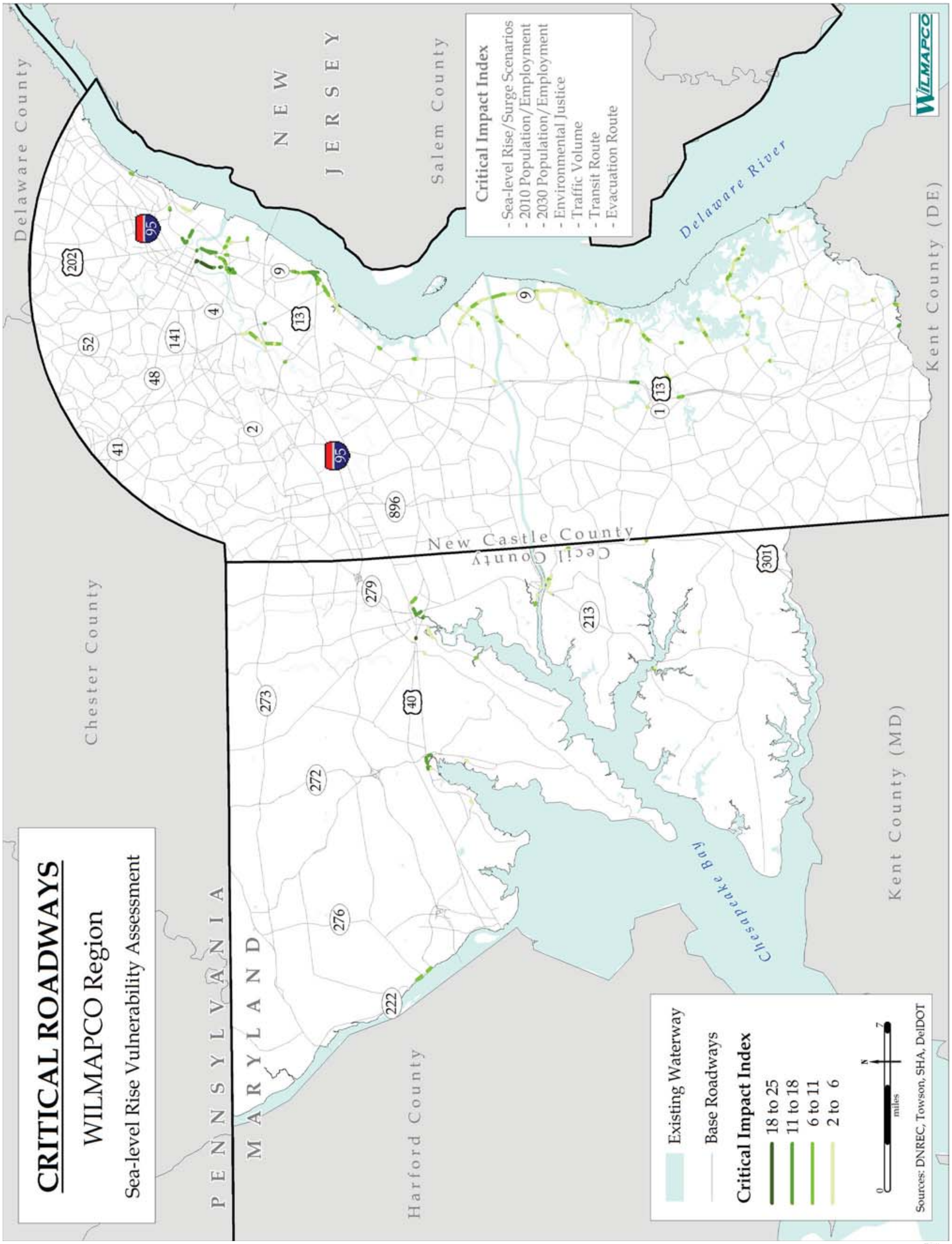


High-scoring, inundated road segments can be found throughout the region. Illustrated by Map 14, the heaviest concentrations are along the US 13 and SR 9 corridor in northeastern New Castle County, and in the towns of Elkton and North East in Cecil County. Table 15 lists the inundated roadway segments with the highest scores. US 40 in Elkton and Walnut Street in Wilmington topped the list.

Table 15: Impacts on Critical Roadways

Roadway	Cluster	Miles	Score
New Castle County			
Walnut Street (b/t Howard St. and Garasches Ln.)	South Wilmington (6)	0.18	24
Walnut Street (b/t A St. and Howard St.)	South Wilmington (6)	0.21	22
Walnut Street (b/t Howard St. and Garasches Ln.)	South Wilmington (6)	0.36	22
US 13 (at I-495)	South Wilmington (6)	0.21	21
Walnut Street (north of A St.)	South Wilmington (6)	0.02	20
Walnut Street (b/t Howard St. and Garasches Ln.)	South Wilmington (6)	0.03	20
Walnut Street (north of Howard St.)	South Wilmington (6)	0.02	20
Front Street (at Walnut St.)	Wilmington Riverfront (7)	0.07	20
Cecil County			
US 40 (b/t SR 7 and SR 279)	Elkton (18)	0.03	25
US 40 (northwest of SR 213)	Elkton (18)	0.02	22

Map 14: Critical Roadway Impacts



Chapter 4

Cluster Profiles

This chapter assesses the neighborhood-level impacts of SLR. As described in Chapter 2, a total of 20 clusters were identified for close examination. Census block groups that experience inundation were grouped into clusters based on spatial proximity, whereas block groups with no impacts were not included. A series of three maps are laid out for each cluster: (1) an aerial map that profiles current and future demographics and socioeconomic data[4], (2) impacted infrastructure categorized by level of inundation, and (3) impacted transportation projects.

Observations

Both size and extent of SLR impacts vary across the clusters. Roughly a half dozen clusters show minimal inundation, while the remaining clusters are subject to widespread flows. Infrastructure and planned projects at risk of inundation varies considerably, depending upon location, topography, and proximity to existing waterways. As discussed in the previous chapter, social equity is a concern with regards to SLR. We found half of our clusters are home to EJ neighborhoods.

Cluster Infrastructure Impacts

The cluster infrastructure maps categorizes impacted infrastructure by level of inundation. Inundation scenarios apply to roadways, railways, and bridges, and are represented by three different colored lines, as shown in the legend. In New Castle County, inundated roadways, railways, and bridges correspond to rises of 0.5 meter (light blue), 1.0 meter (medium blue), and 1.5 meters (dark blue). In Cecil County, inundated roadways, railways, and bridges correspond to rises of 2 feet (light blue), 5 feet (dark blue), and 10 feet (red). In both New Castle and Cecil Counties, roadways, railways and bridges that are not challenged by SLR are shaded in grey. Each map includes a table with the total mileage of impacted roadways and railways, and number of bridges, which are all summed cumulatively. While not shown graphically, exposed residential and commercial properties are listed for each inundation scenario as well (refer to Chapter 3 for commercial and residential impact maps).

4. A mixture of Census and WILMAPCO TAZ data are presented here, including population and employment forecasts and household (HH) poverty.

Our mapping analysis revealed numerous inundation risks to infrastructure. Per cluster, the total roadway mileage impacted by SLR ranges from a low of 0.003 mile (C14—Conowingo) to a high of 8.26 miles (C12—Port Penn). Clusters with the most extensive challenges at the 1.5 meter scenario are C12—Port Penn (8.26 miles), C13—Blackbird (7.05 miles), and C6—South Wilmington (3.69 miles). Blackbird is the most severely-impacted at the 0.5 meter scenario. Wilmington clusters face the most significant tests to railroads: C6—South Wilmington (2.98 miles), C7—Wilmington Riverfront (1.71 miles), and C4—East Wilmington (1.35 miles). Along the Christina River, Churchmans Marsh, and both the Augustine and Appoquinimink State Wildlife Areas, C8—West Minquadale, C9—Upper Christina, and C12—Port Penn each have more than a dozen bridges that will face SLR.

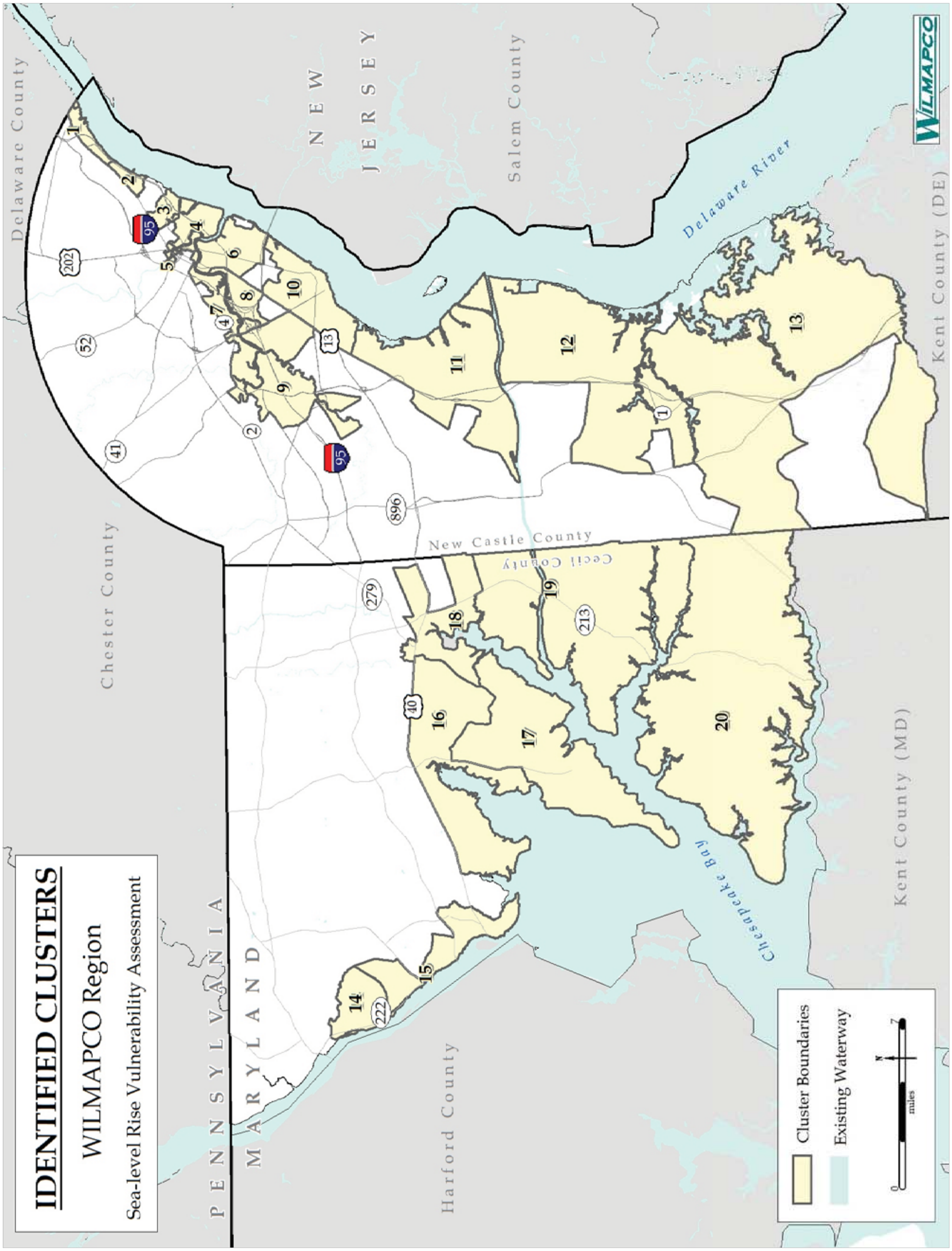
While Cecil County clusters have fewer inundation risks to roadways compared to New Castle County, their count for potentially inundated residential properties is high. Of the six clusters in Cecil County, five have more than 100 residential properties that are impacted, with C16—North East totaling 505 properties at a 10 foot surge. With 417 challenged properties, C6—South Wilmington tops the list in New Castle County at its 1.5 meter scenario. Overall, South Wilmington is the most challenged cluster, because it falls into the top five of each bridge, road, rail, and property categories.

Cluster Planned Project Impacts

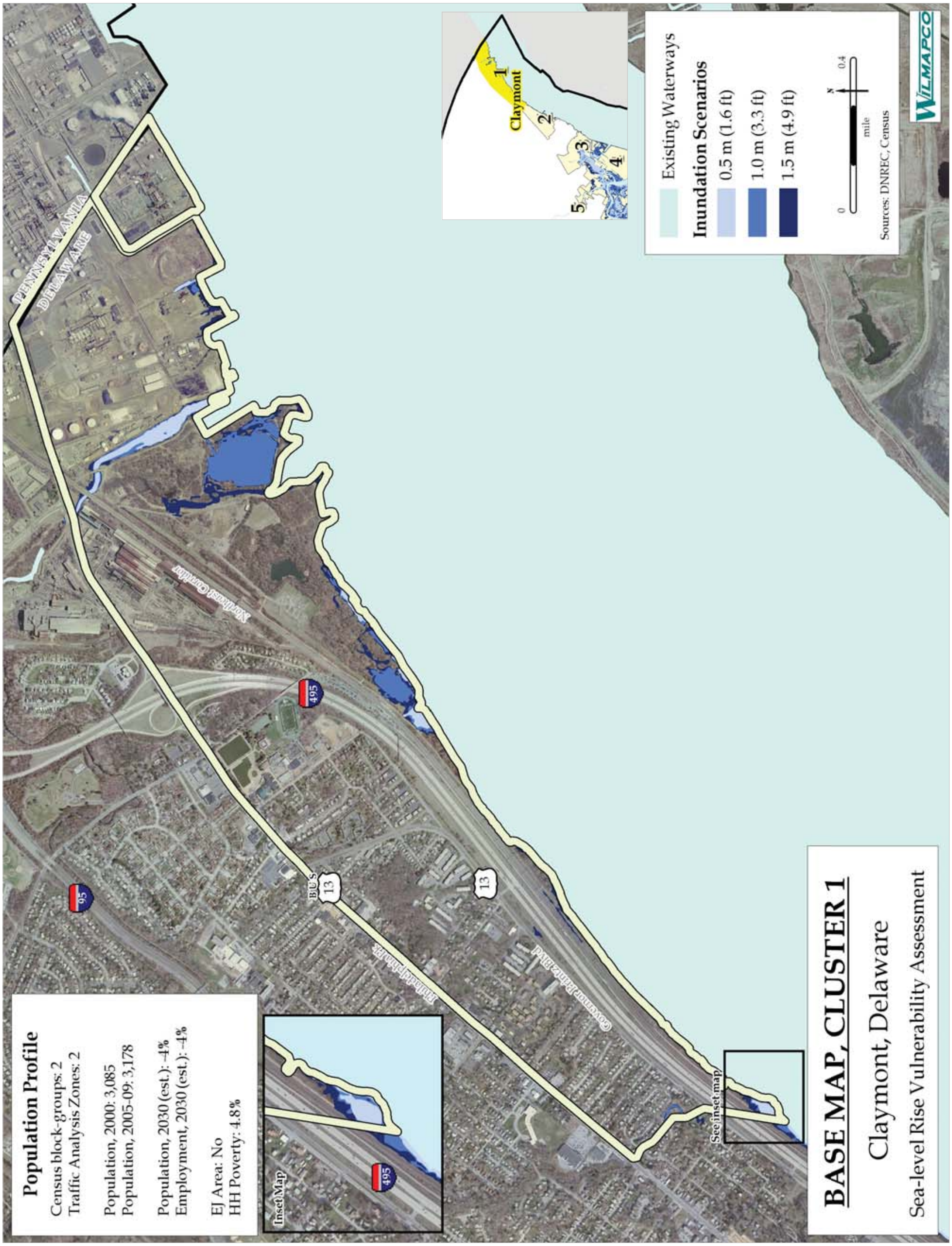
Our region's planned transportation projects potentially impacted by SLR were flagged. Impacted projects are included for each cluster; projects include those that may be challenged both at their surface or sub-structure. For example, consider the Interstate Maintenance project in C7 —Wilmington Riverfront. Because the roadway is raised, its surface would not be overtaken by SLR. However, its sub-structure supports may face pressures from SLR. Also, note that many transportation projects are corridor- and region-wide. These projects, such as Interstate Maintenance and Metropolitan Area Bus Service Expansion, are represented in more than one cluster.

Overall our planned project analysis uncovered many funded and unfunded transportation projects challenged by SLR. C7—Wilmington Riverfront shows 14 planned transportation projects challenged by SLR, the most of any cluster. This includes the South Walnut Street Bridge Area and the Wilmington Train Station projects. C10—New Castle is close behind with a dozen projects at risk such as the City of New Castle Improvement (SR9/ Delaware St.) and the Route 9 Heritage Scenic Byway.

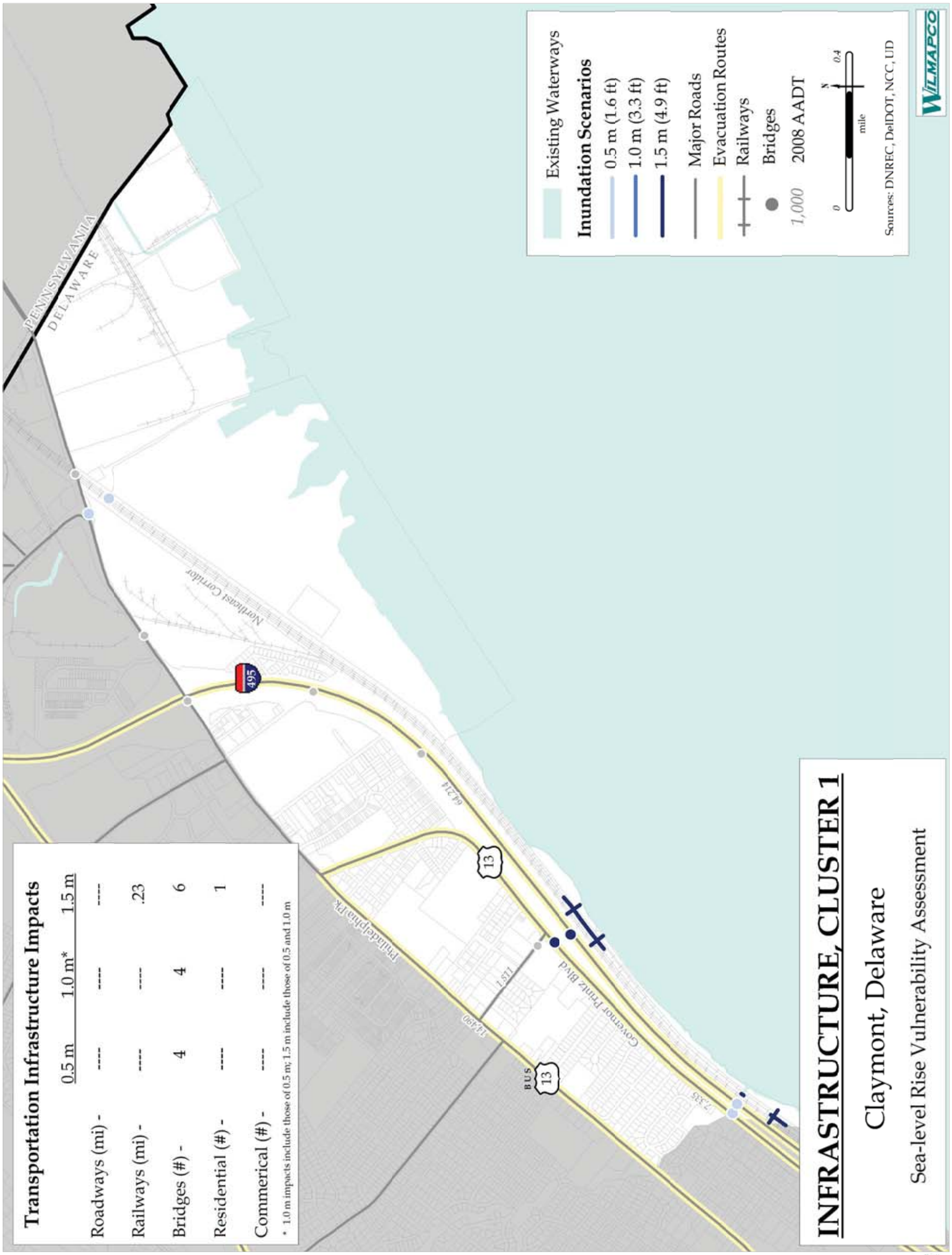
Map 15: Identified Clusters



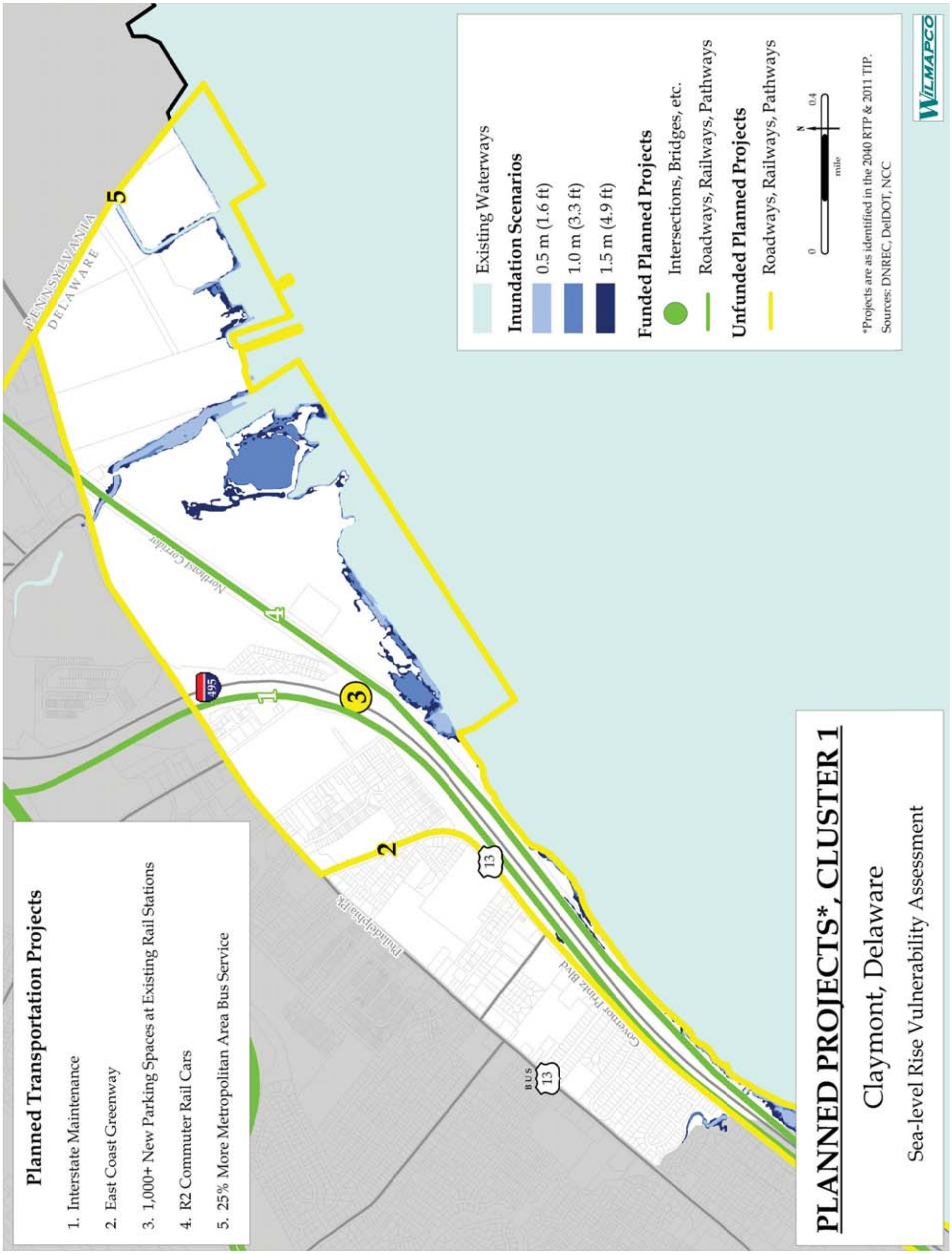
Map 16: C1 Base



Map 17: C1 Infrastructure



Map 18: C1 Planned Projects

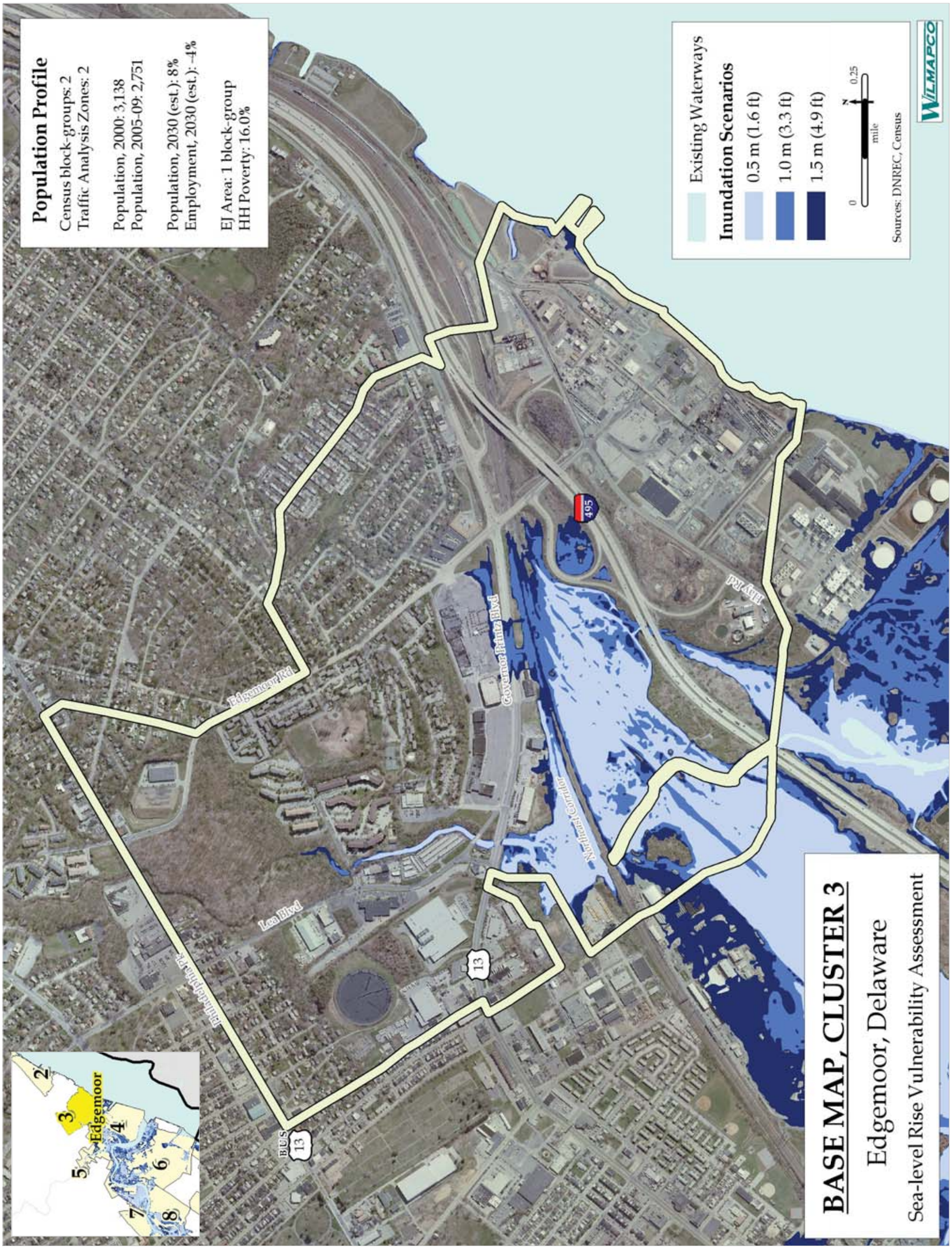


Map 19: C2 Base

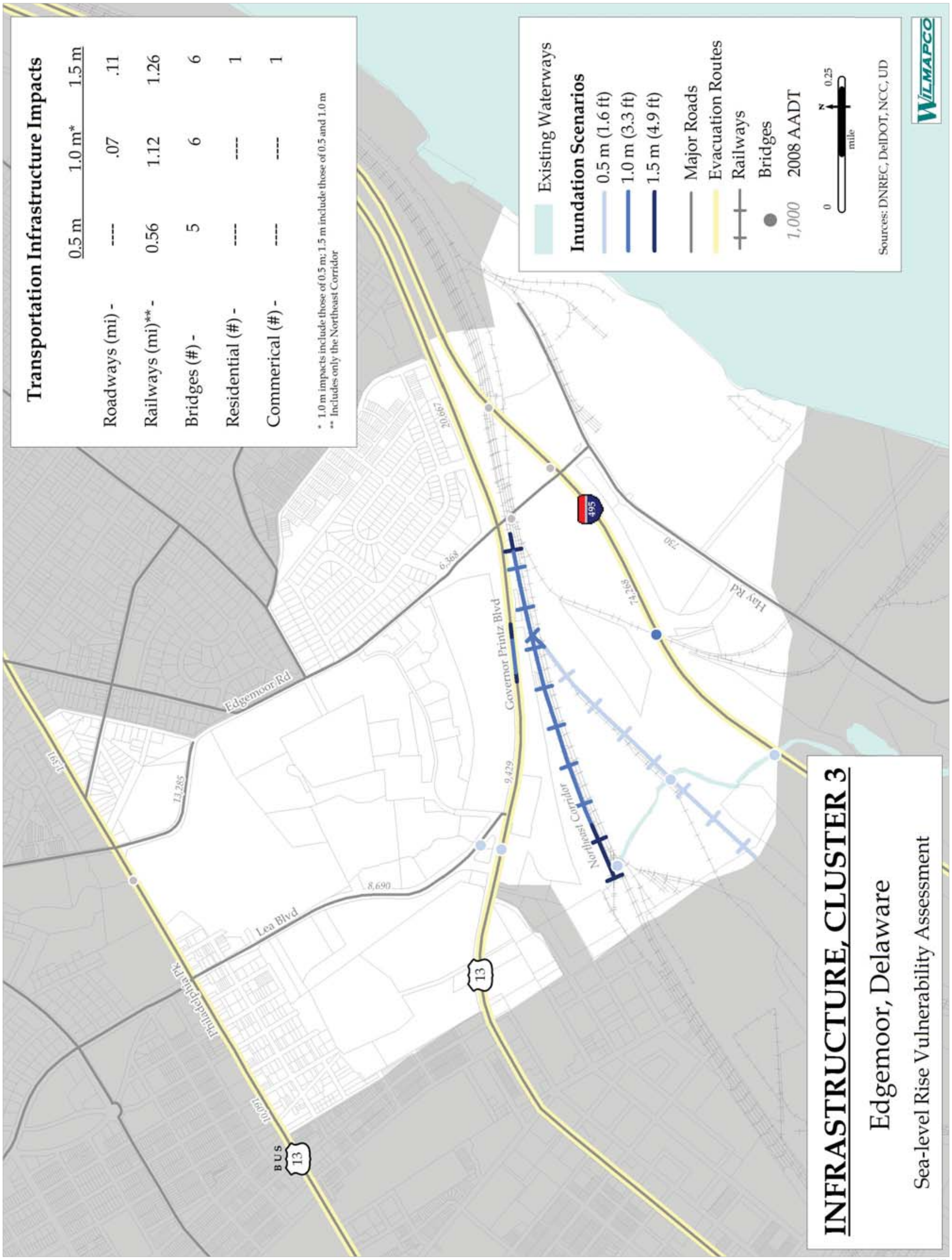
Map 20: C2 Infrastructure

Map 21: C2 Planned Projects

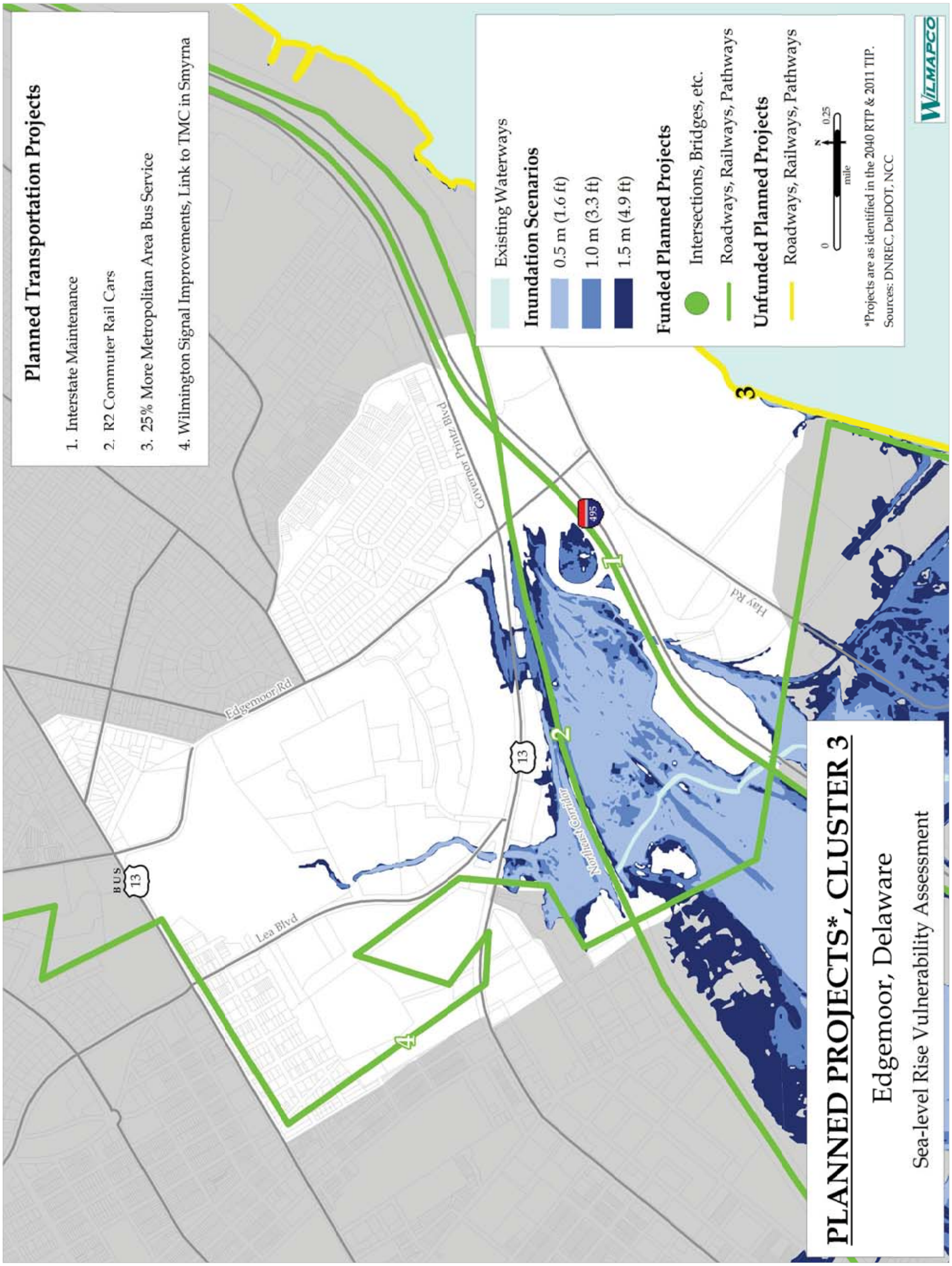
Map 22: C3 Base



Map 23: C3 Infrastructure

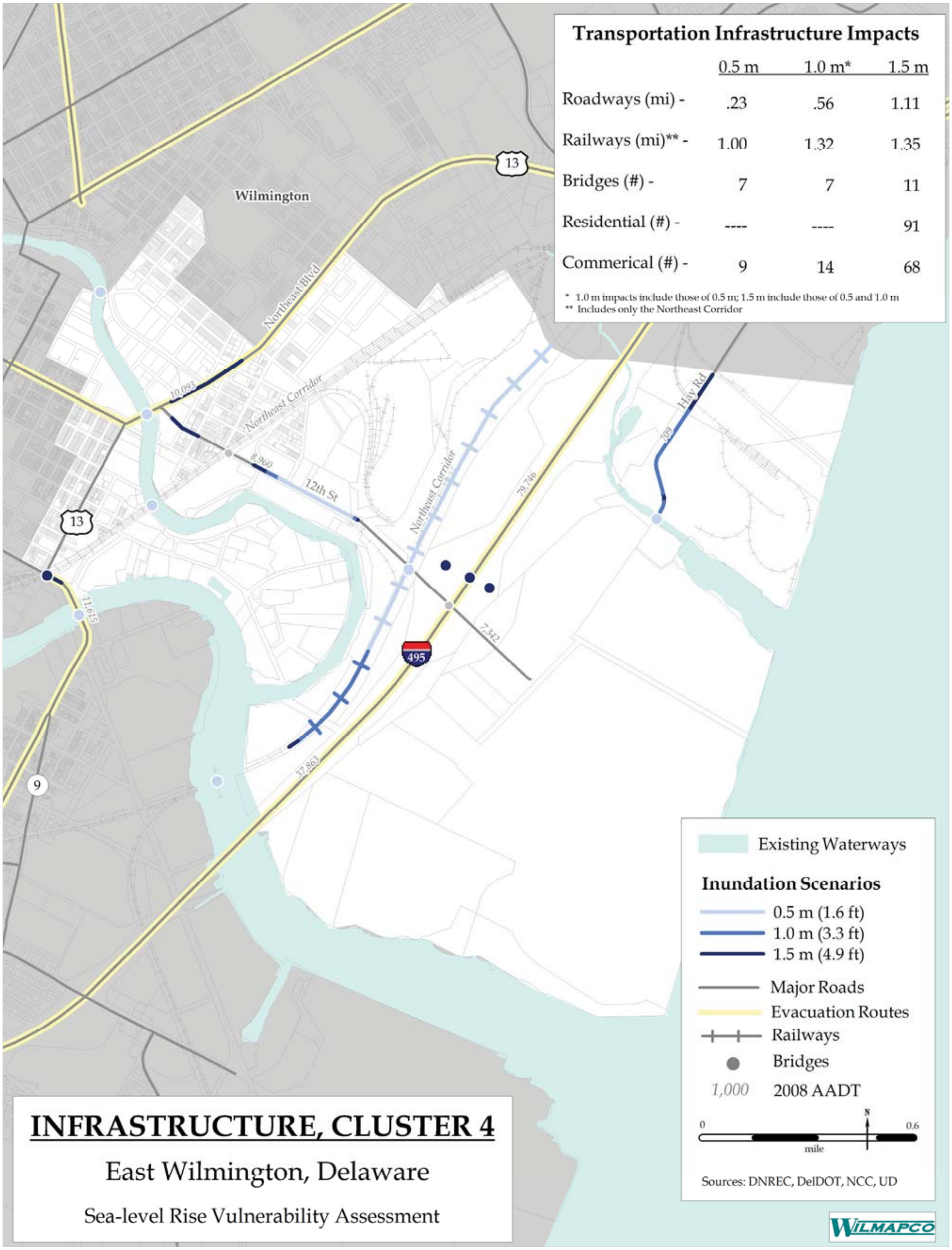


Map 24: C3 Planned Projects

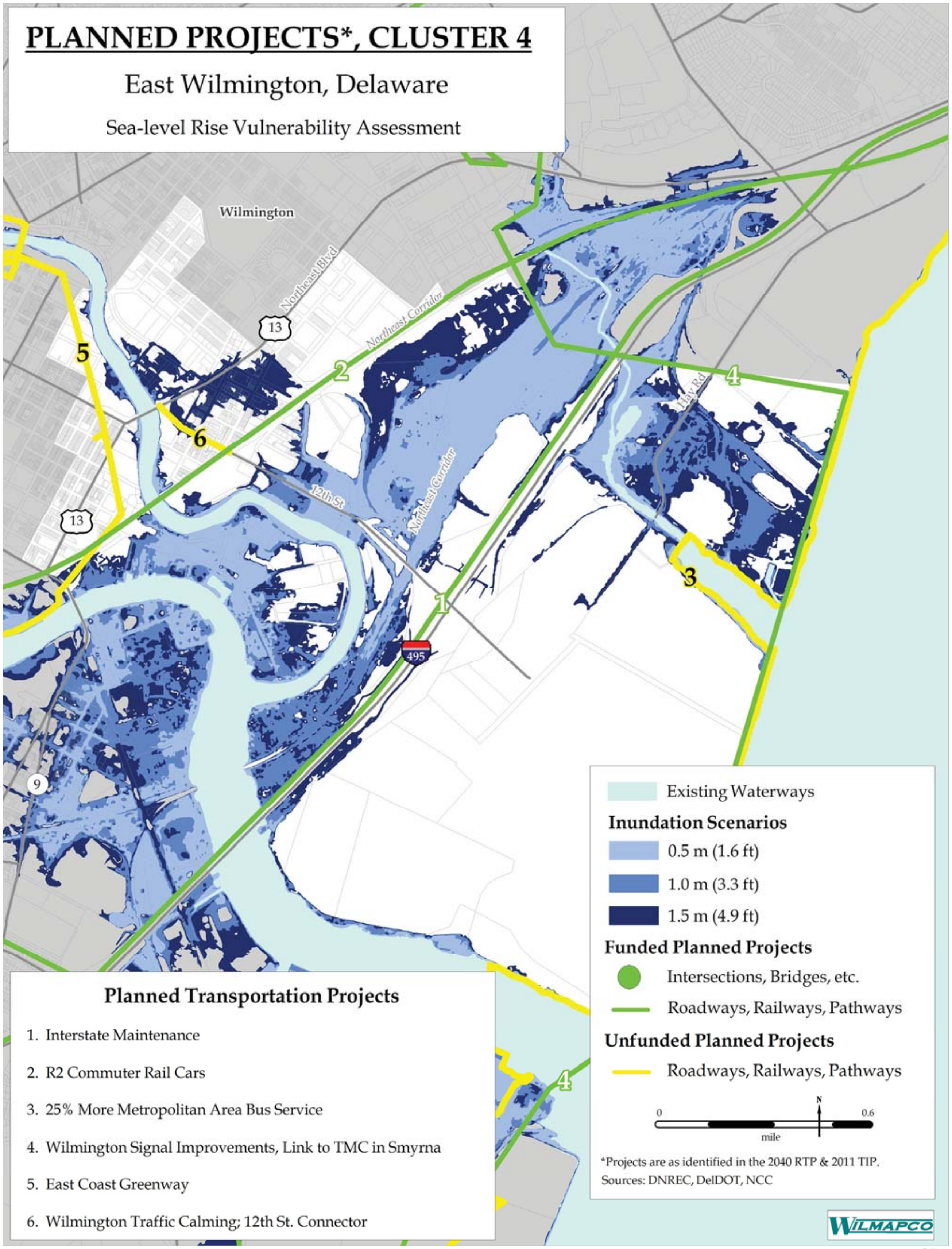


Map 25: C4 Base

Map 26: C4 Infrastructure

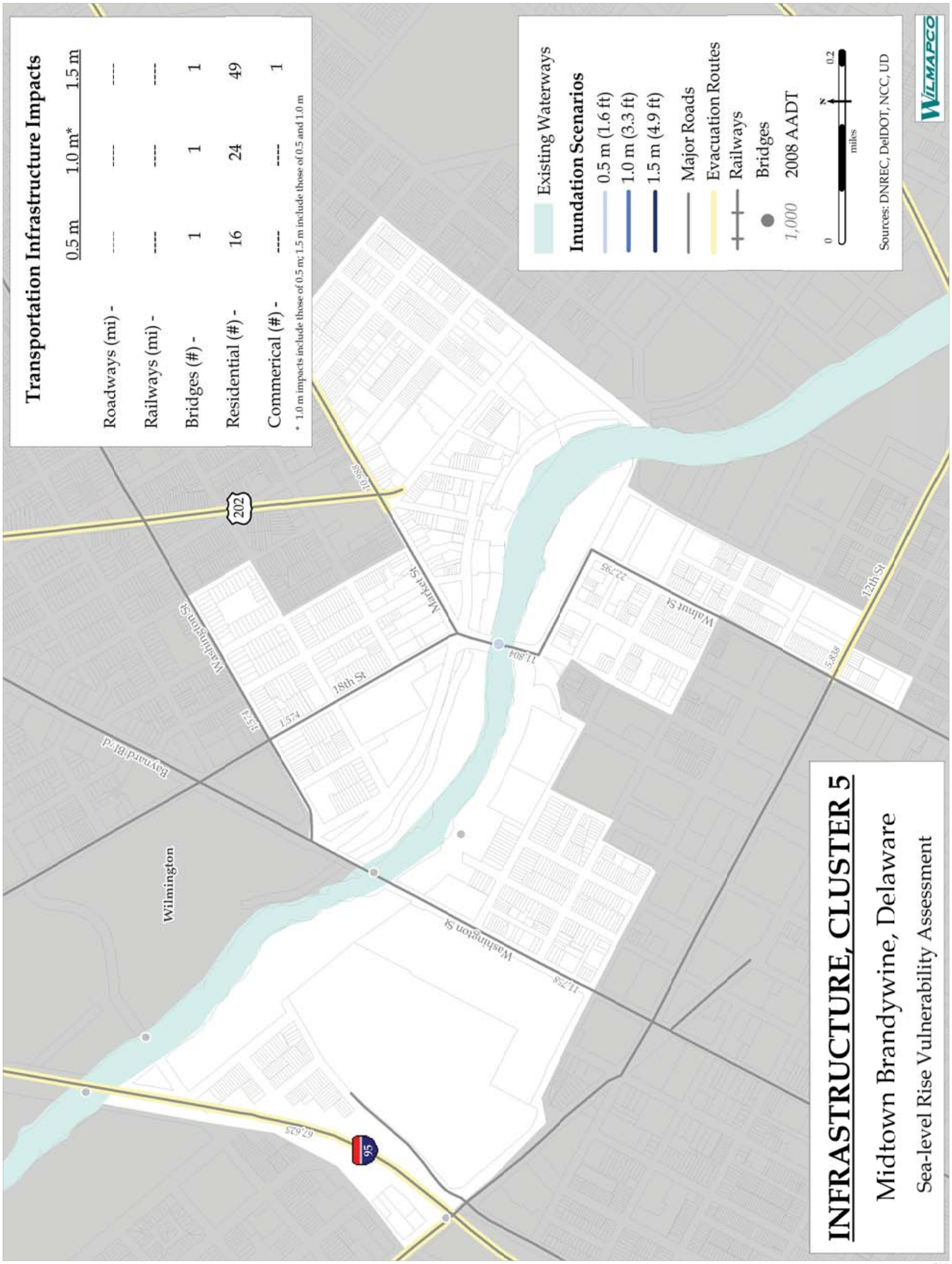


Map 27: C4 Planned Projects

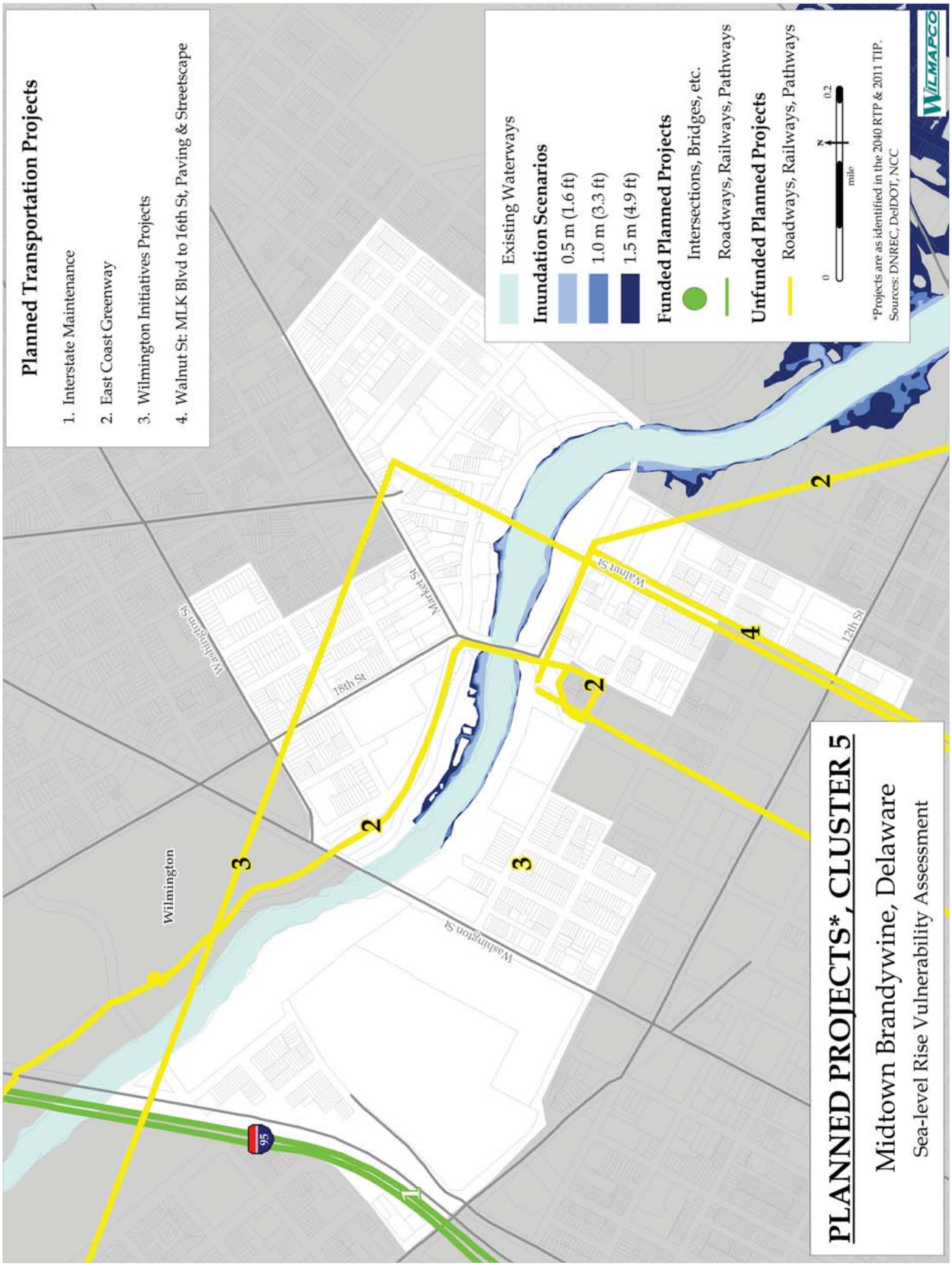


Map 28: C5 Base

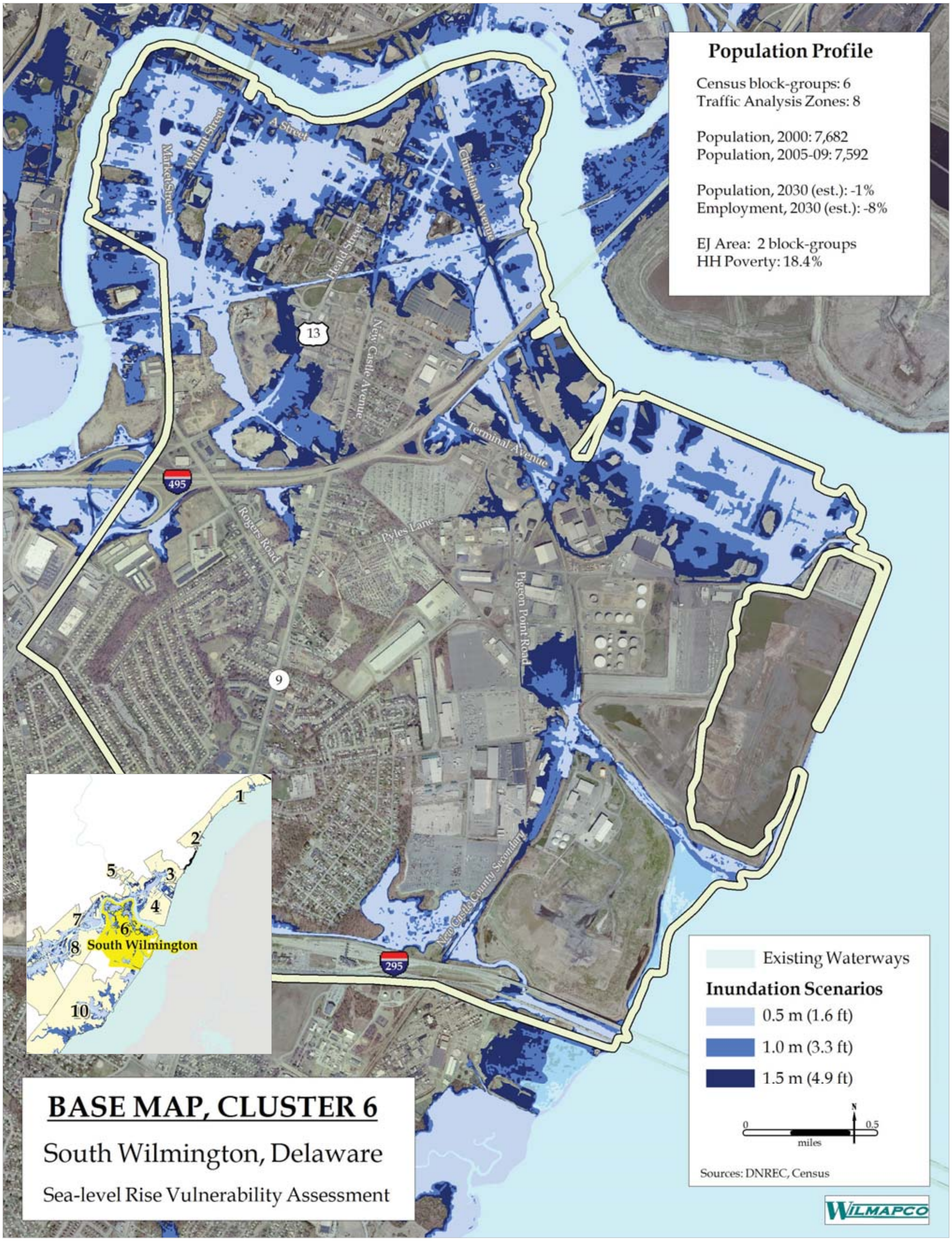
Map 29: C5 Infrastructure



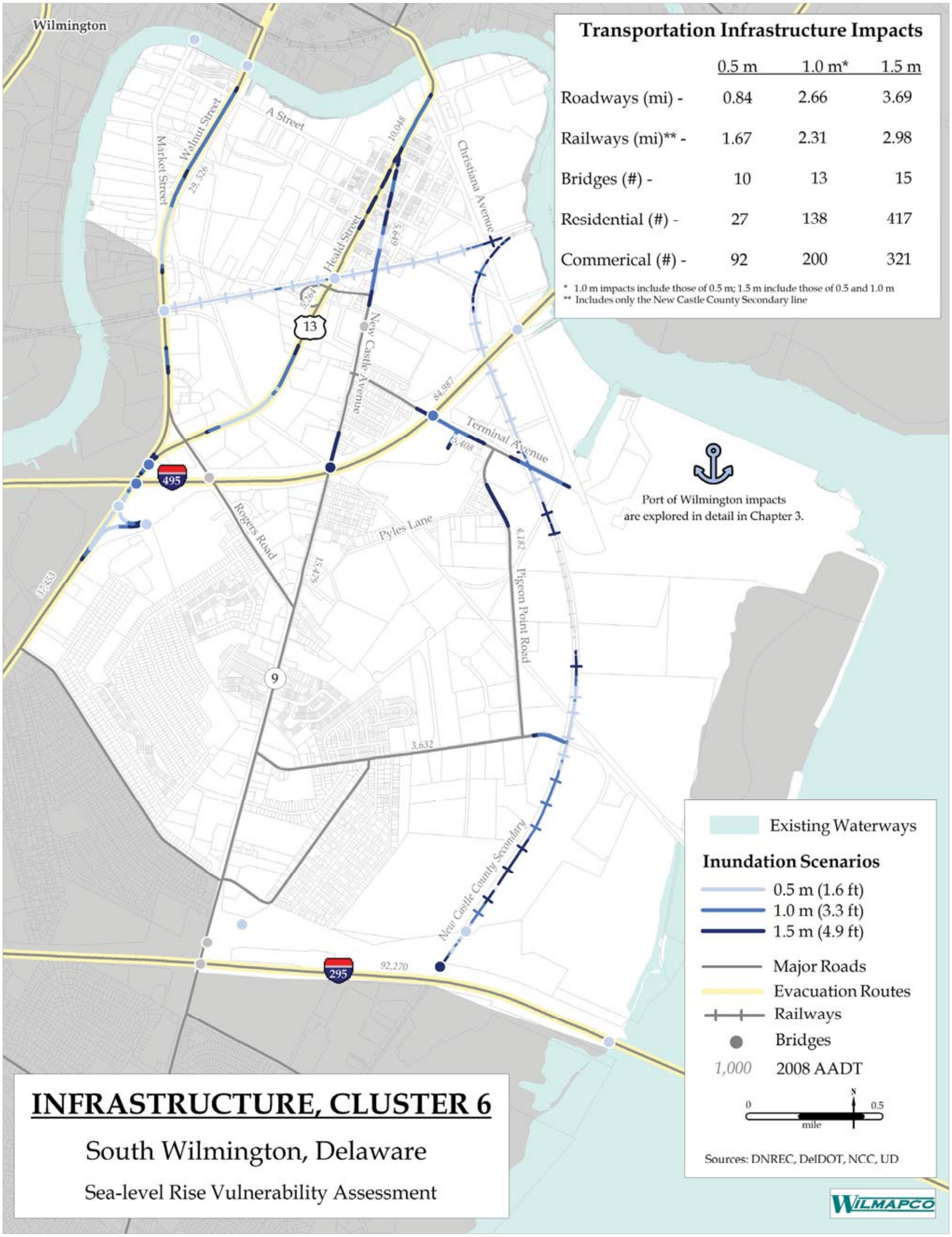
Map 30: C5 Planned Projects



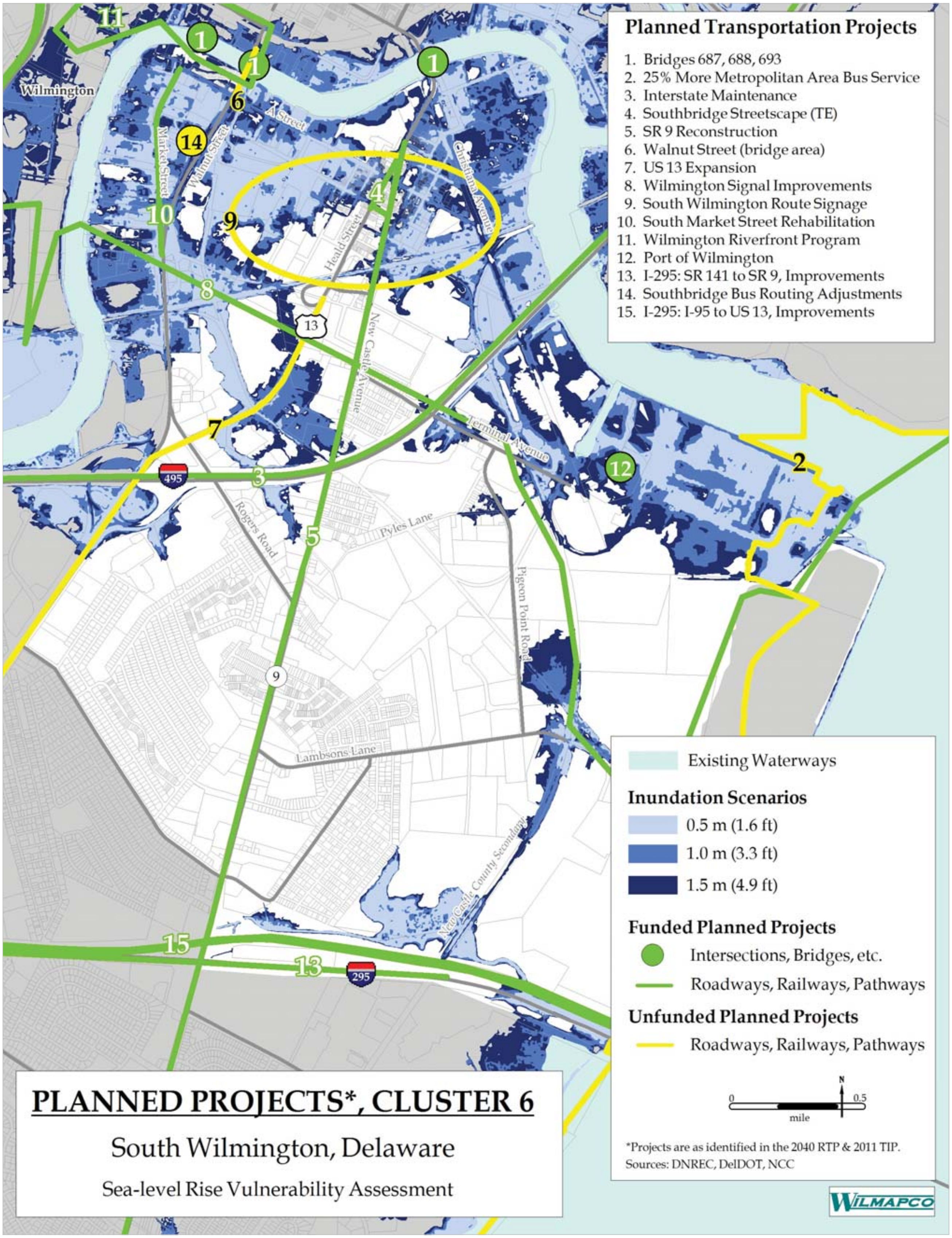
Map 31: C6 Base



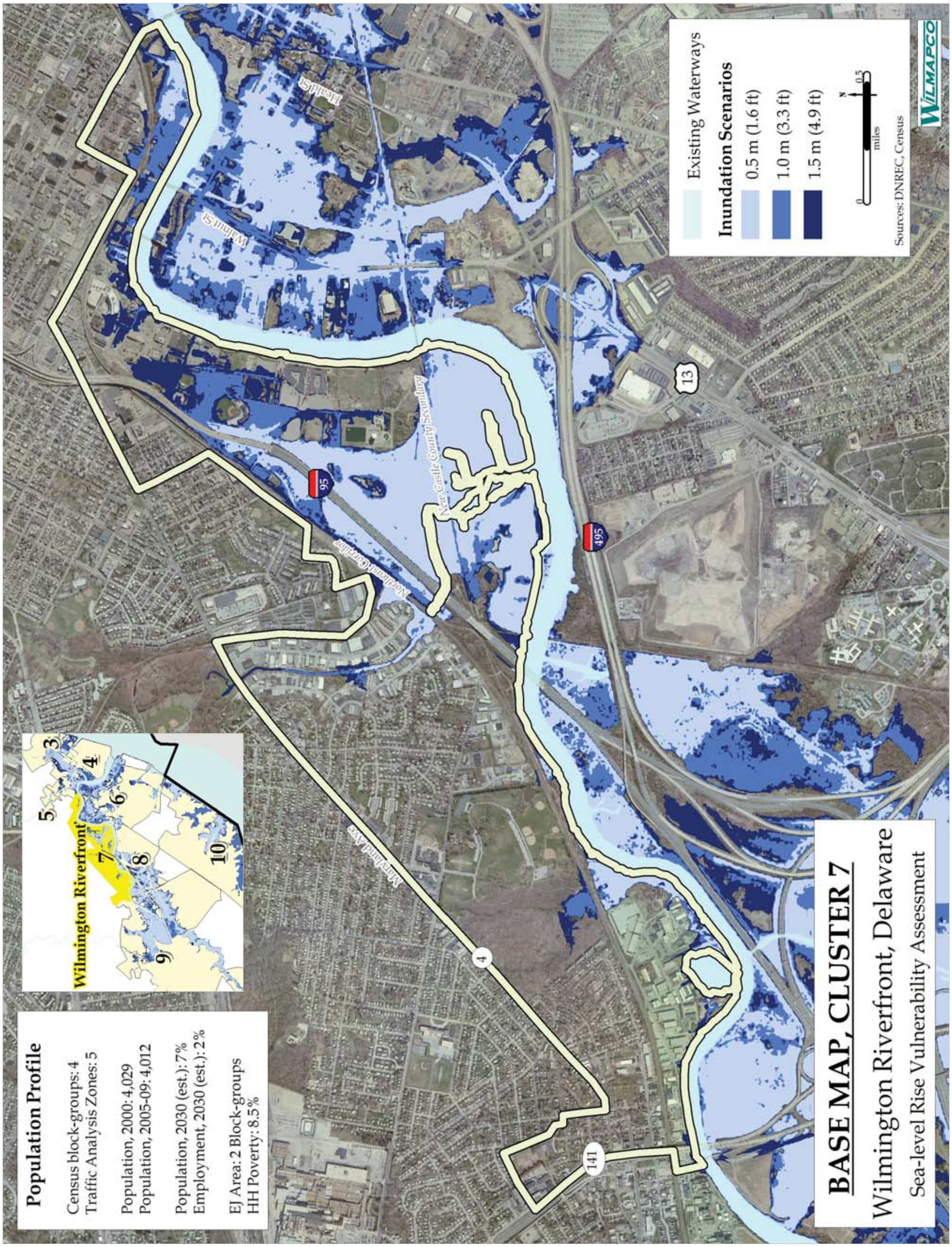
Map 32: C6 Infrastructure



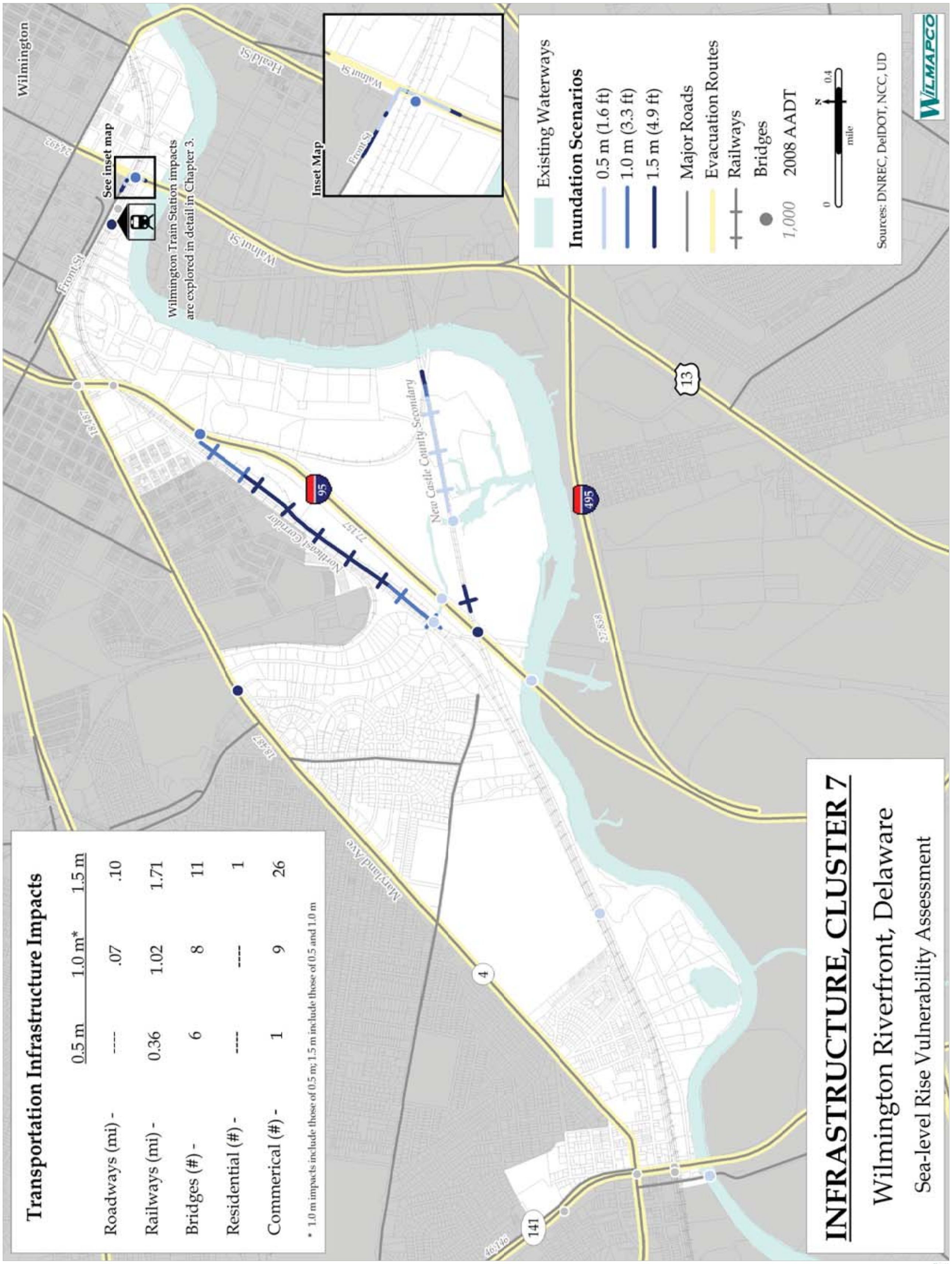
Map 33: C6 Planned Projects



Map 34: C7 Base



Map 35: C7 Infrastructure

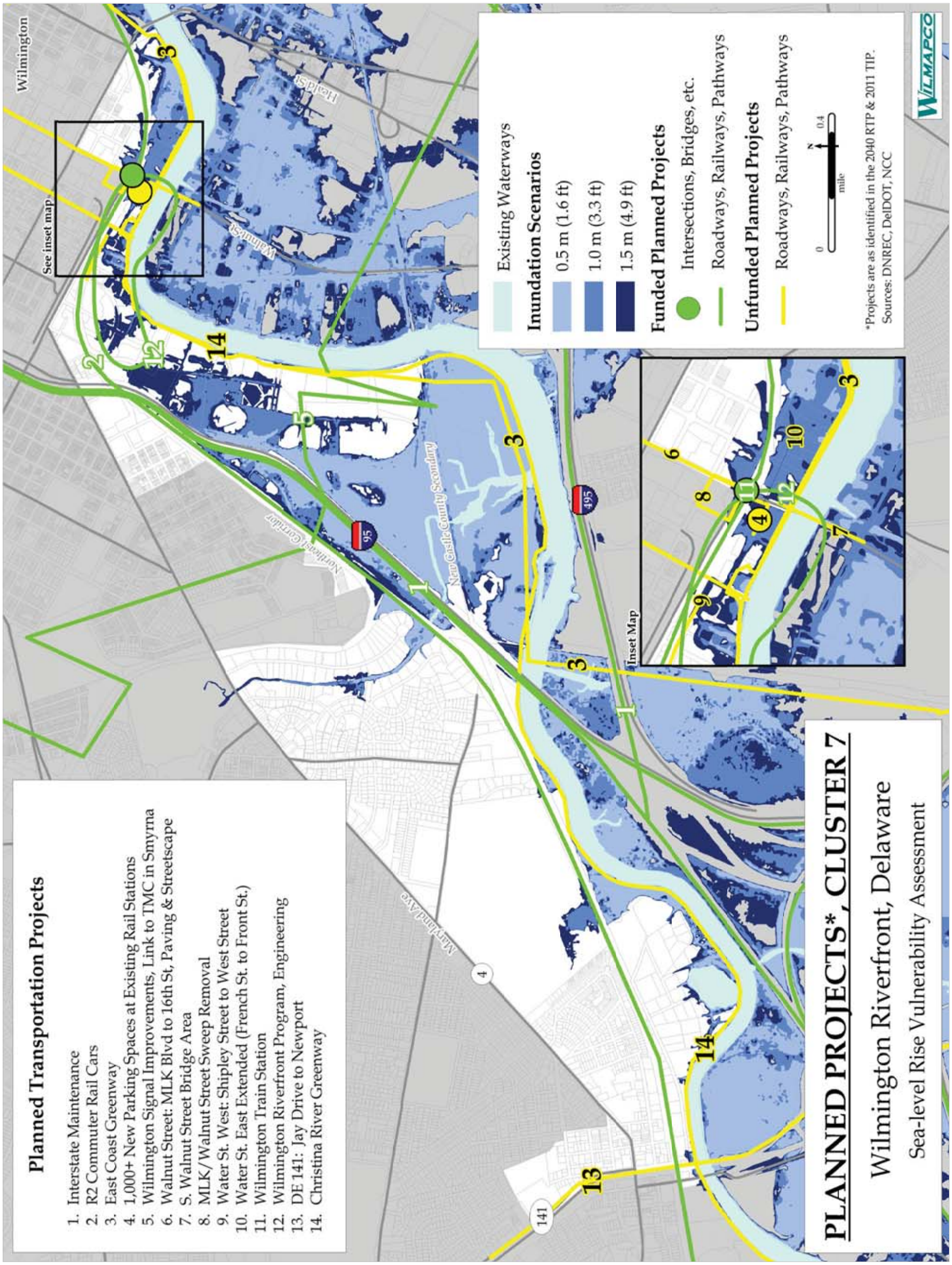


Transportation Infrastructure Impacts

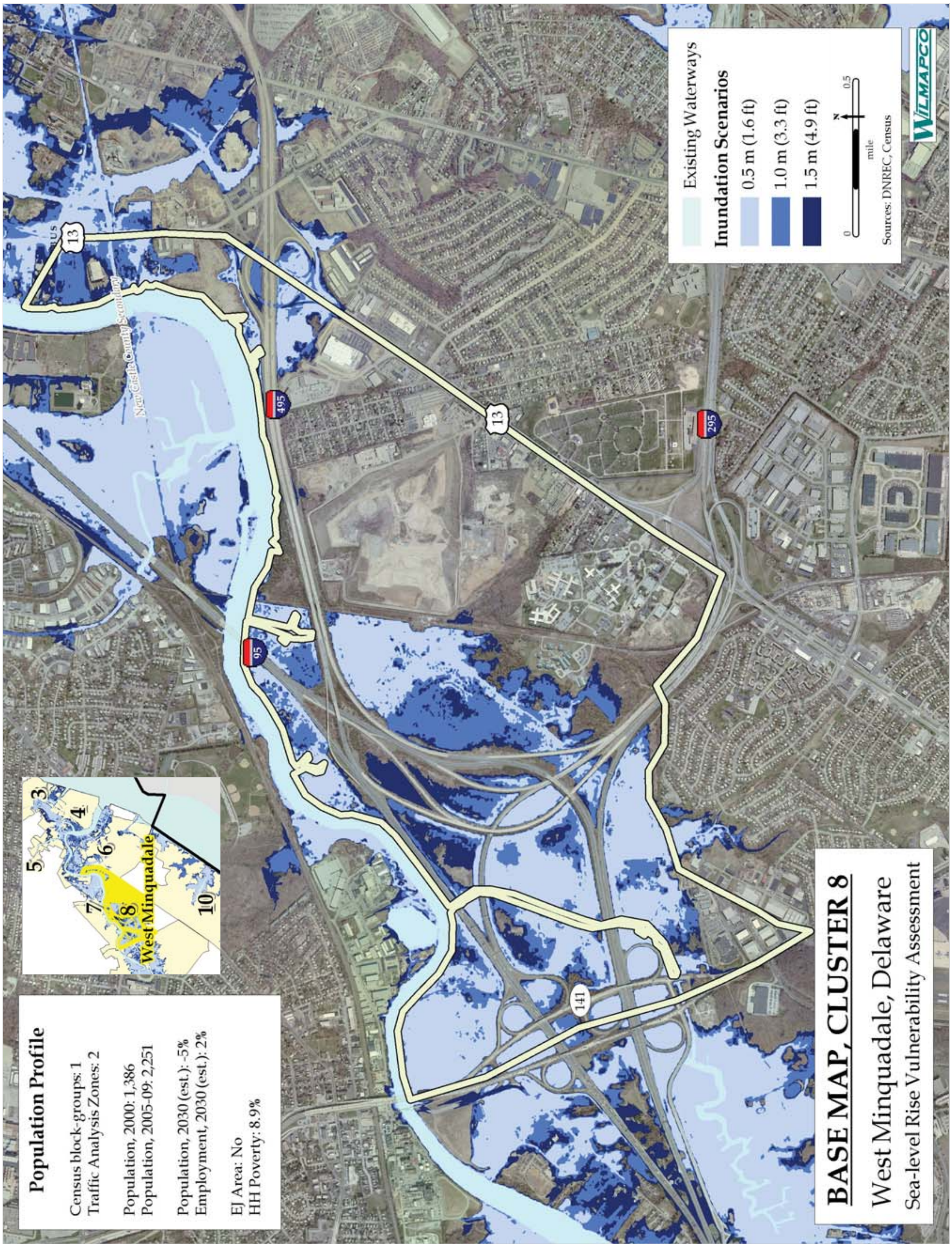
	0.5 m	1.0 m*	1.5 m
Roadways (mi) -	----	.07	.10
Railways (mi) -	0.36	1.02	1.71
Bridges (#) -	6	8	11
Residential (#) -	----	----	1
Commerical (#) -	1	9	26

* 1.0 m impacts include those of 0.5 m; 1.5 m include those of 0.5 and 1.0 m

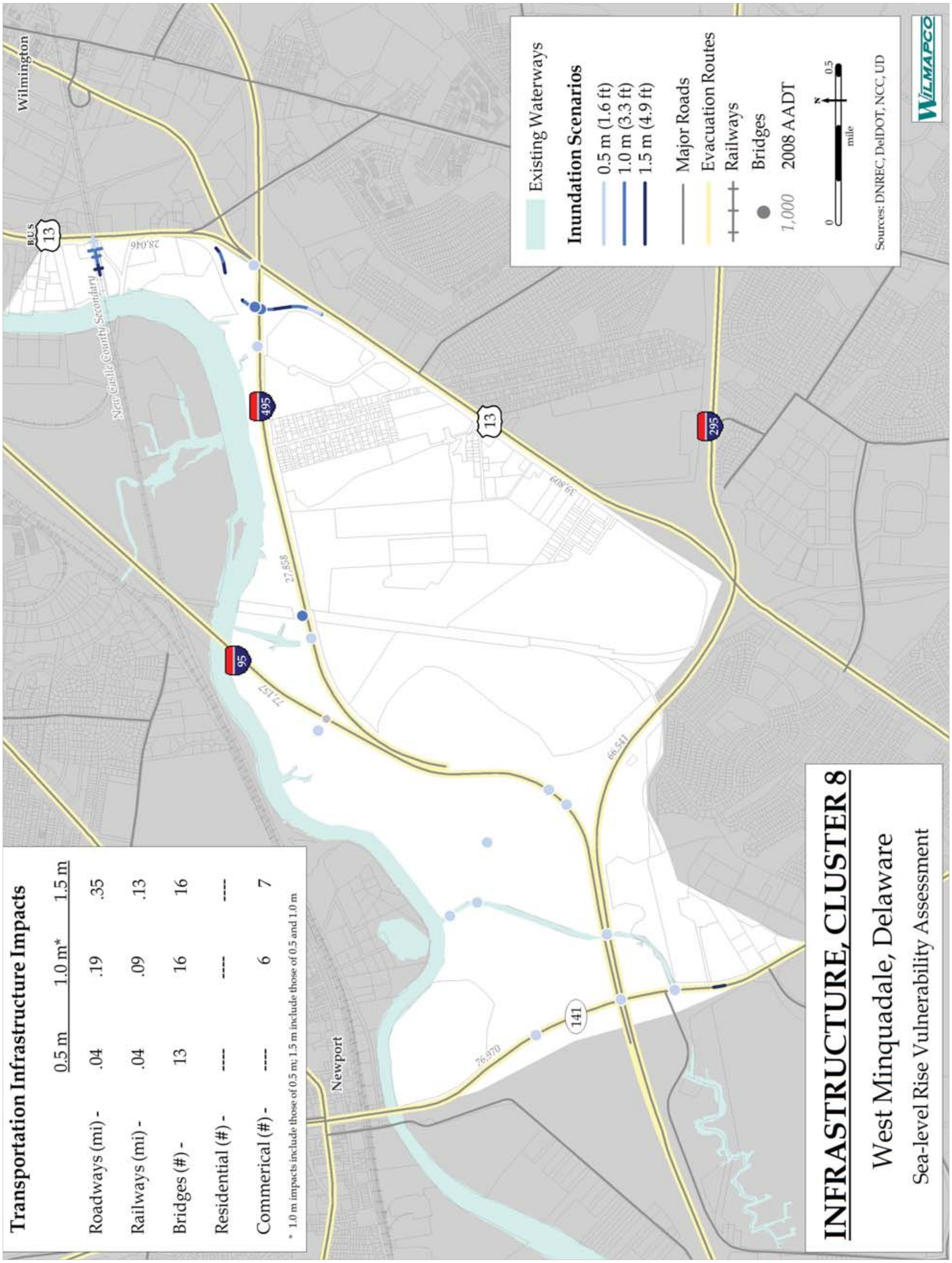
Map 36: C7 Planned Projects



Map 37: C8 Base



Map 38: C8 Infrastructure

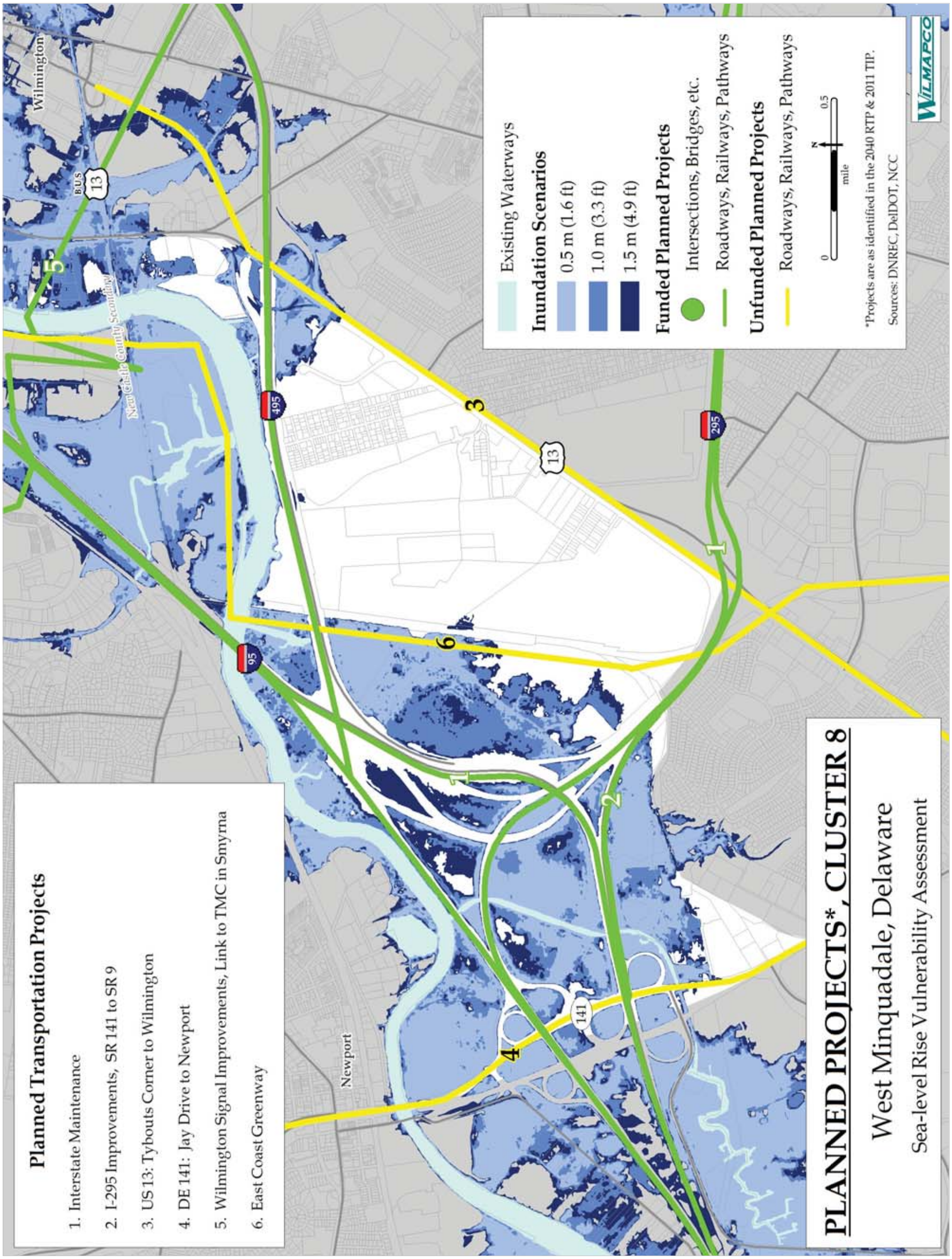


Transportation Infrastructure Impacts

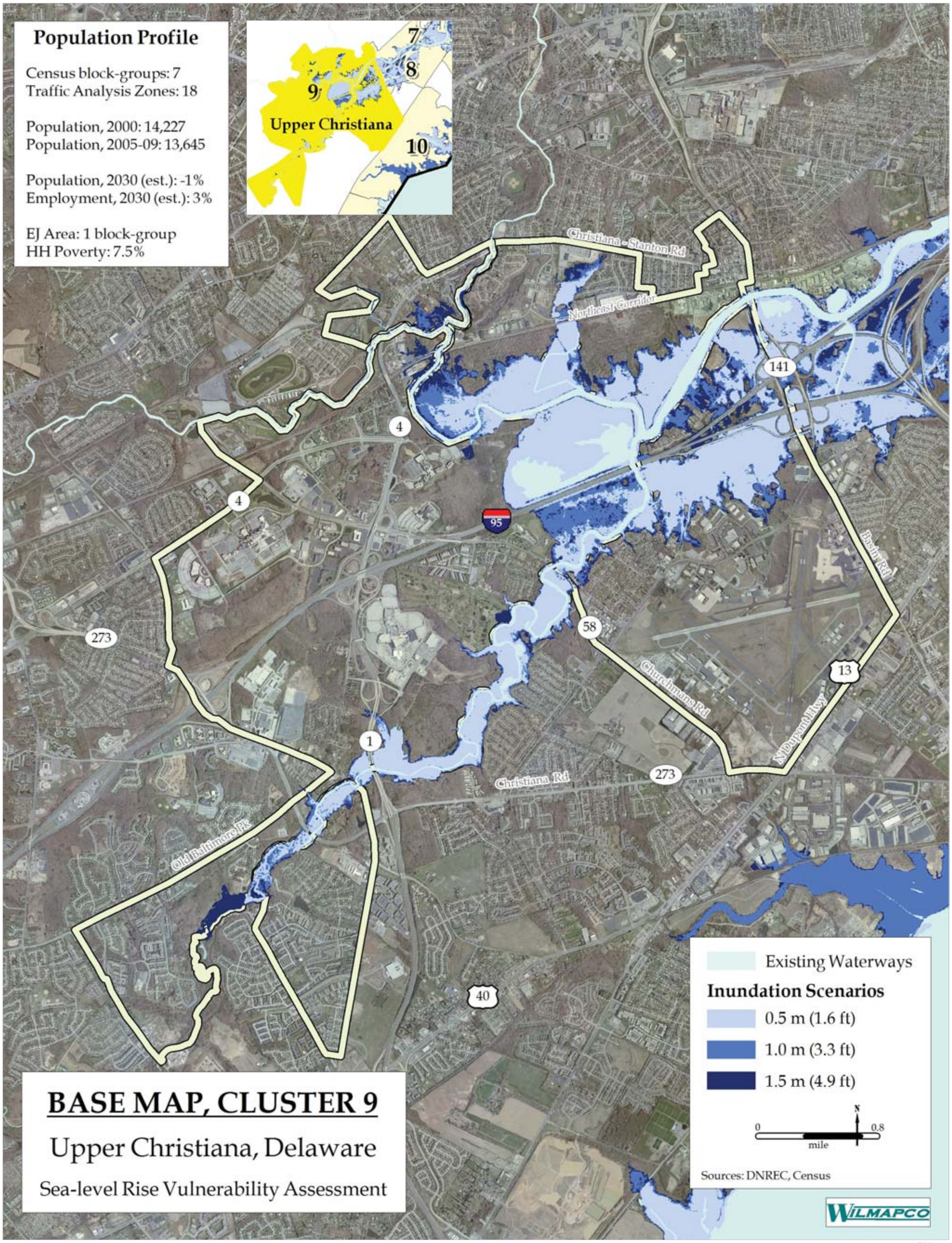
	0.5 m	1.0 m*	1.5 m
Roadways (mi) -	.04	.19	.35
Railways (mi) -	.04	.09	.13
Bridges (#) -	13	16	16
Residential (#) -	---	---	---
Commerical (#) -	---	6	7

* 1.0 m impacts include those of 0.5 m; 1.5 m include those of 0.5 and 1.0 m

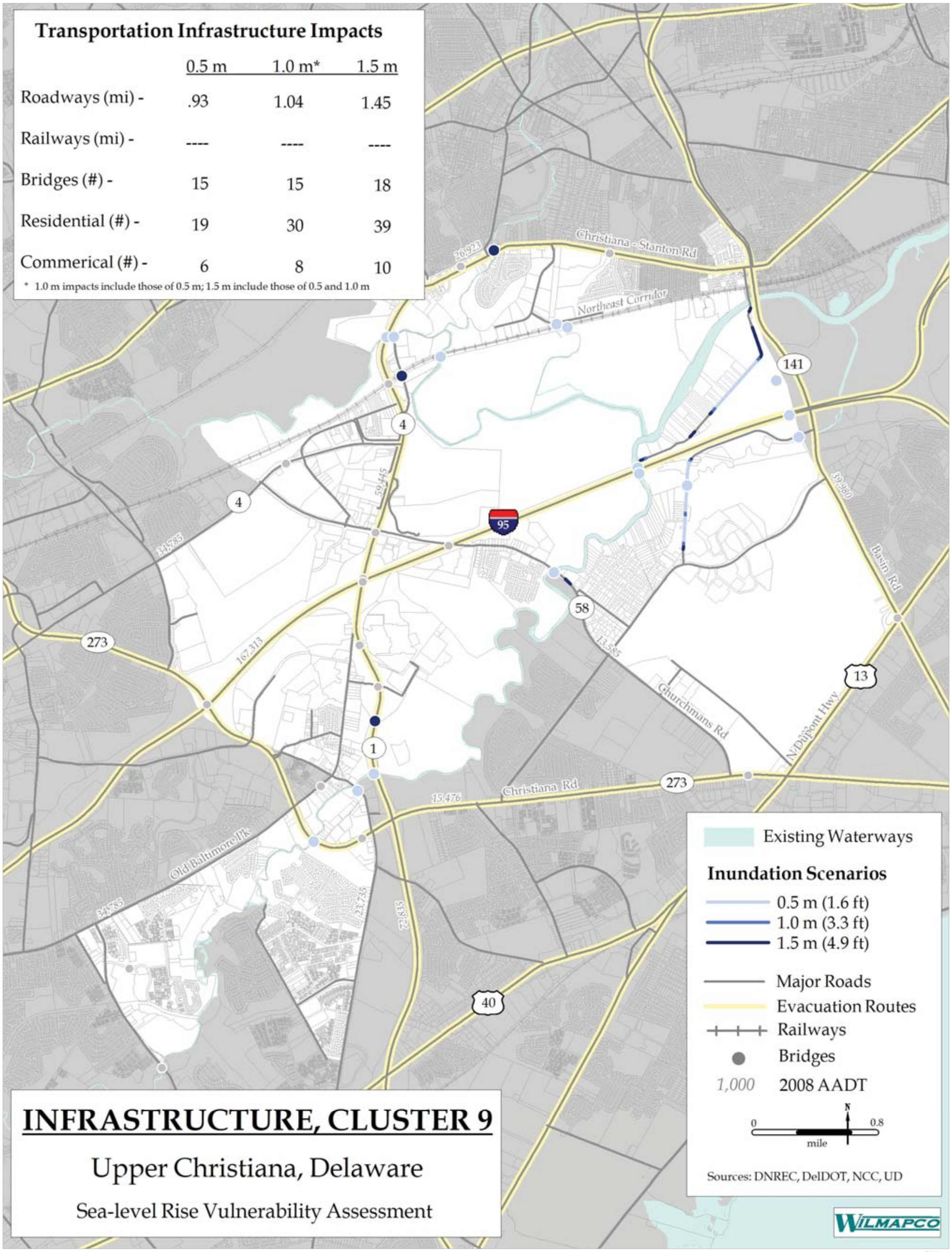
Map 39: C8 Planned Projects



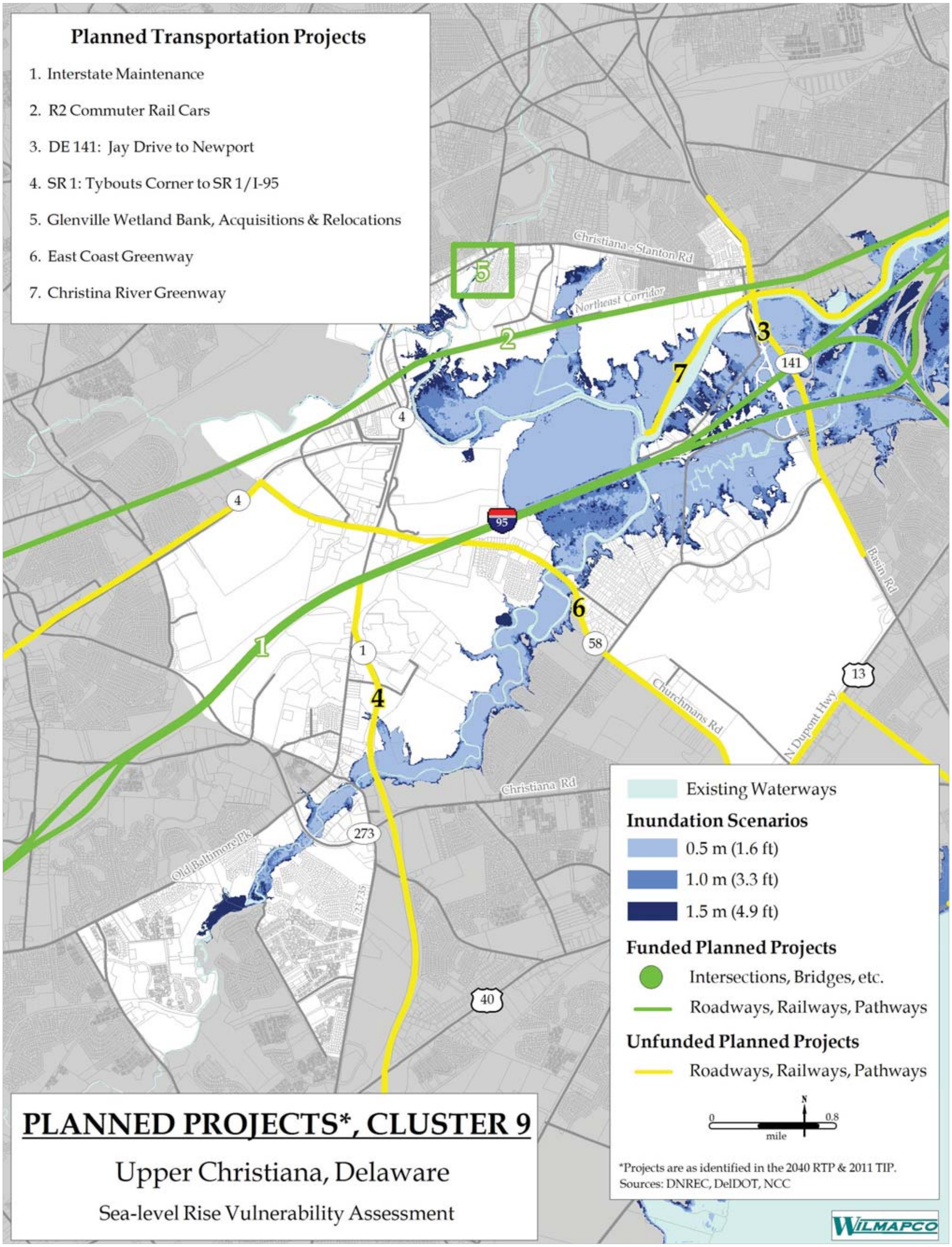
Map 40: C9 Base



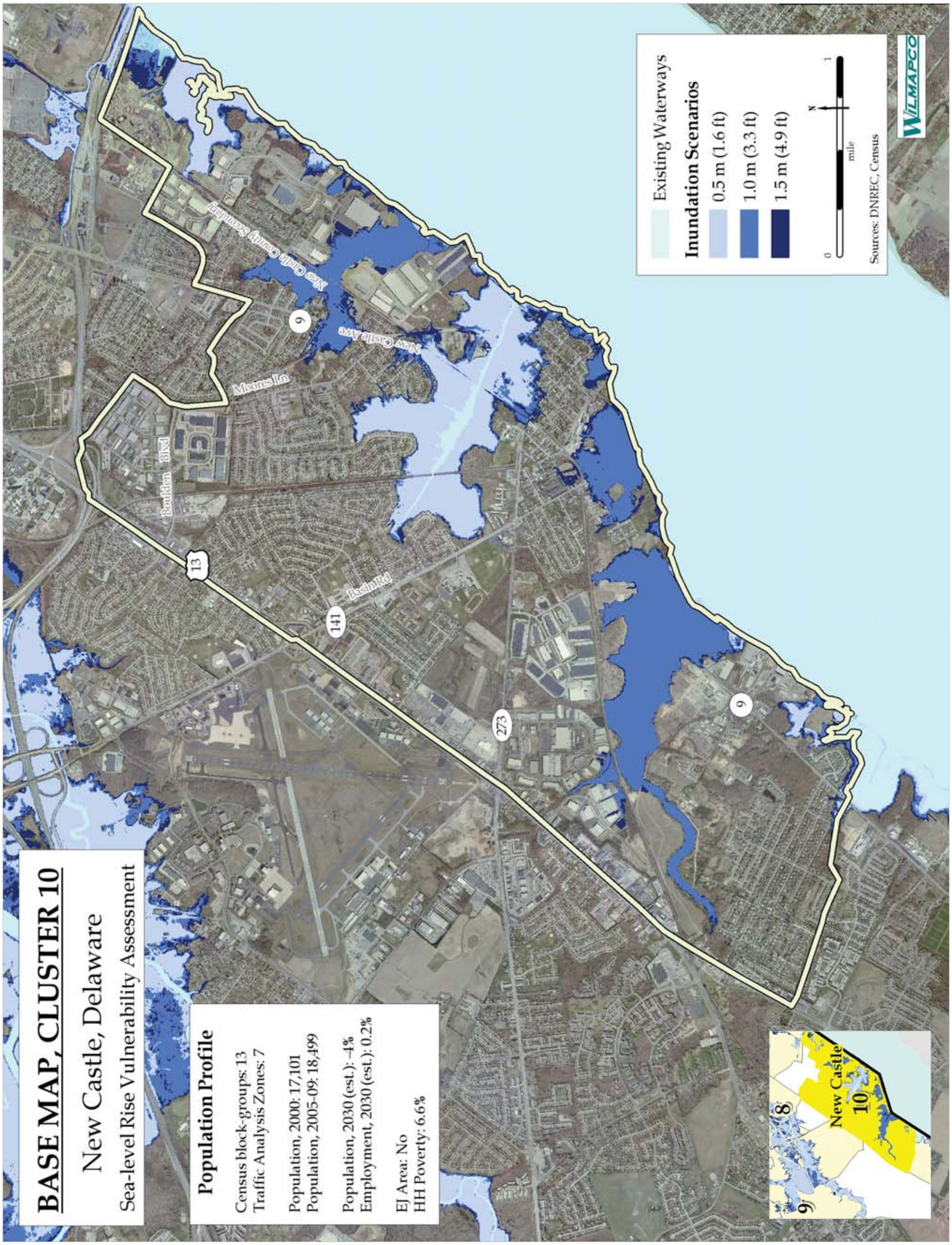
Map 41: C9 Infrastructure



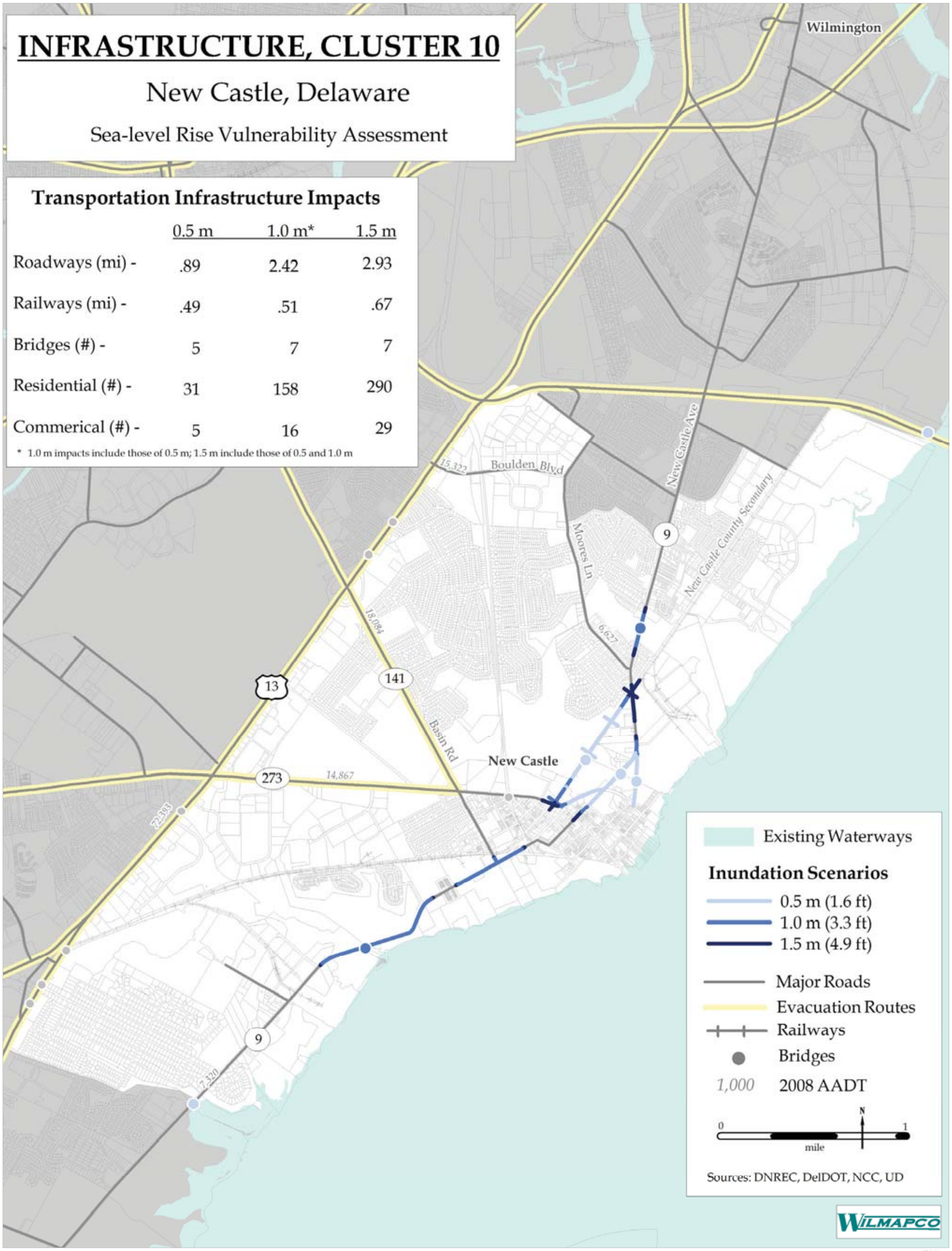
Map 42: C9 Planned Projects



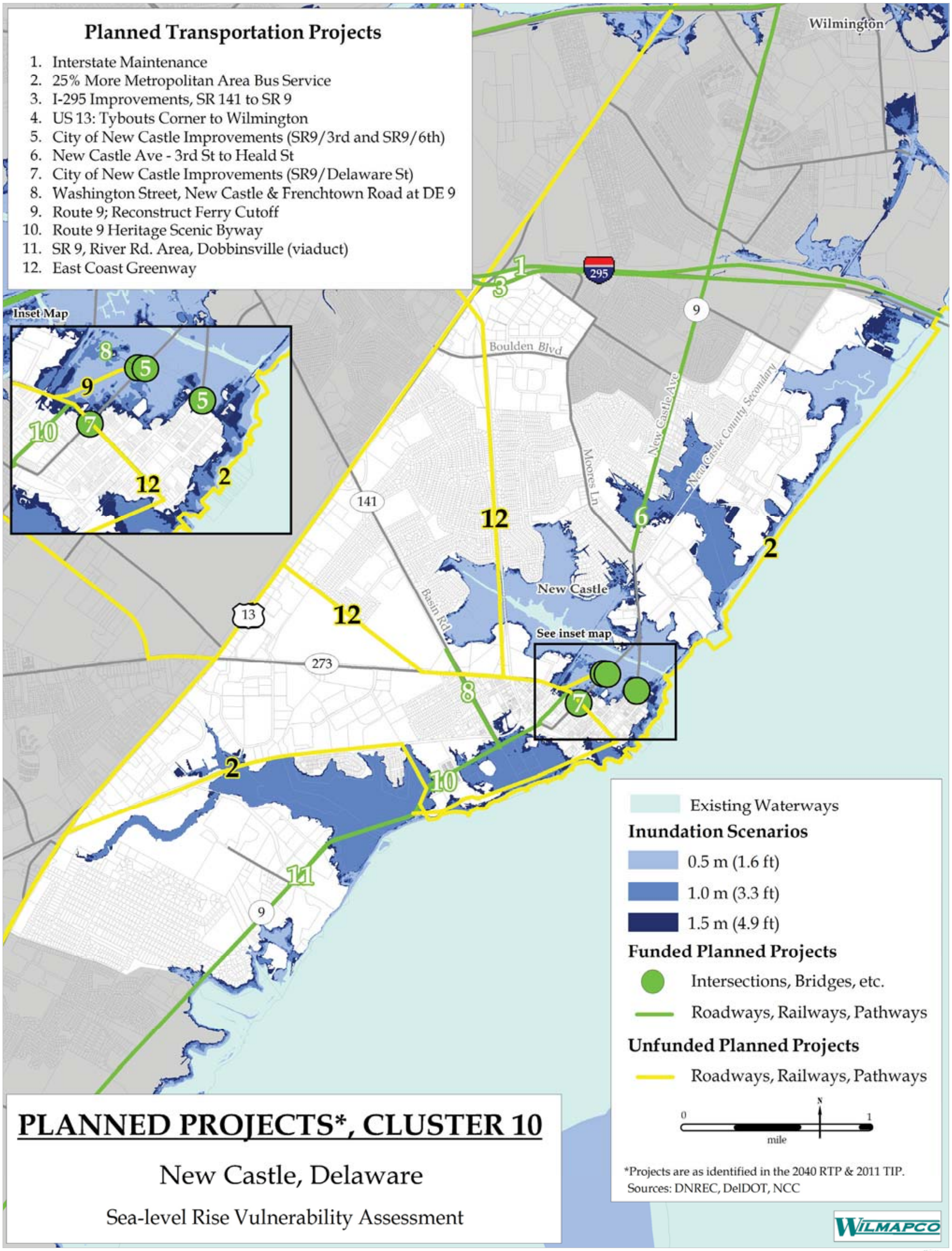
Map 43: C10 Base



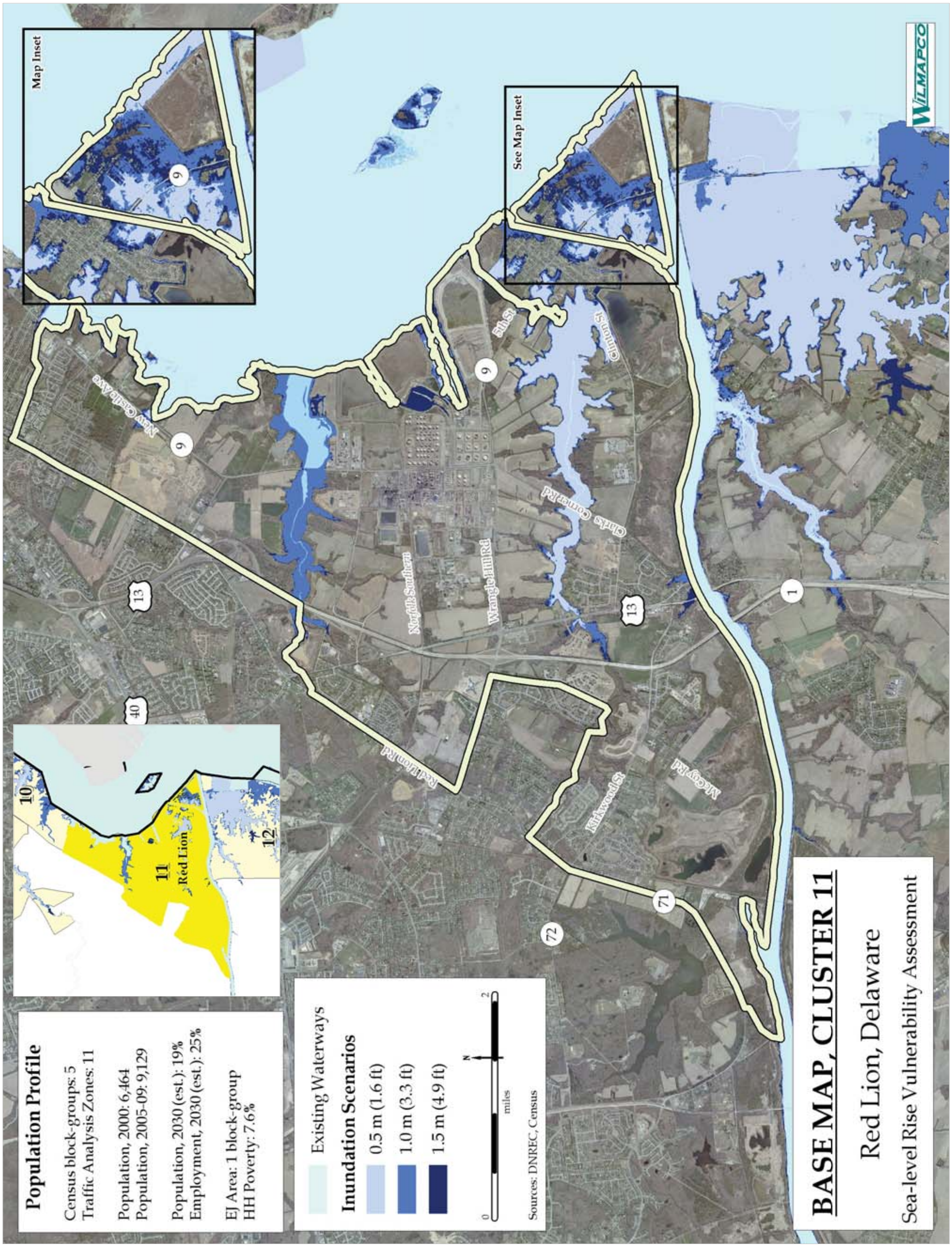
Map 44: C10 Infrastructure



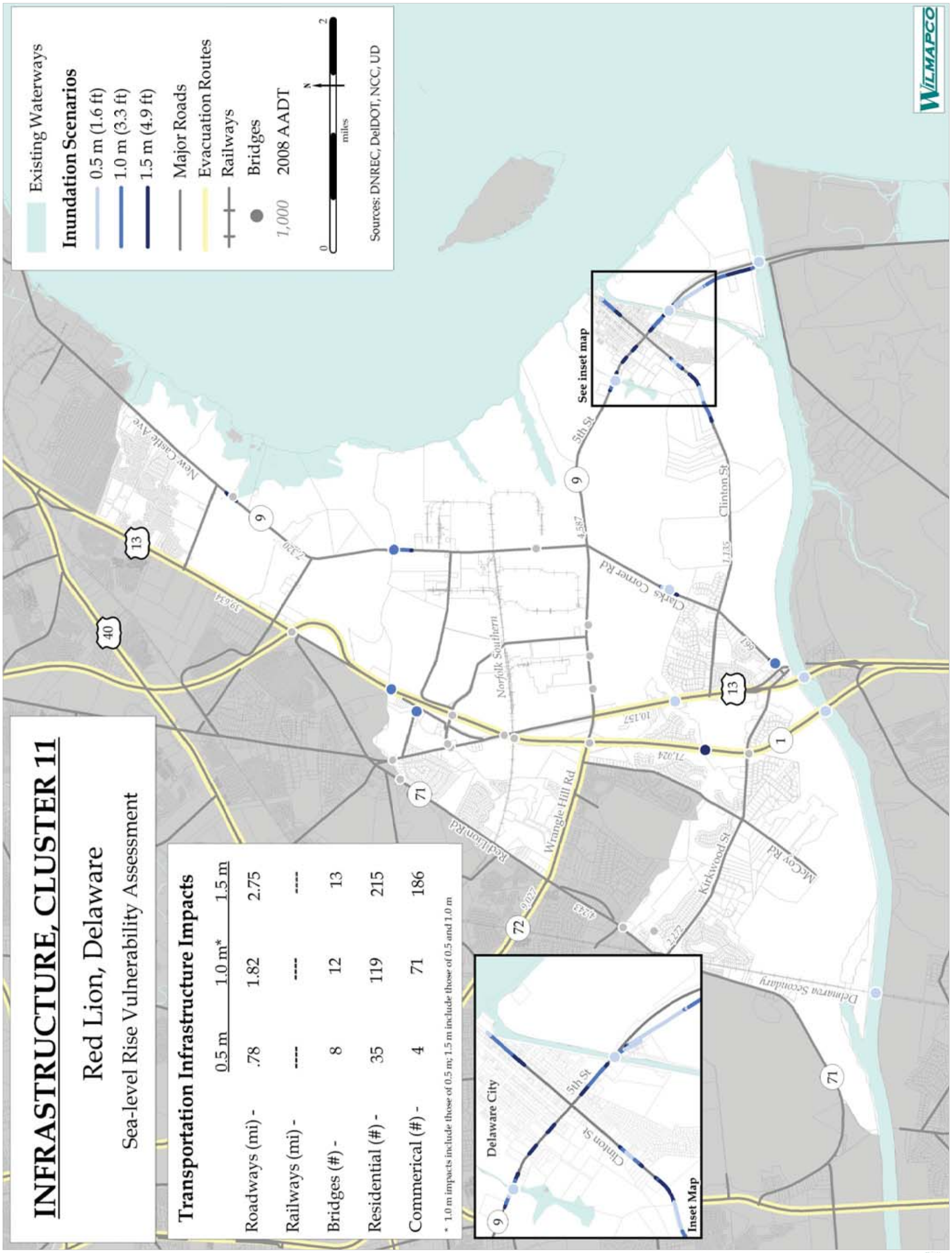
Map 45: C10 Planned Projects



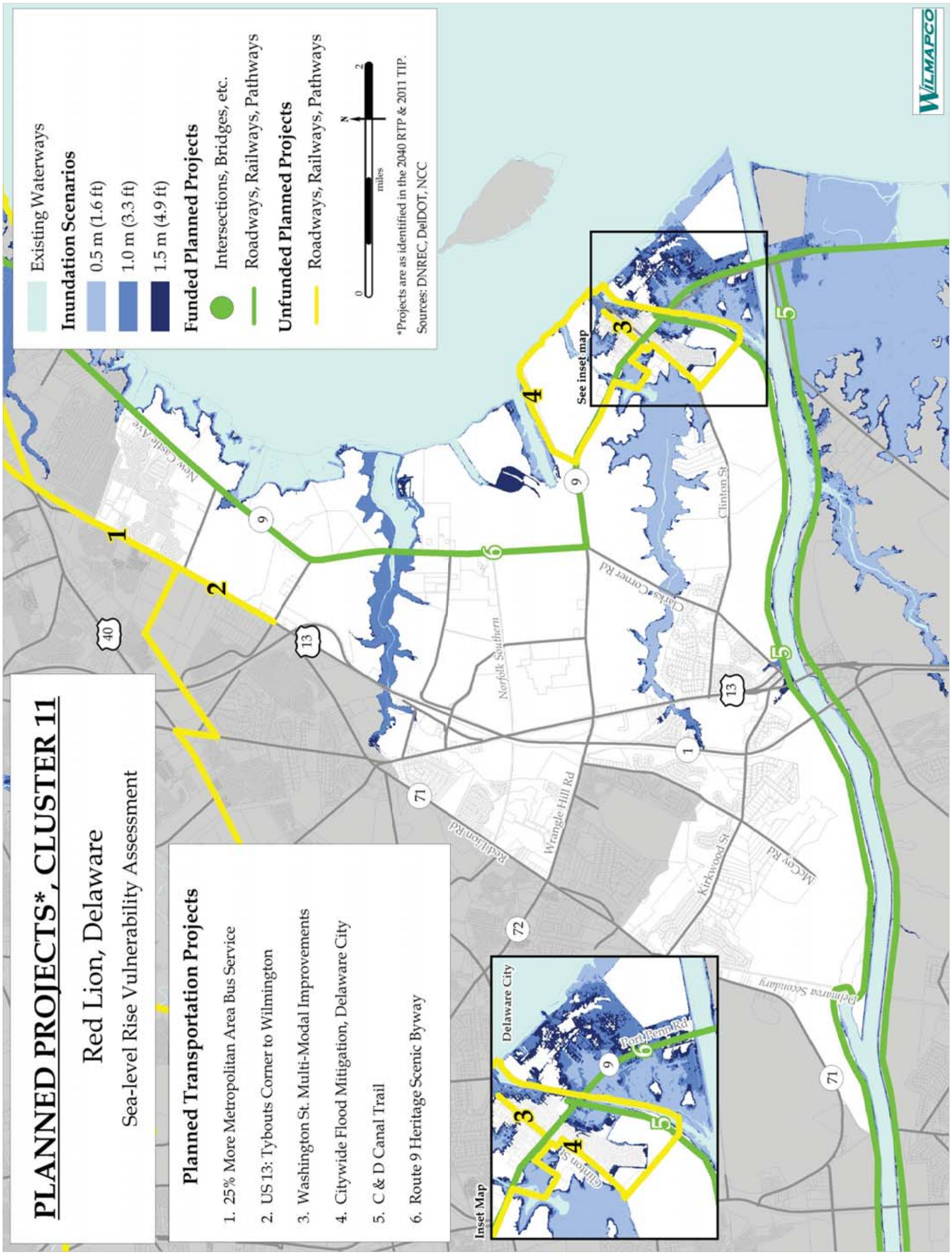
Map 46: C11 Base



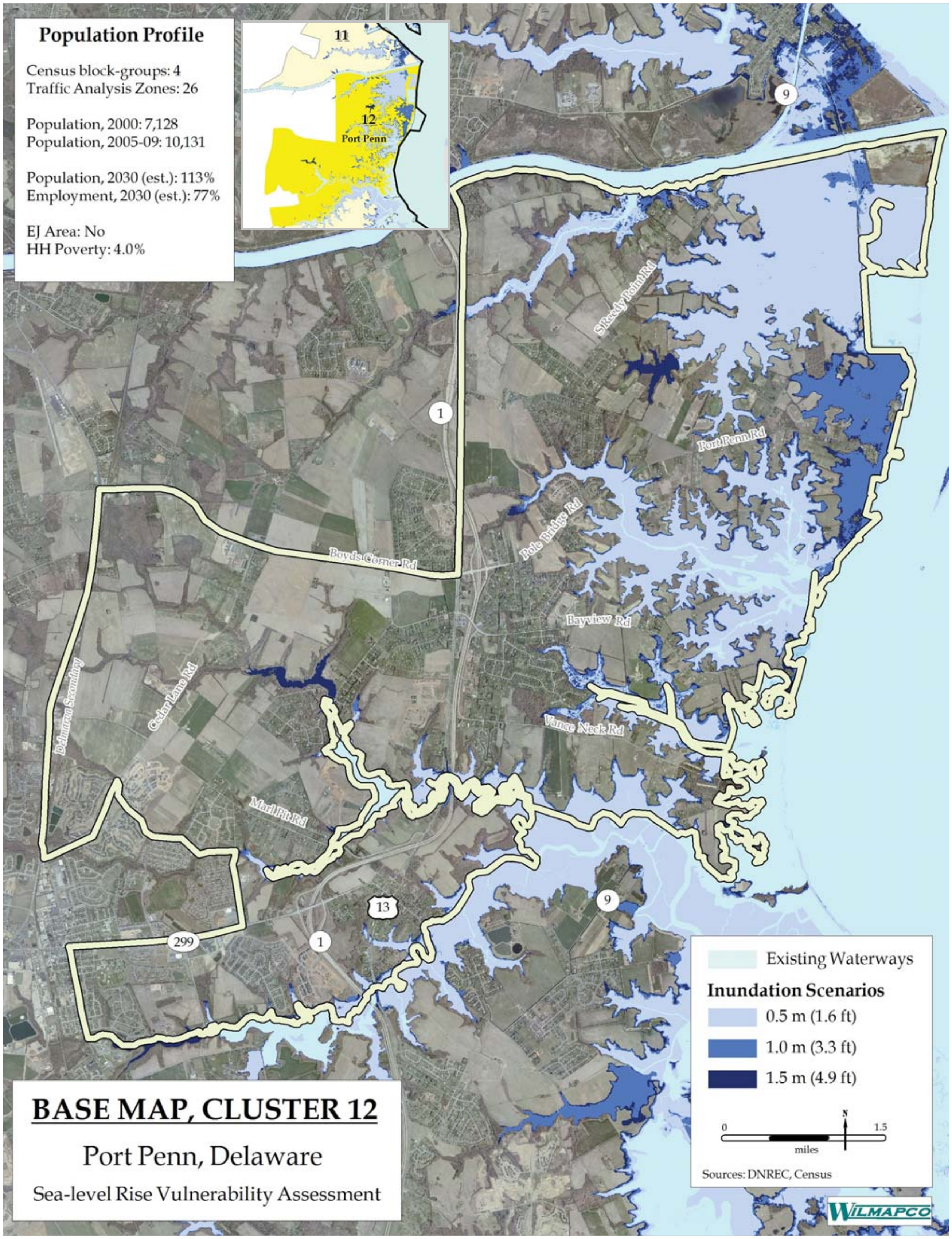
Map 47: C11 Infrastructure



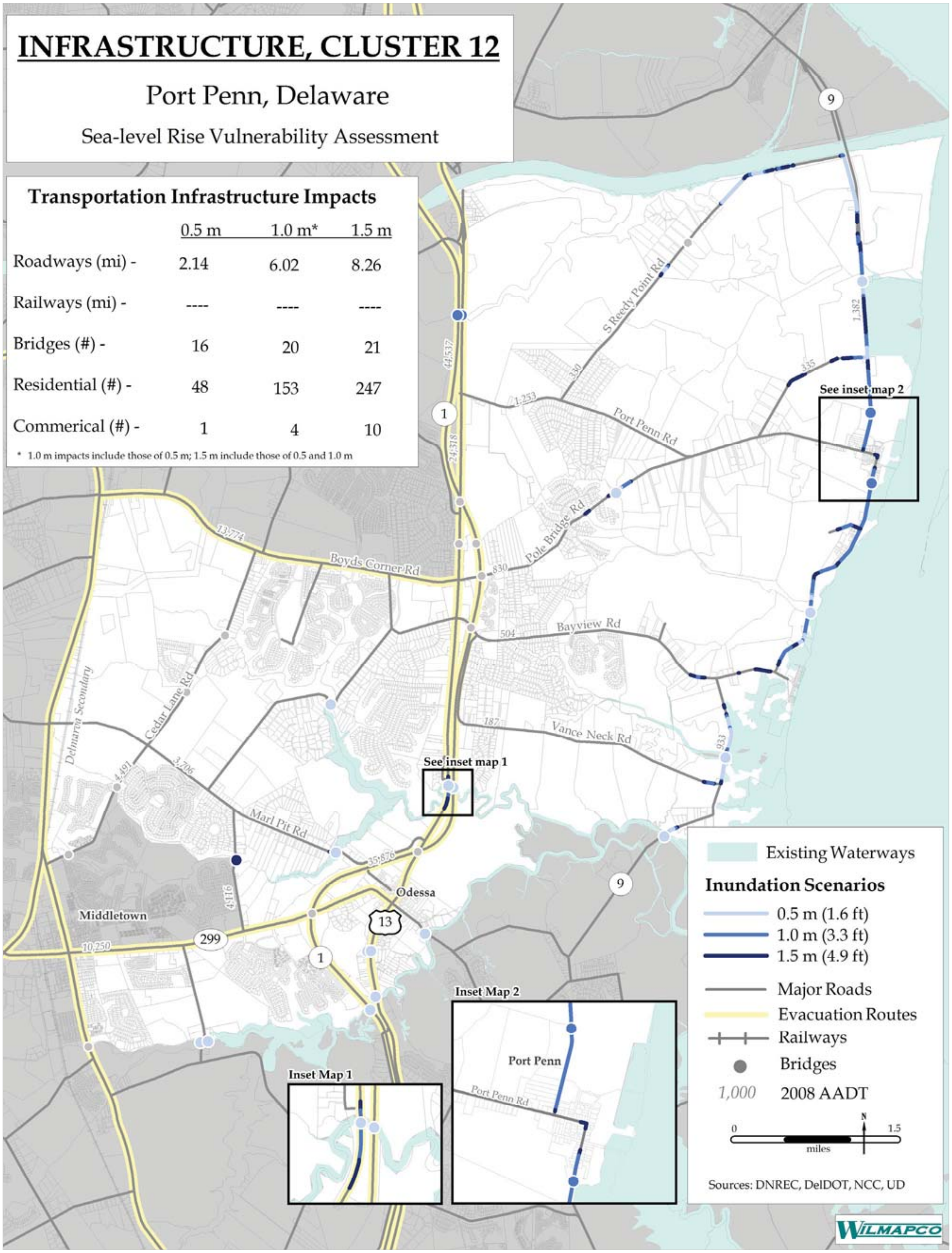
Map 48: C11 Planned Projects



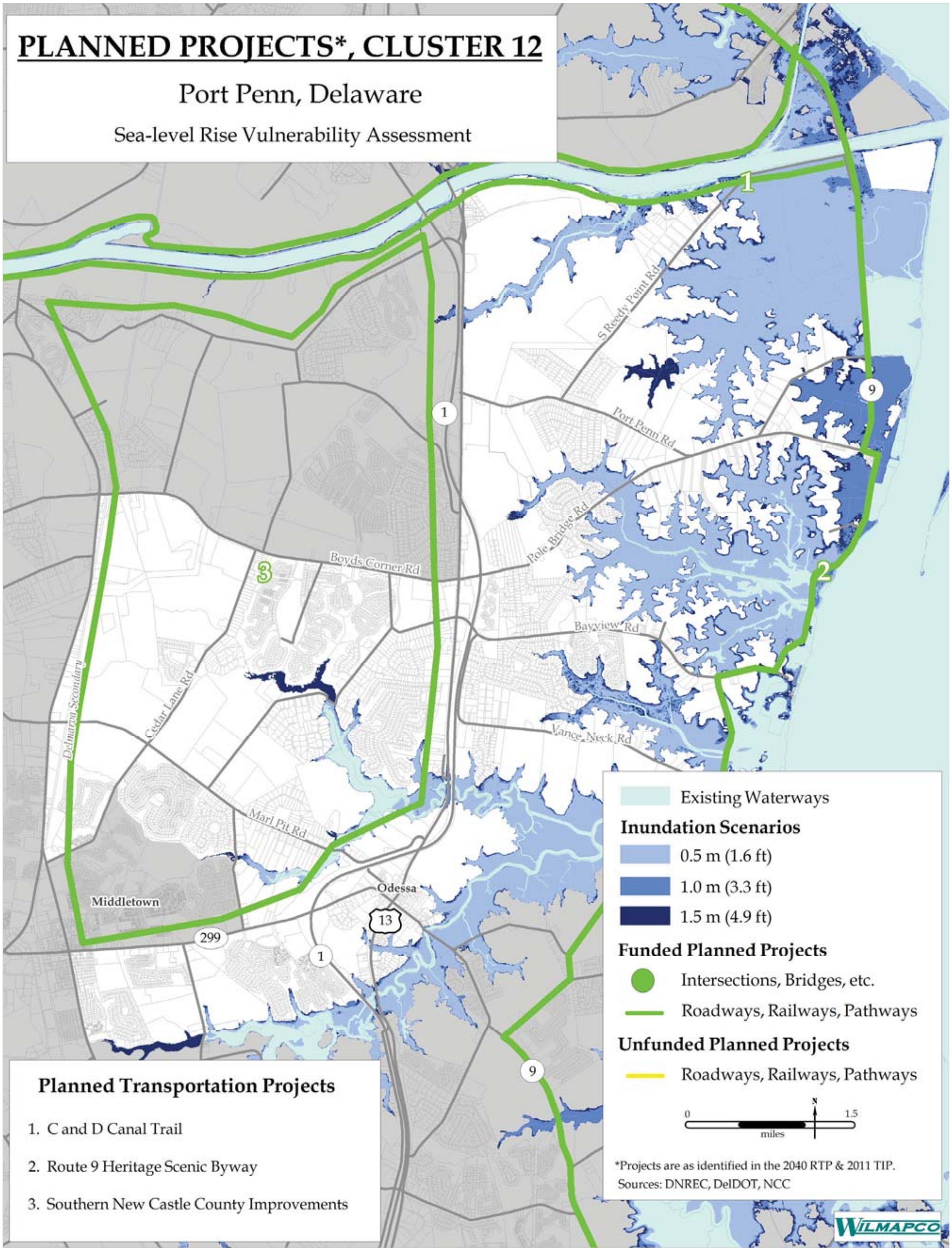
Map 49: C12 Base



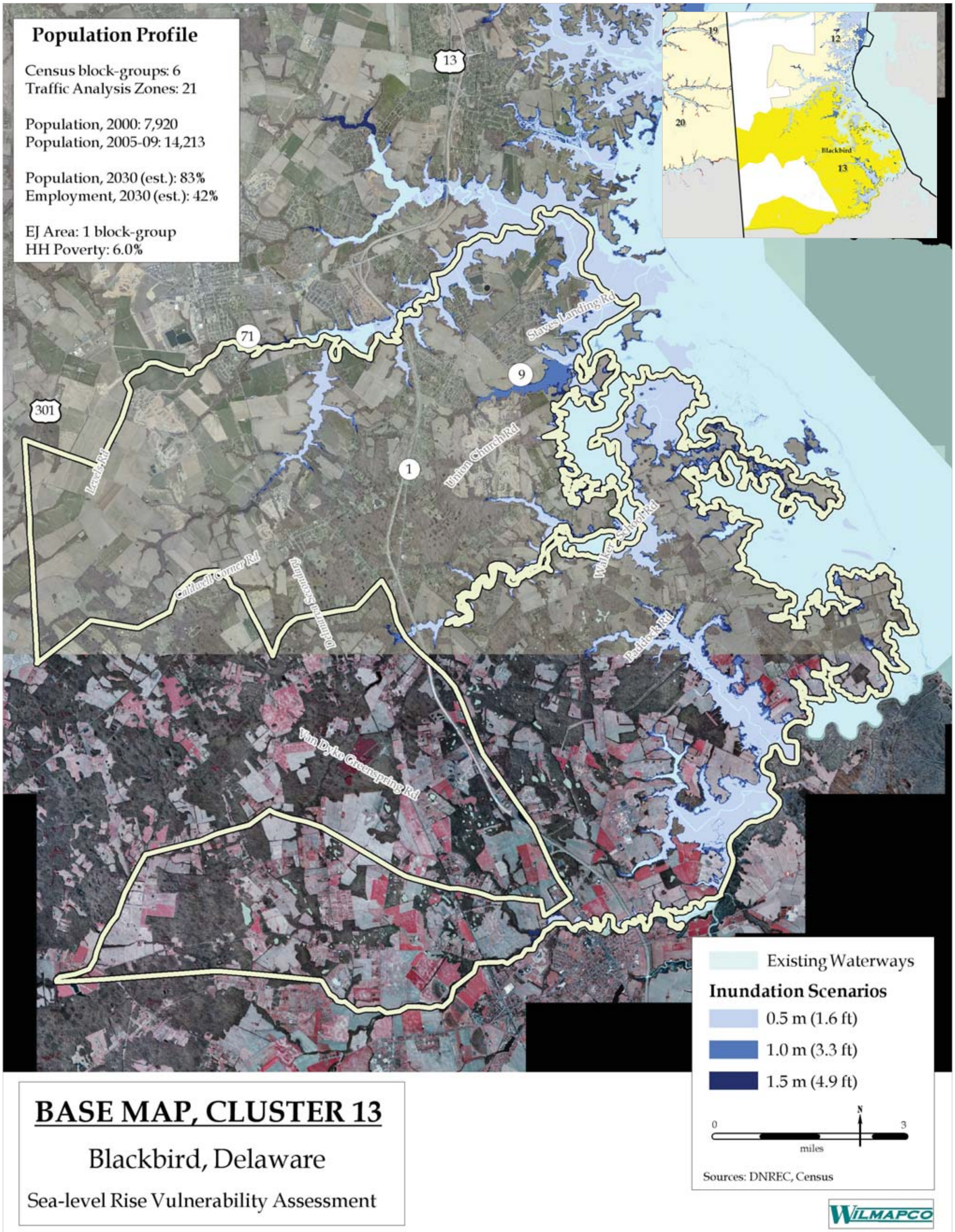
Map 50: C12 Infrastructure



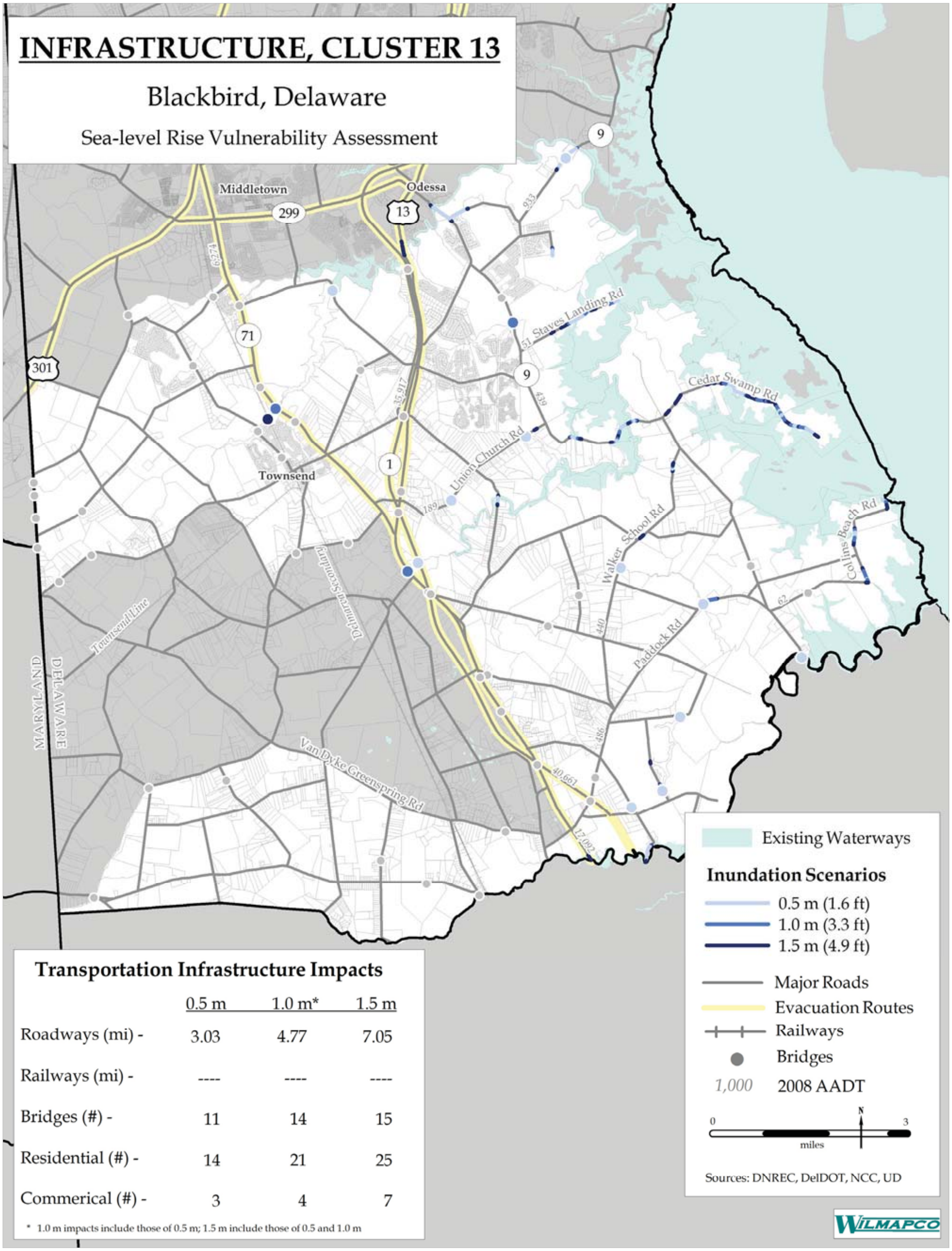
Map 51: C12 Planned Projects



Map 52: C13 Base



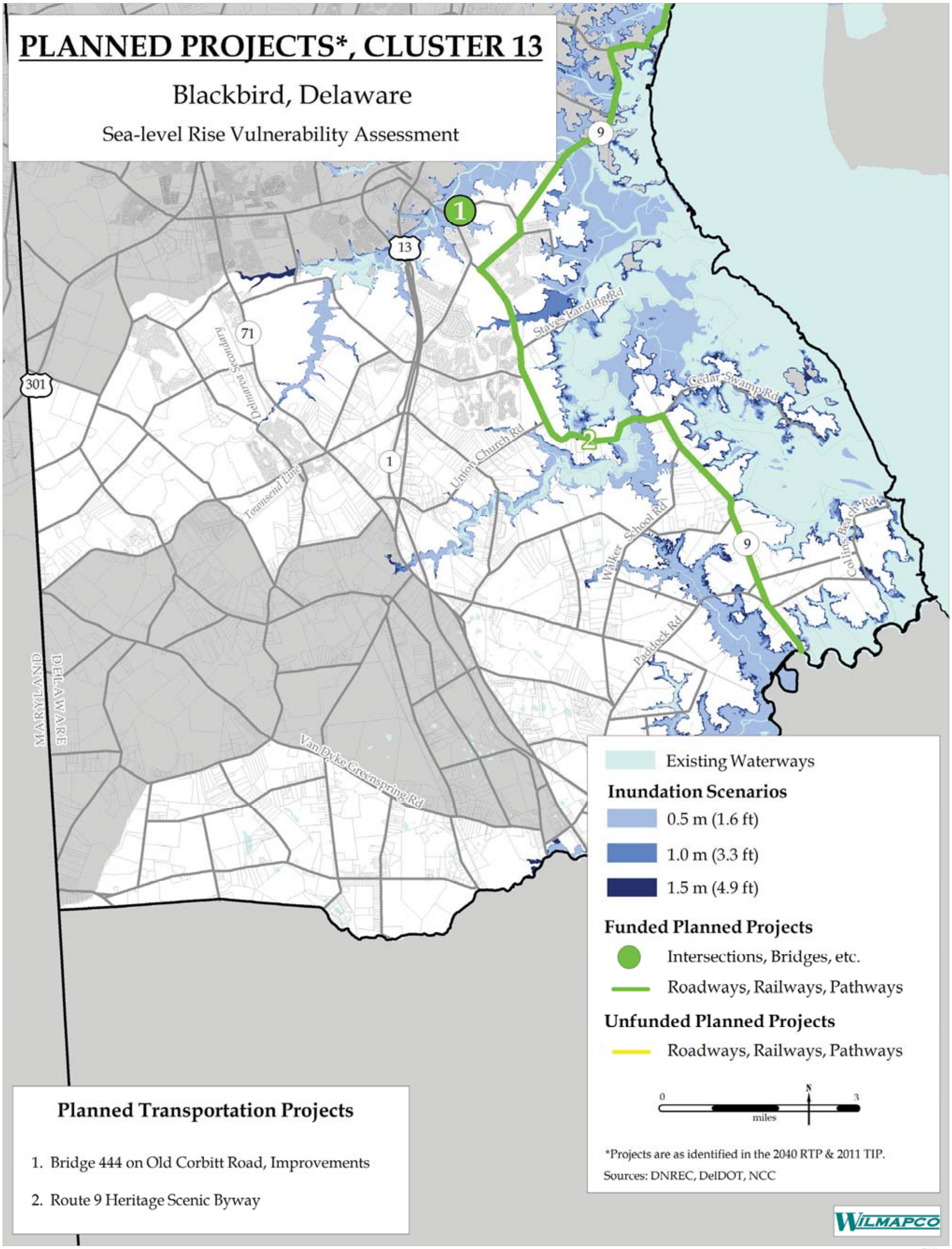
Map 53: C13 Infrastructure



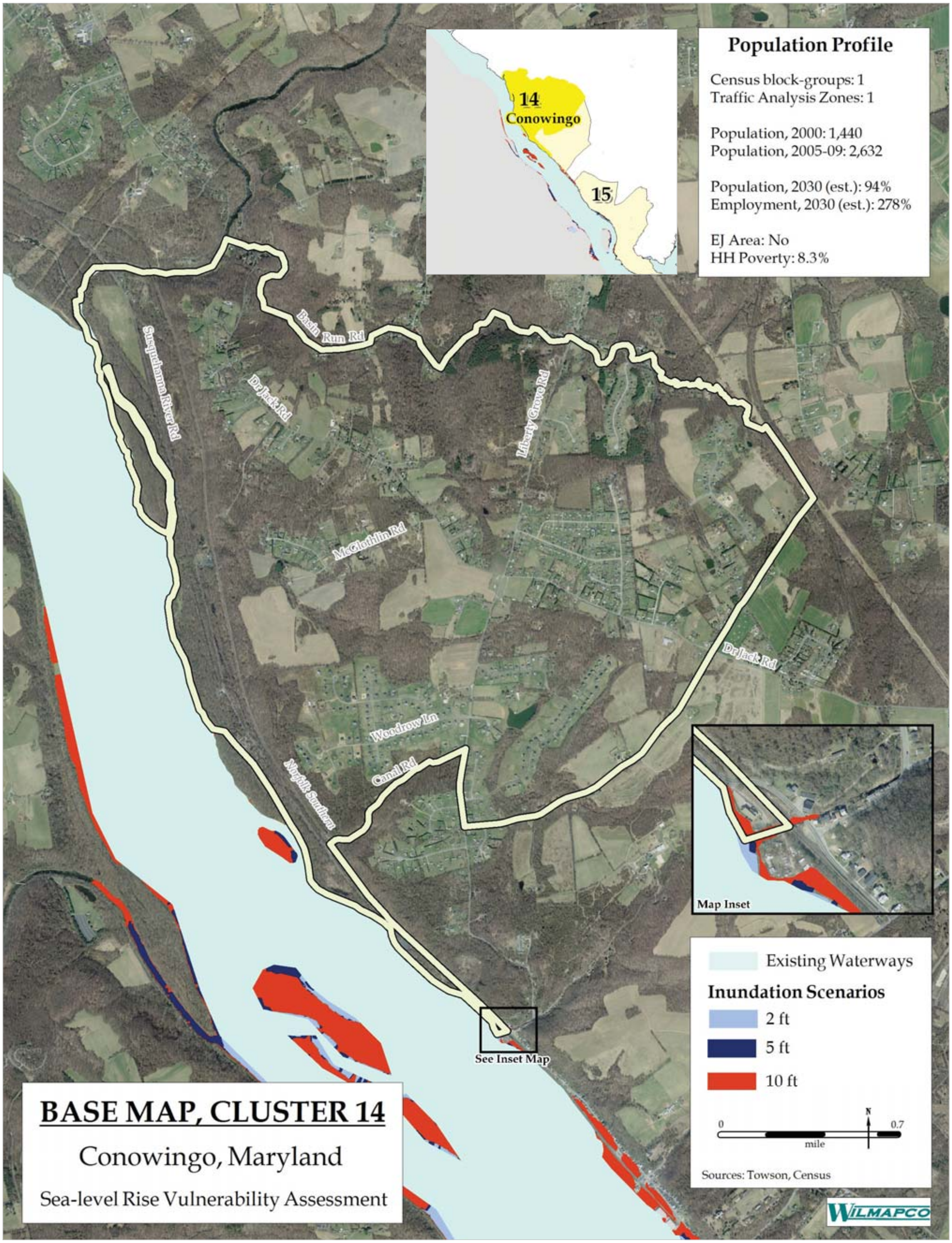
	0.5 m	1.0 m*	1.5 m
Roadways (mi) -	3.03	4.77	7.05
Railways (mi) -	----	----	----
Bridges (#) -	11	14	15
Residential (#) -	14	21	25
Commerical (#) -	3	4	7

* 1.0 m impacts include those of 0.5 m; 1.5 m include those of 0.5 and 1.0 m

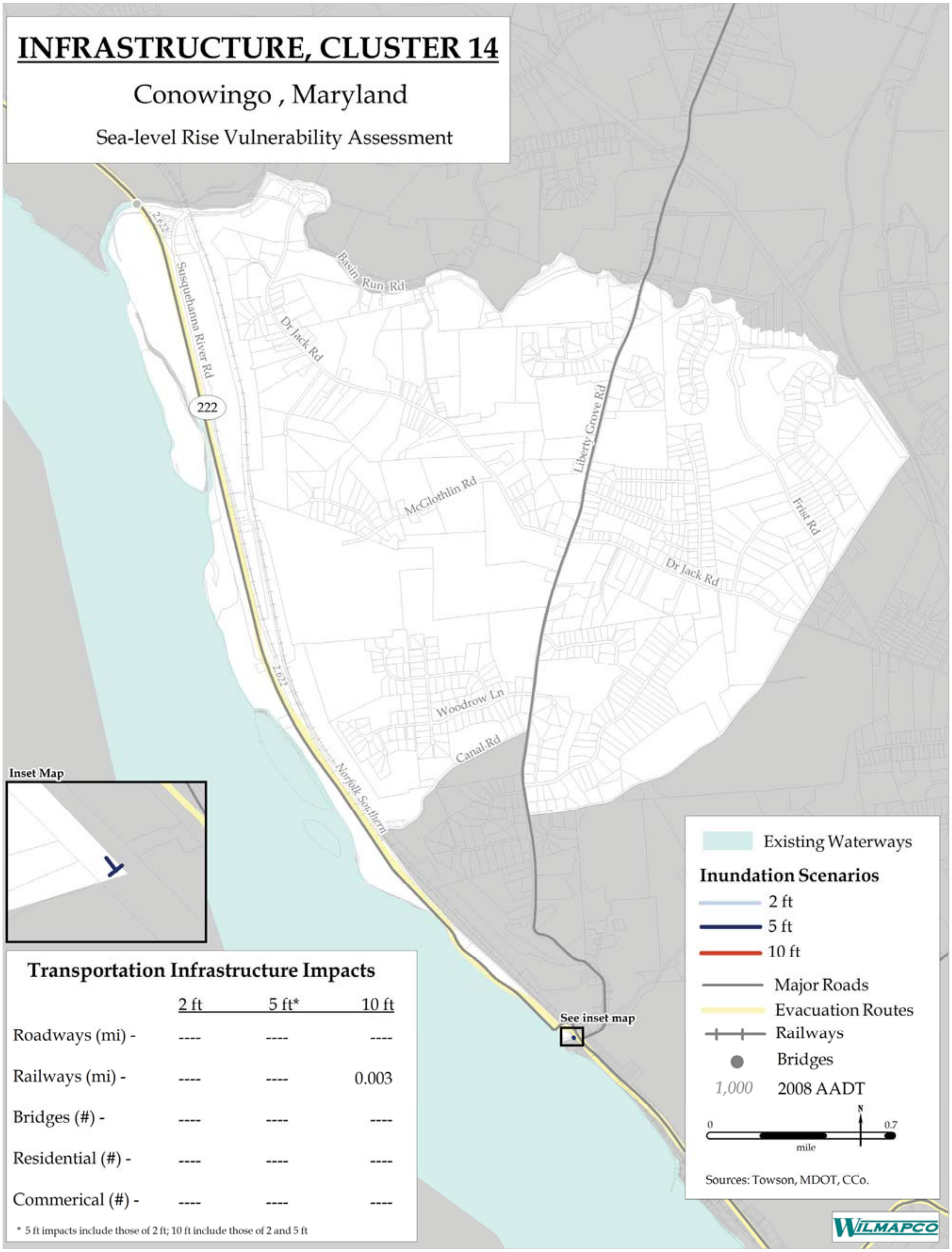
Map 54: C13 Planned Projects



Map 55: C14 Base



Map 56: C14 Infrastructure

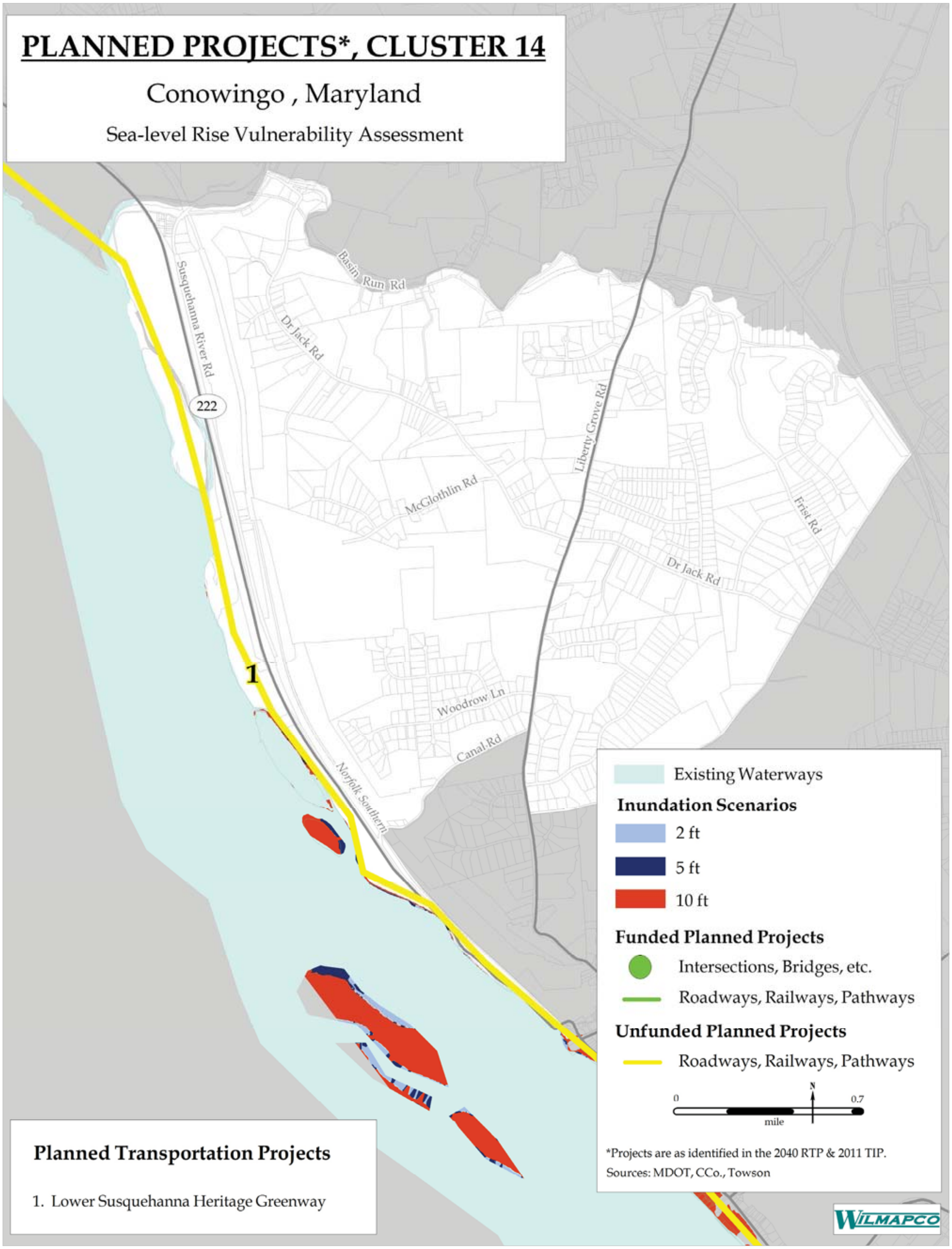


Transportation Infrastructure Impacts

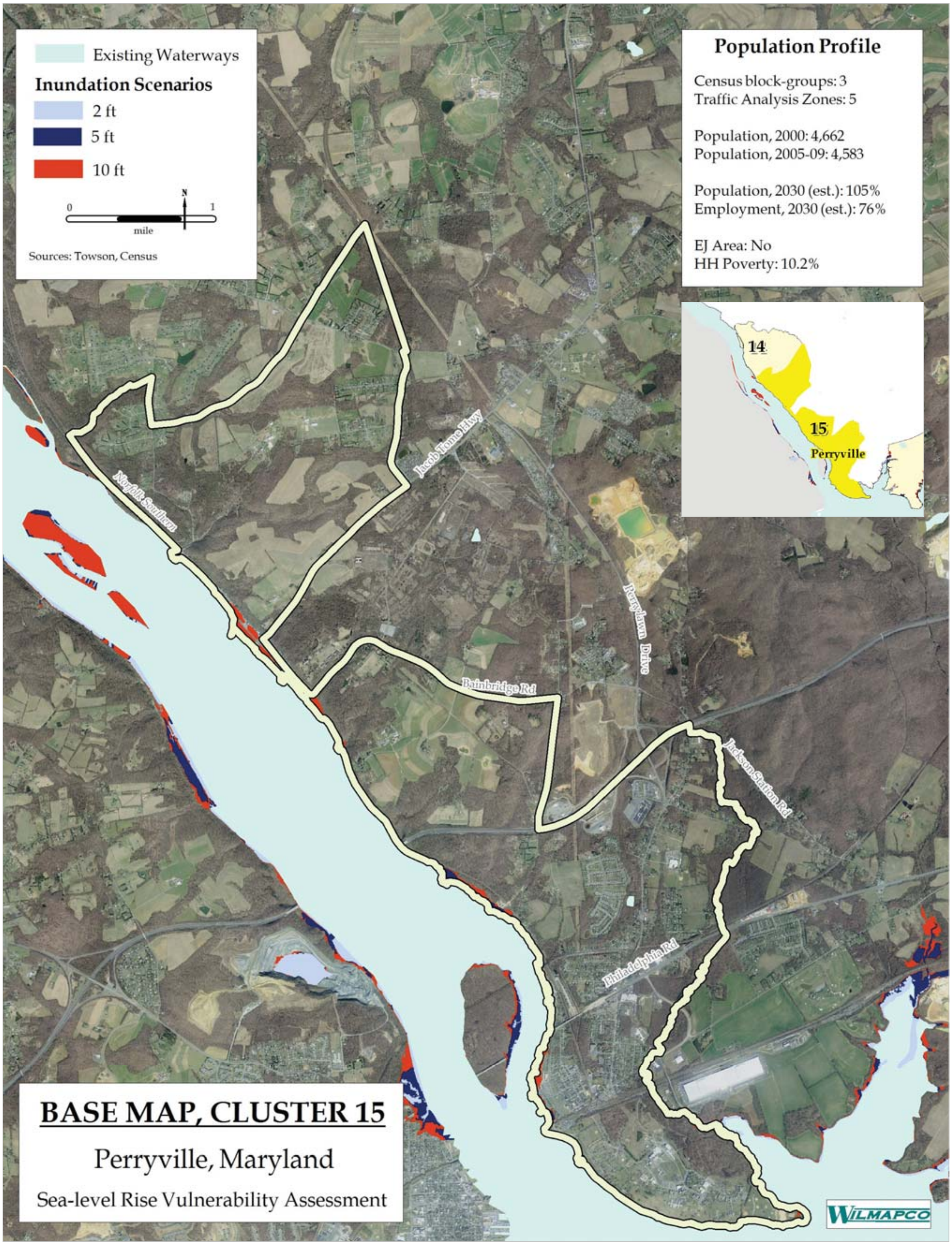
	2 ft	5 ft*	10 ft
Roadways (mi) -	----	----	----
Railways (mi) -	----	----	0.003
Bridges (#) -	----	----	----
Residential (#) -	----	----	----
Commerical (#) -	----	----	----

* 5 ft impacts include those of 2 ft; 10 ft include those of 2 and 5 ft

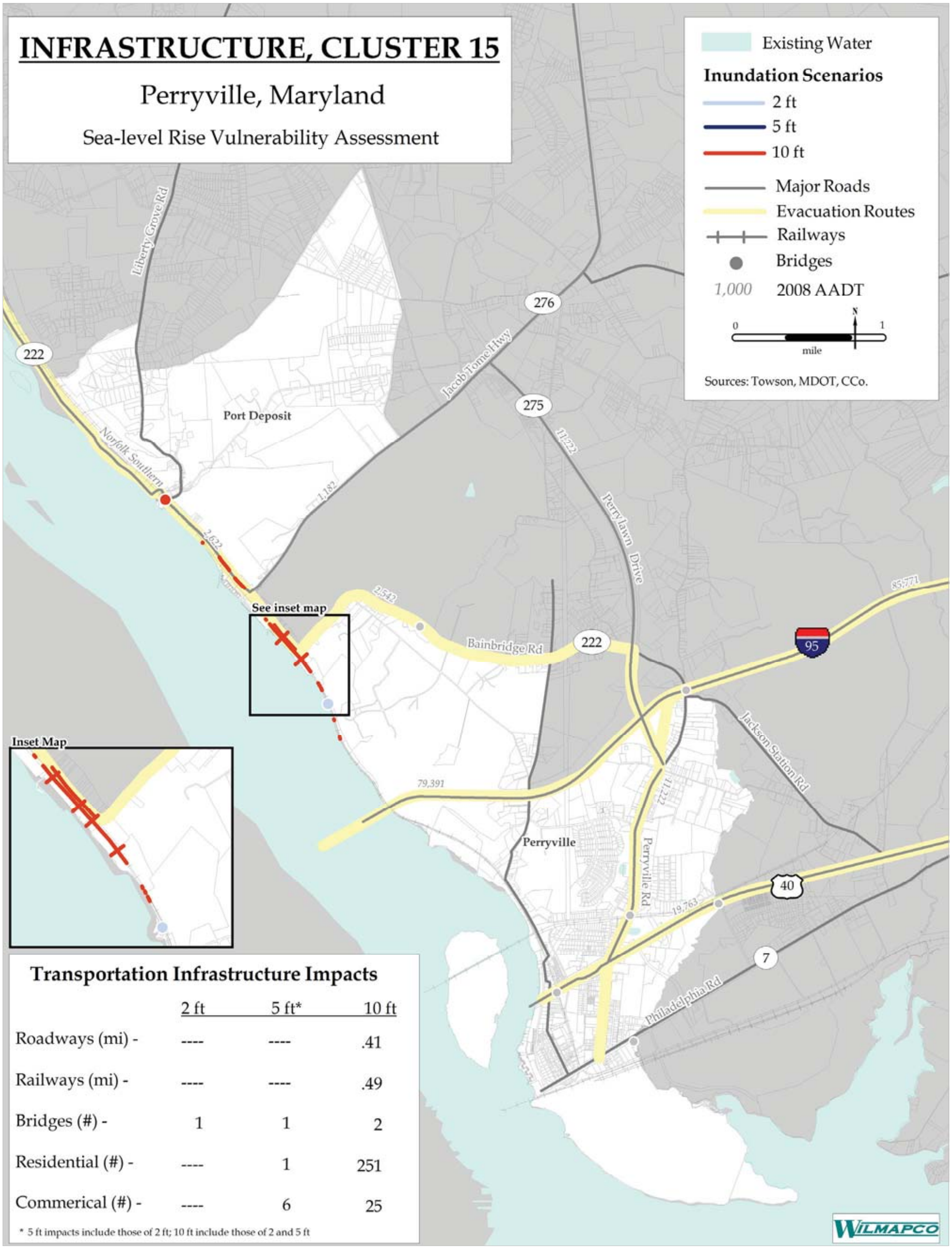
Map 57: C14 Planned Projects



Map 58: C15 Base



Map 59: C15 Infrastructure

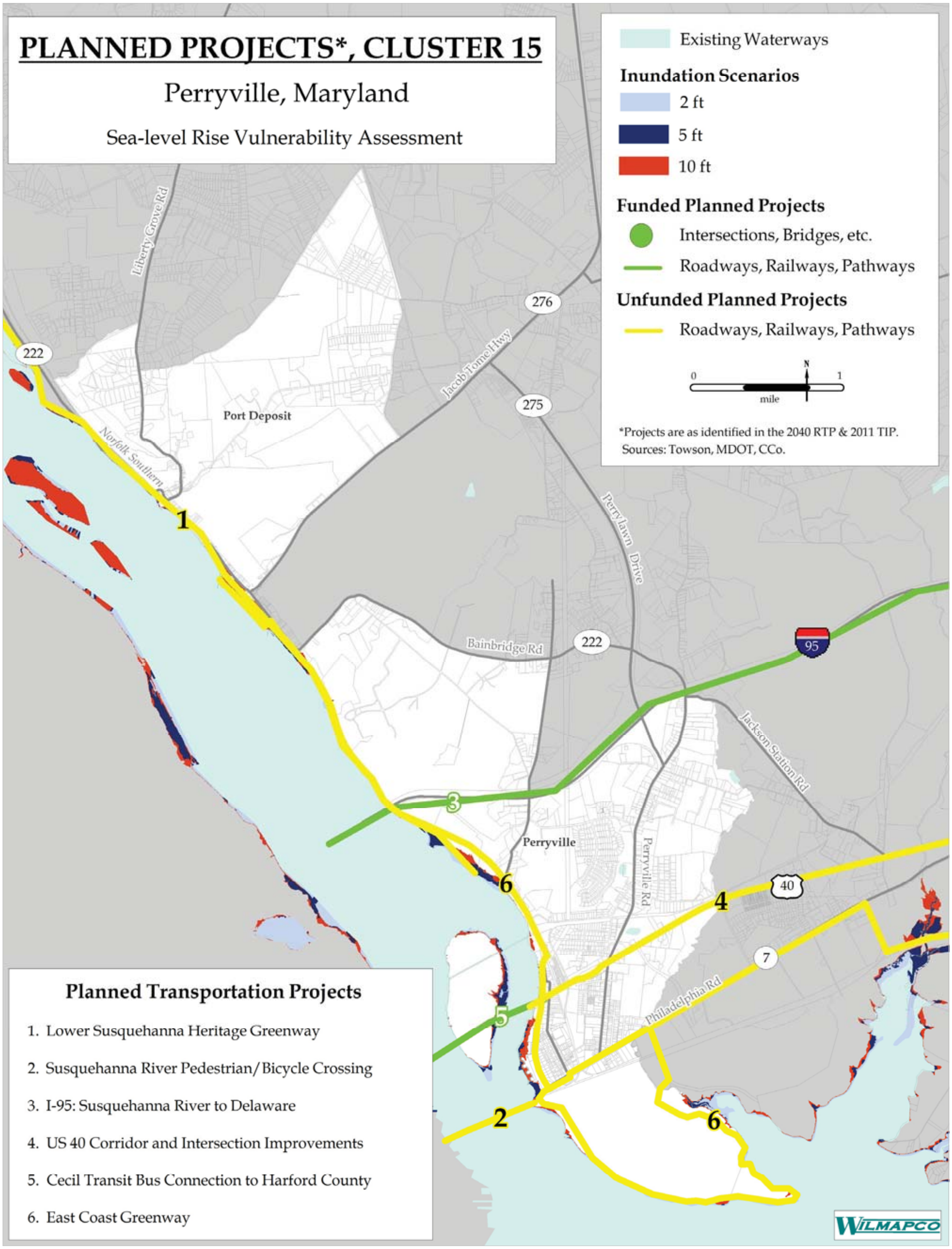


Transportation Infrastructure Impacts

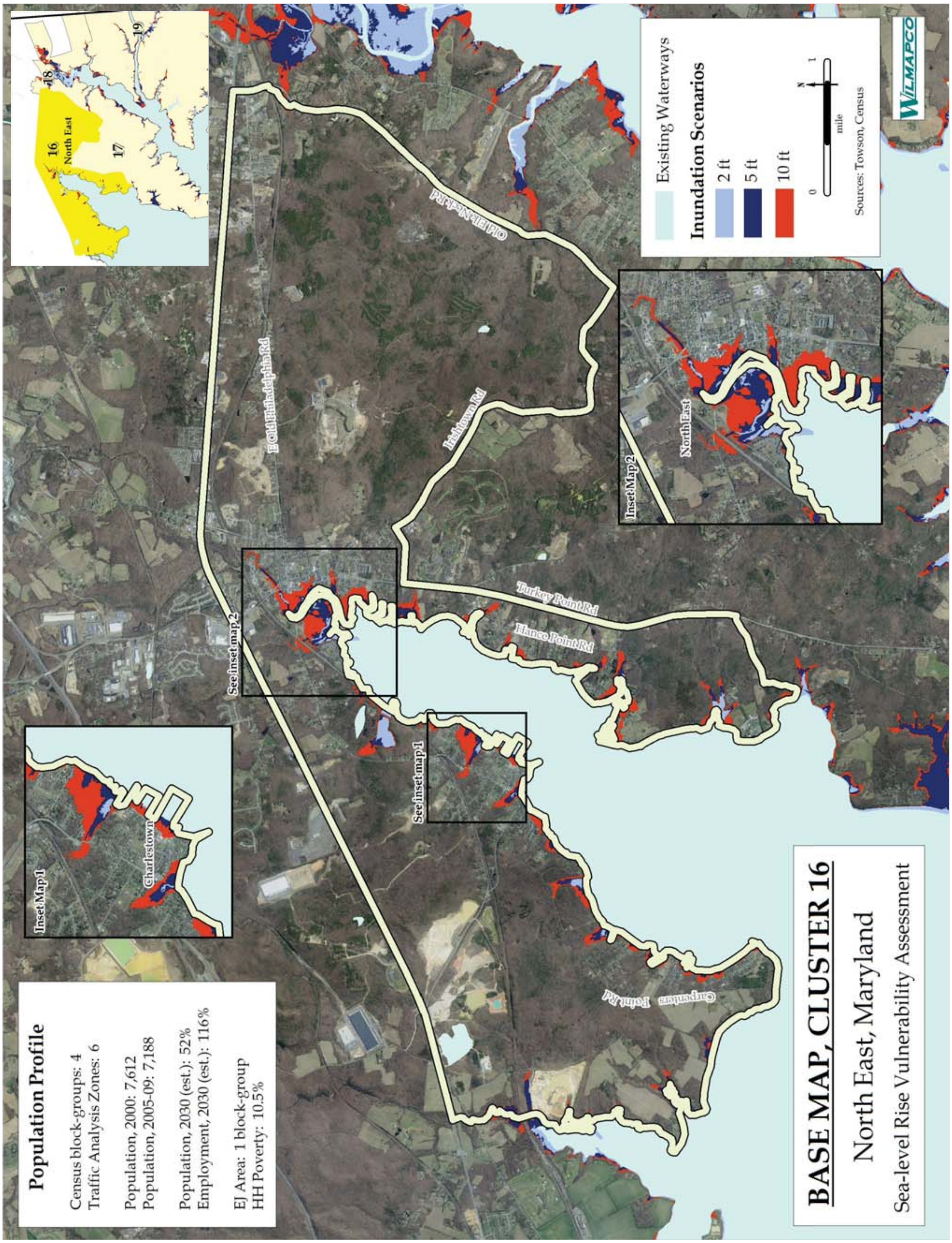
	2 ft	5 ft*	10 ft
Roadways (mi) -	----	----	.41
Railways (mi) -	----	----	.49
Bridges (#) -	1	1	2
Residential (#) -	----	1	251
Commerical (#) -	----	6	25

* 5 ft impacts include those of 2 ft; 10 ft include those of 2 and 5 ft

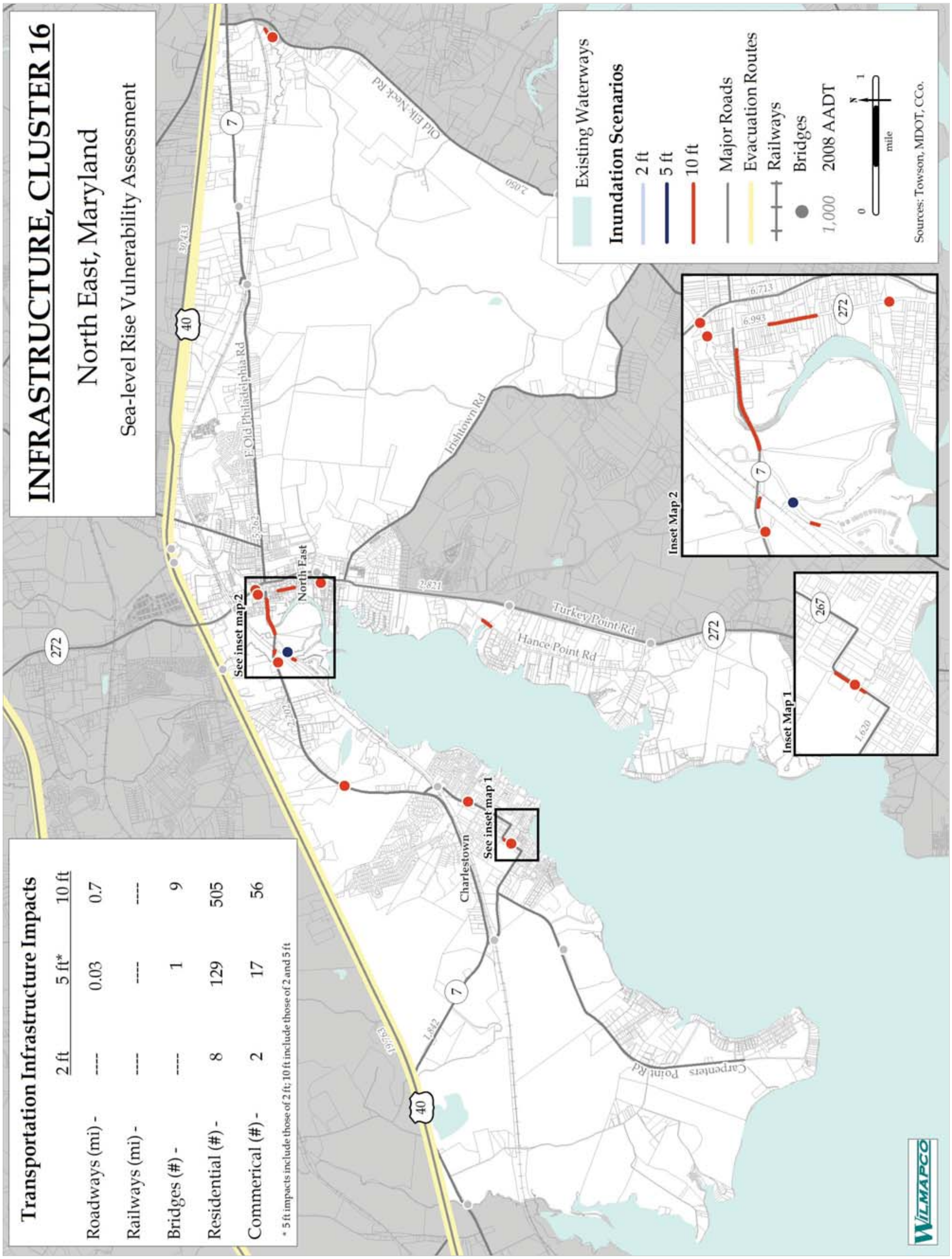
Map 60: C15 Planned Projects



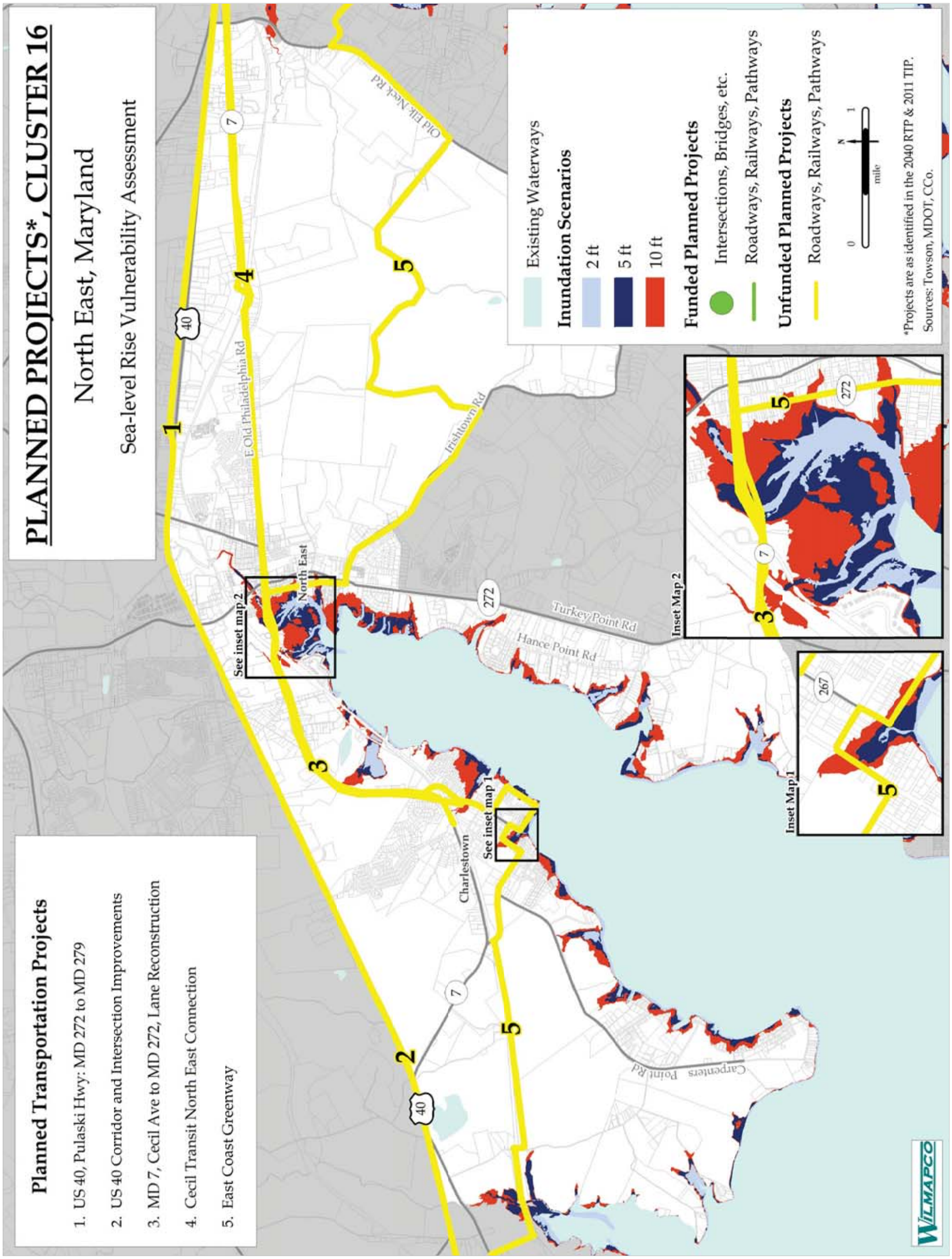
Map 61: C16 Base



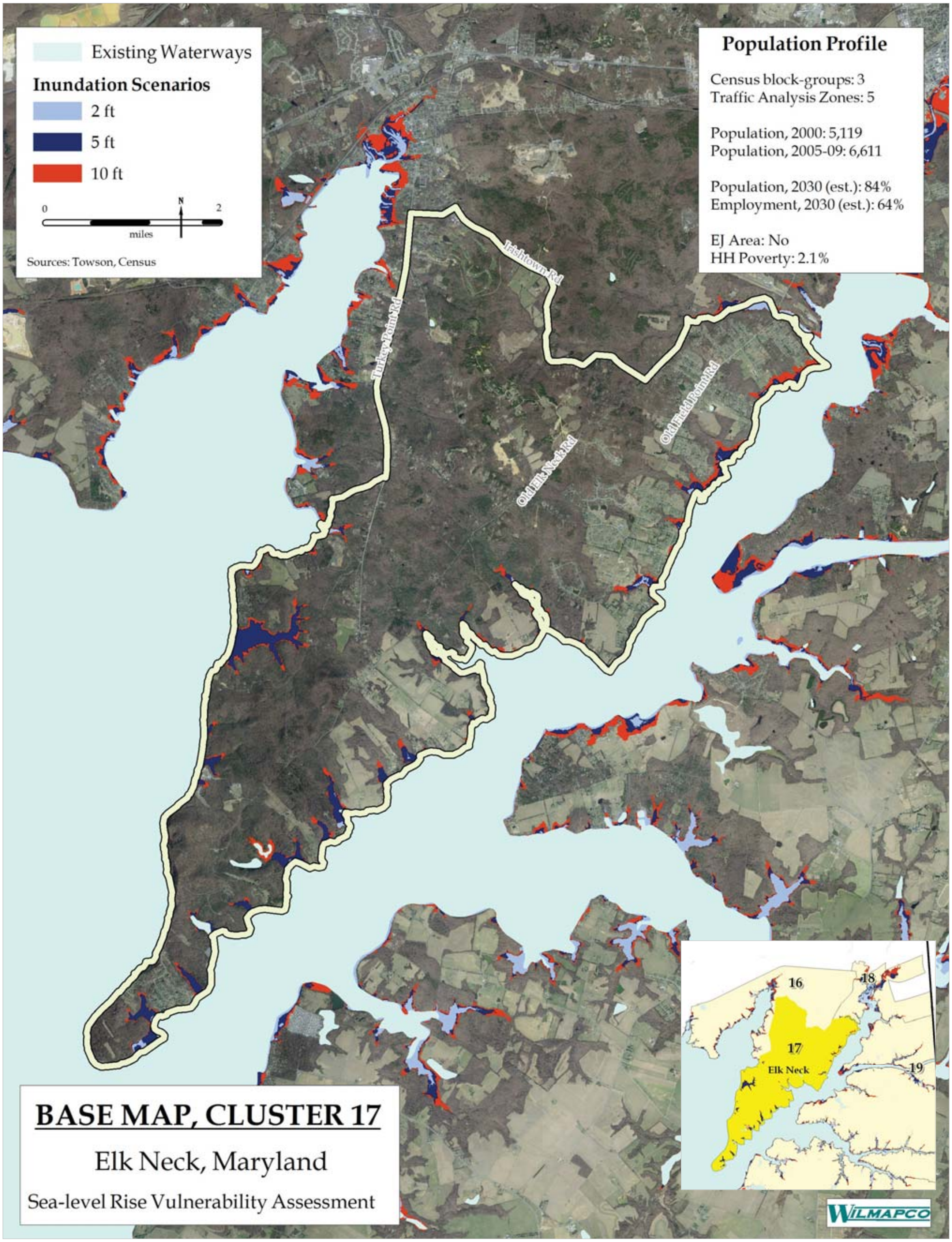
Map 62: C16 Infrastructure



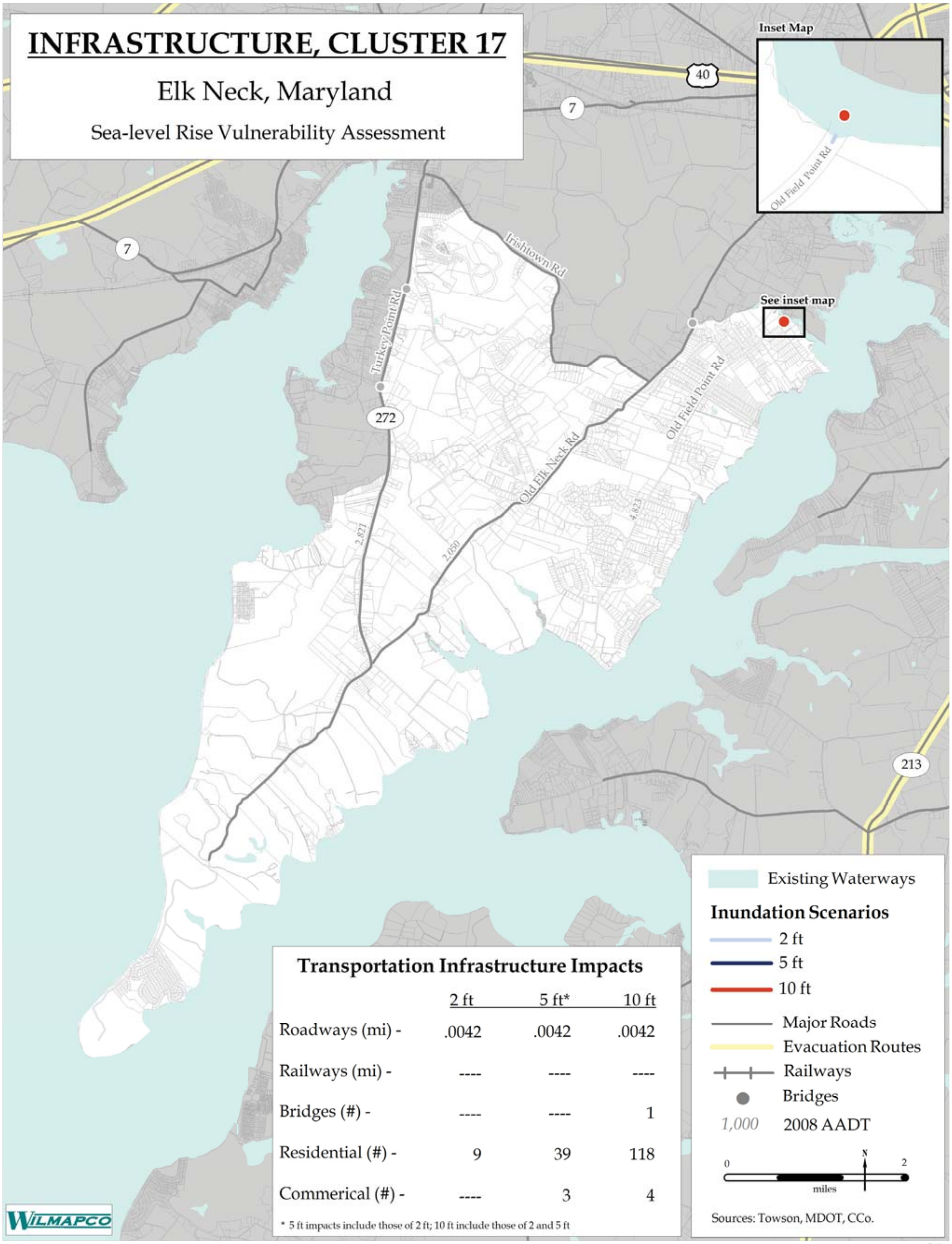
Map 63: C16 Planned Projects



Map 64: C17 Base



Map 65: C17 Infrastructure

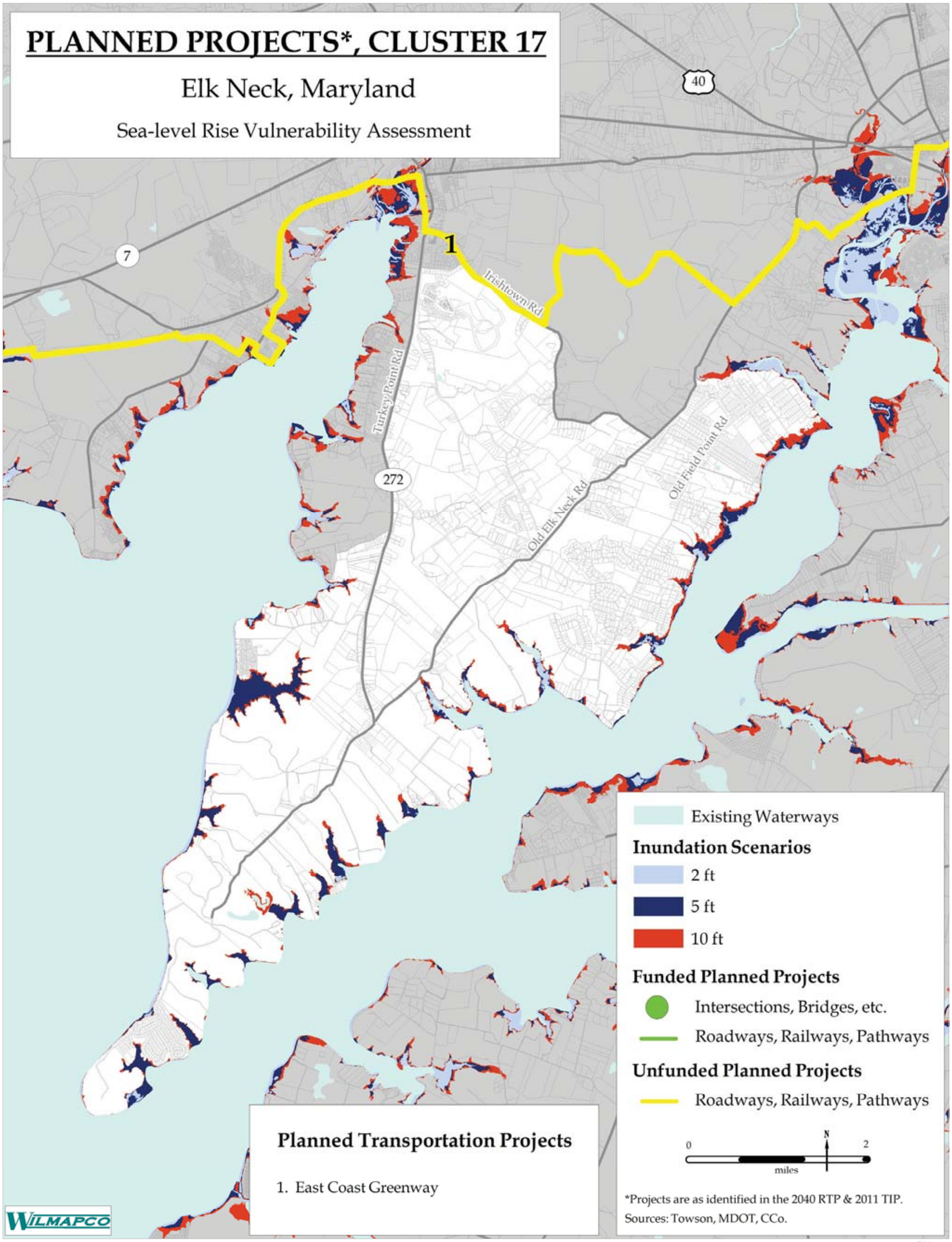


Transportation Infrastructure Impacts

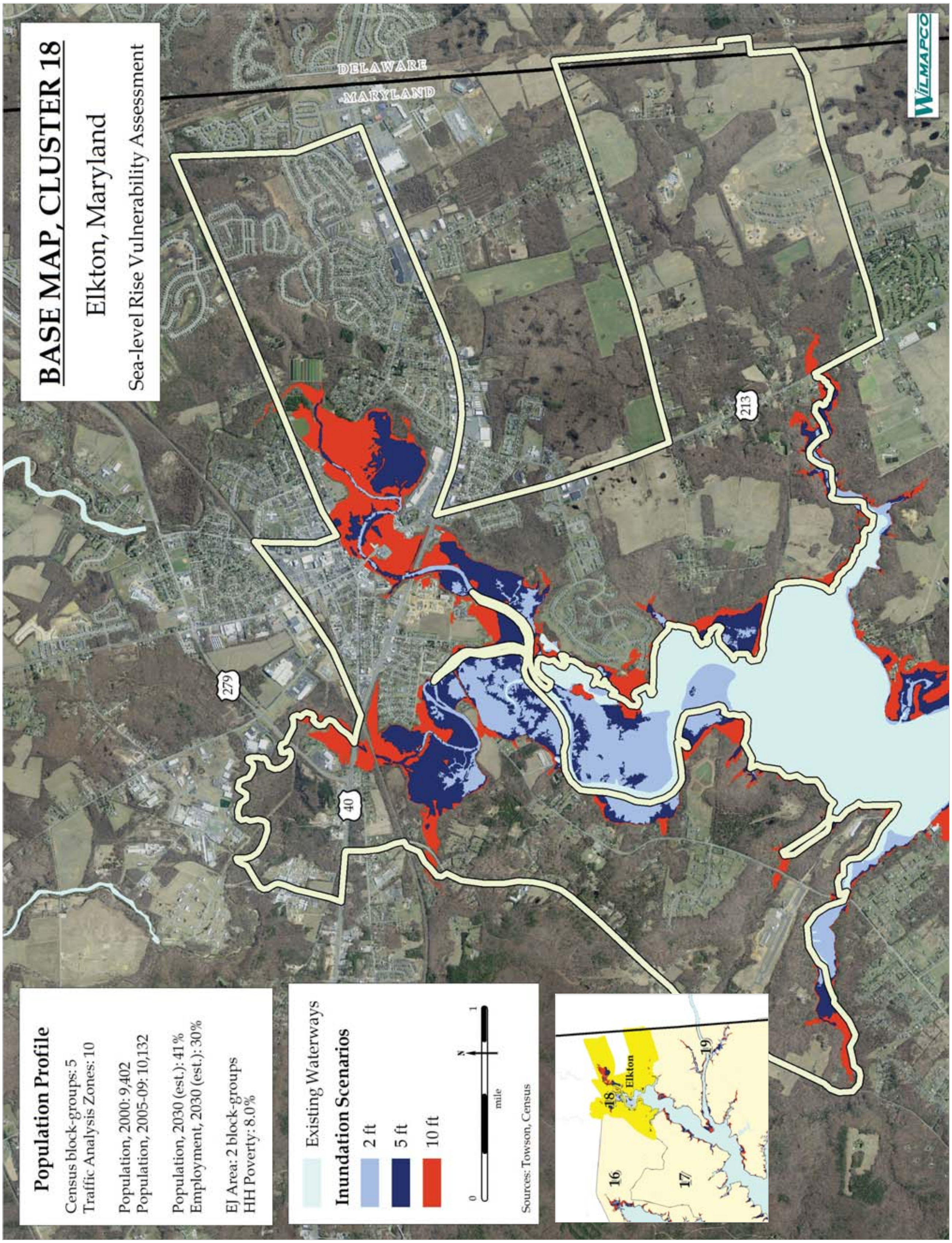
	2 ft	5 ft*	10 ft
Roadways (mi) -	.0042	.0042	.0042
Railways (mi) -	----	----	----
Bridges (#) -	----	----	1
Residential (#) -	9	39	118
Commerical (#) -	----	3	4

* 5 ft impacts include those of 2 ft; 10 ft include those of 2 and 5 ft

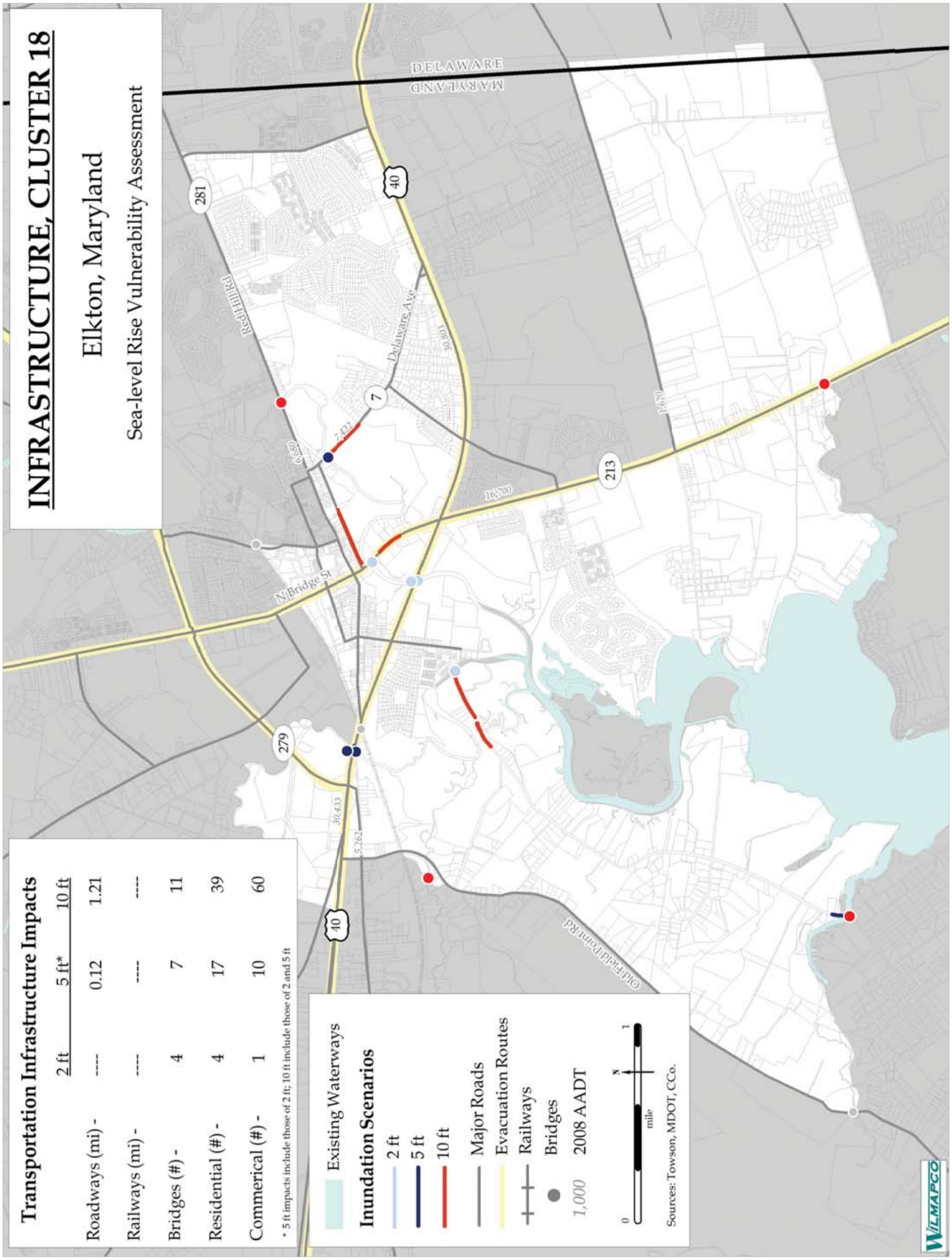
Map 66: C17 Planned Projects



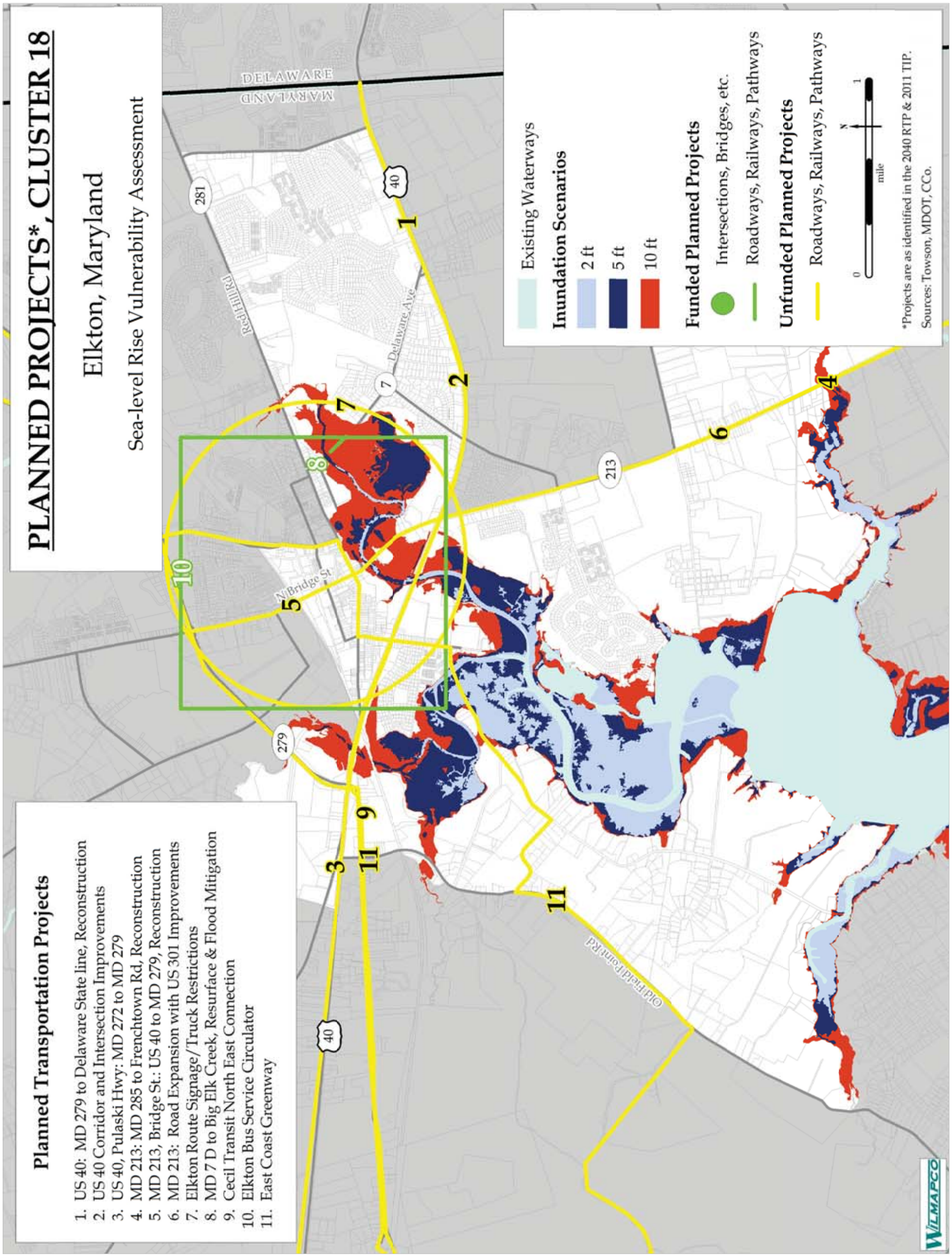
Map 67: C18 Base



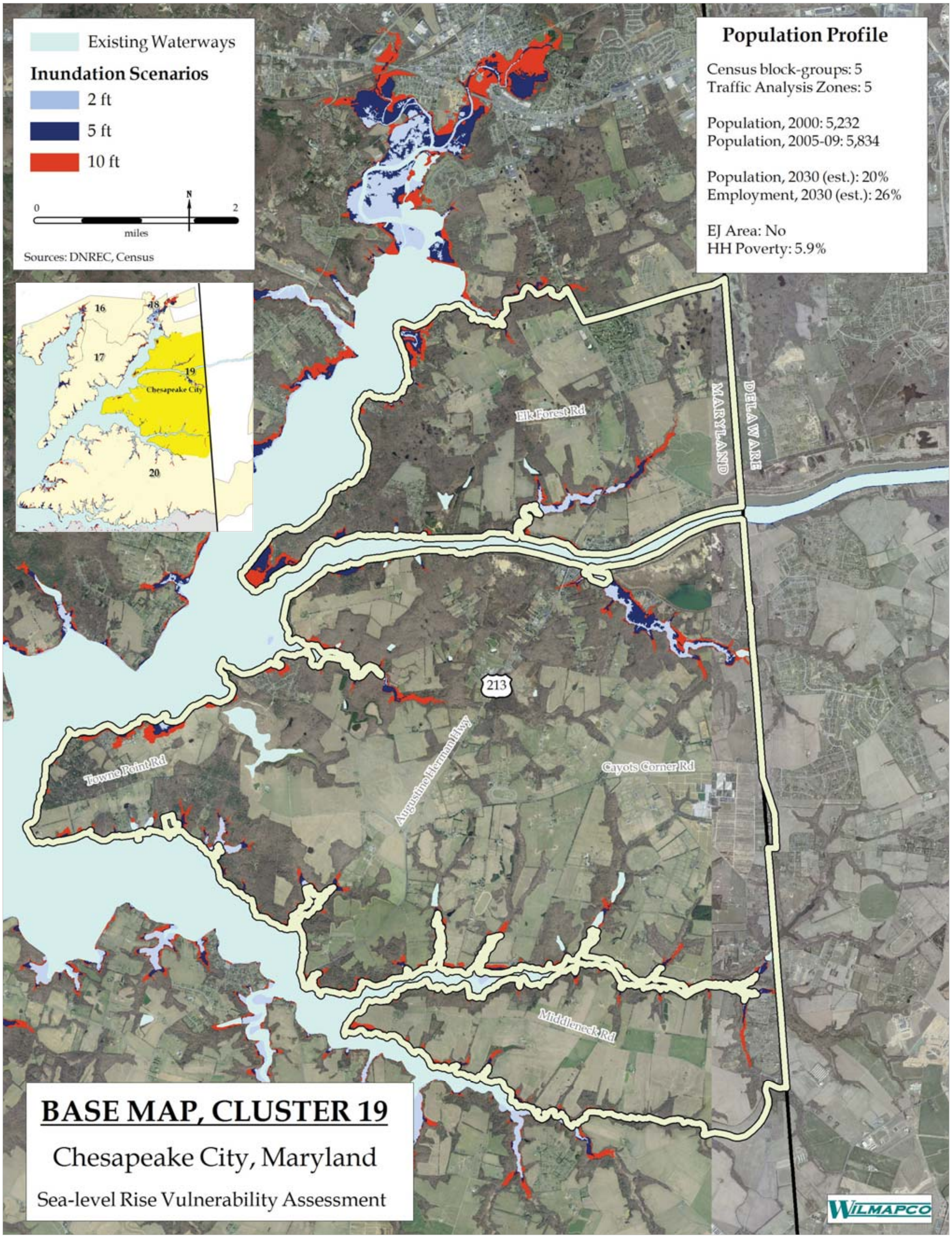
Map 68: C18 Infrastructure



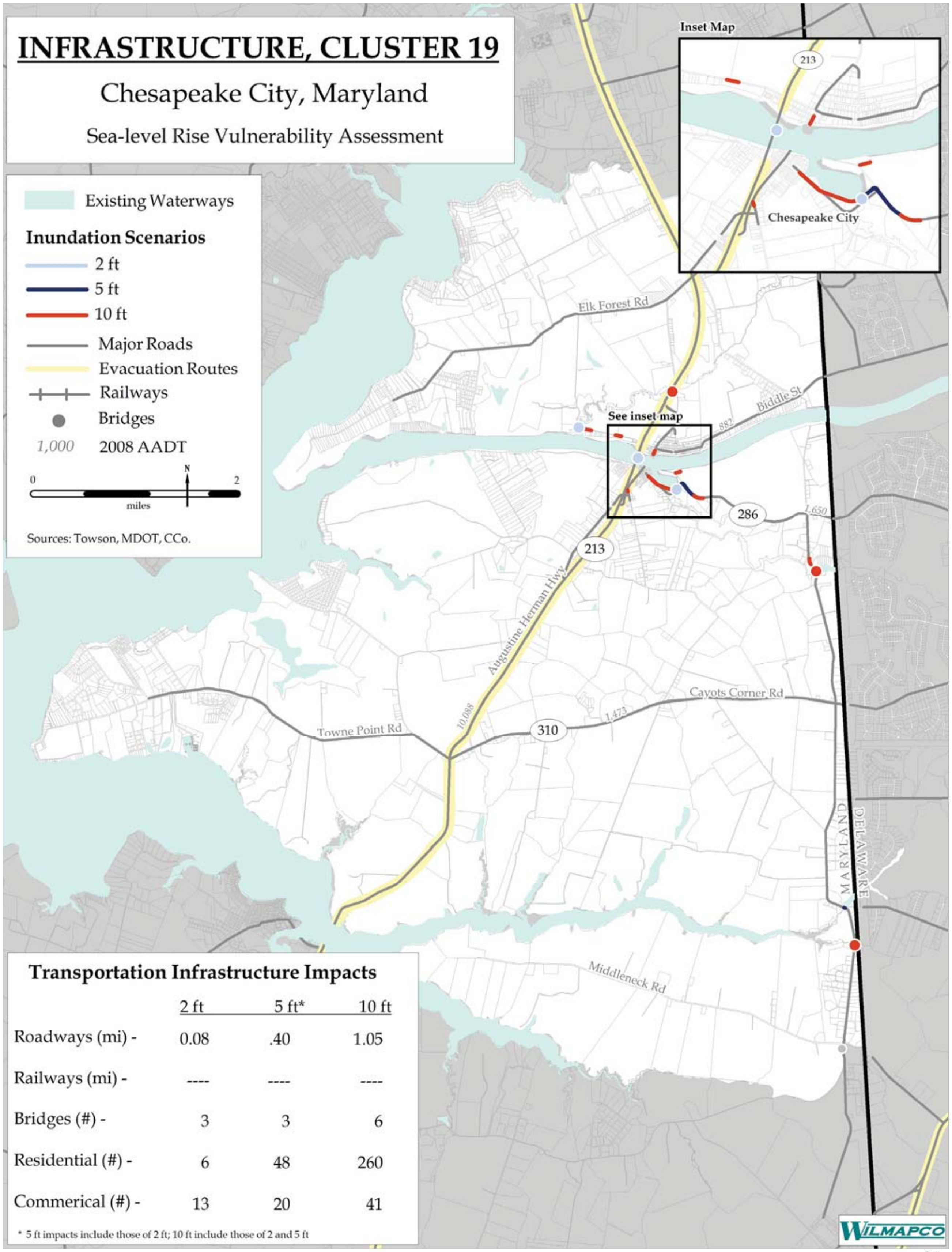
Map 69: C18 Planned Projects



Map 70: C19 Base



Map 71: C19 Infrastructure

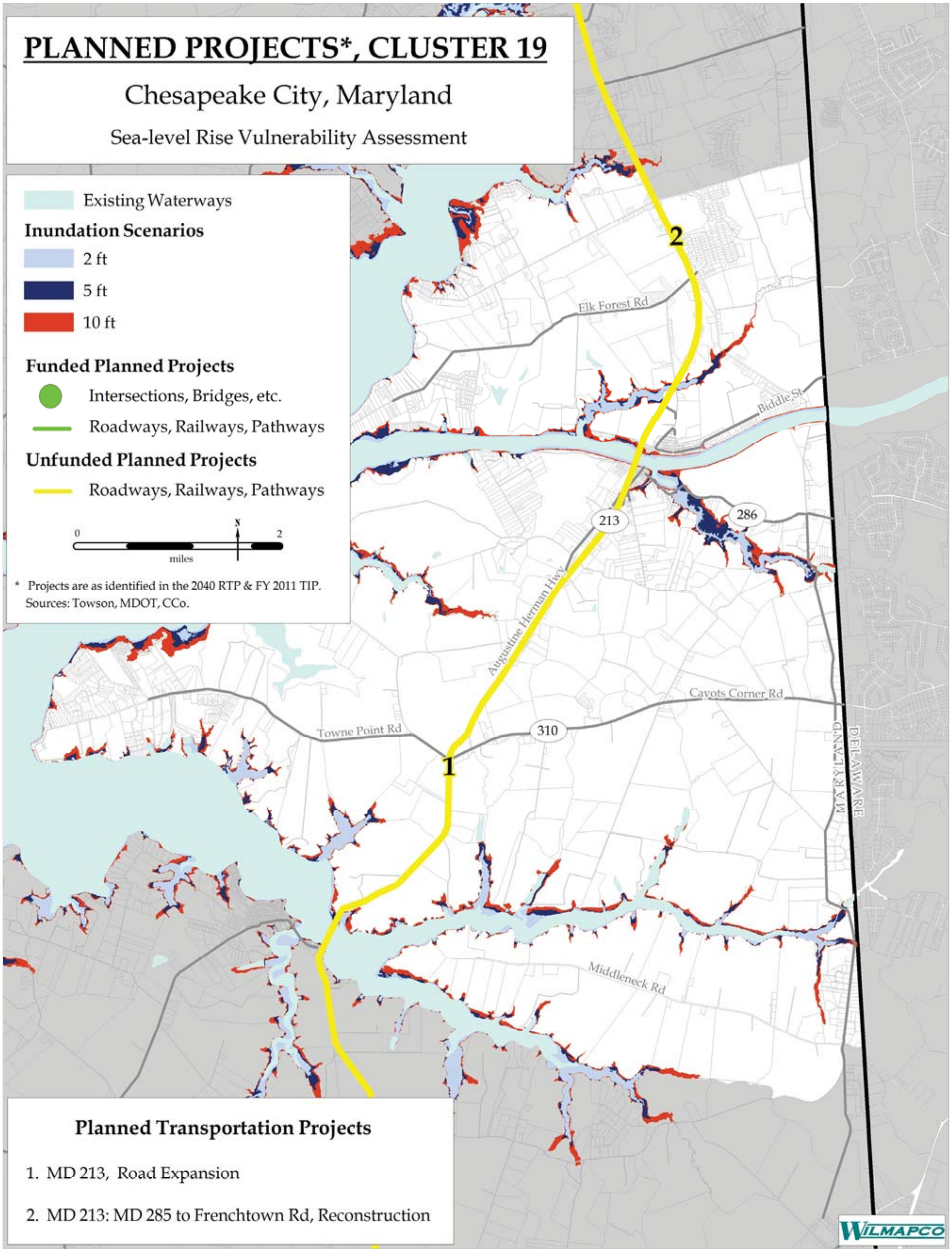


Transportation Infrastructure Impacts

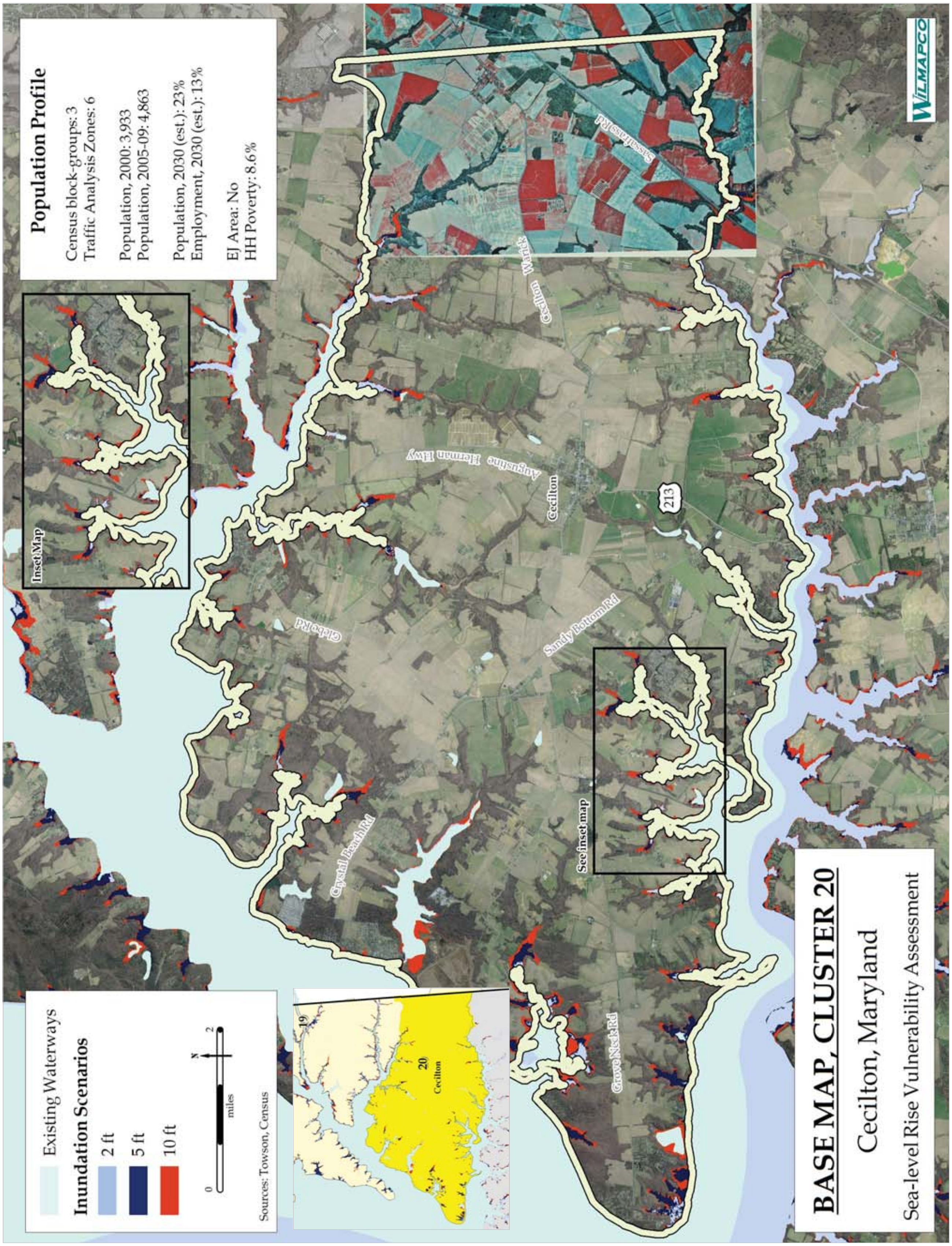
	2 ft	5 ft*	10 ft
Roadways (mi) -	0.08	.40	1.05
Railways (mi) -	----	----	----
Bridges (#) -	3	3	6
Residential (#) -	6	48	260
Commerical (#) -	13	20	41

* 5 ft impacts include those of 2 ft; 10 ft include those of 2 and 5 ft

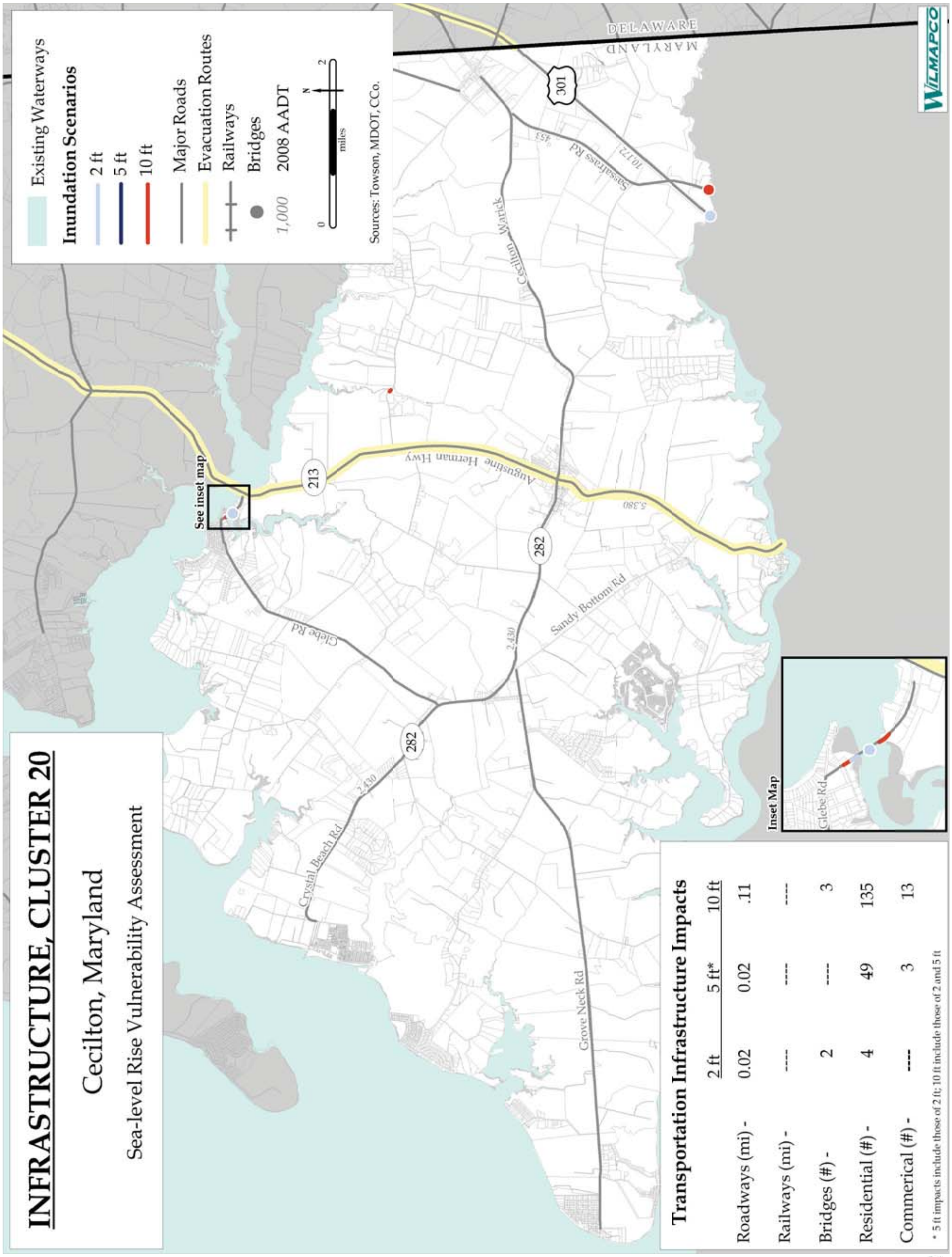
Map 72: C19 Planned Projects



Map 73: C20 Base



Map 74: C20 Infrastructure

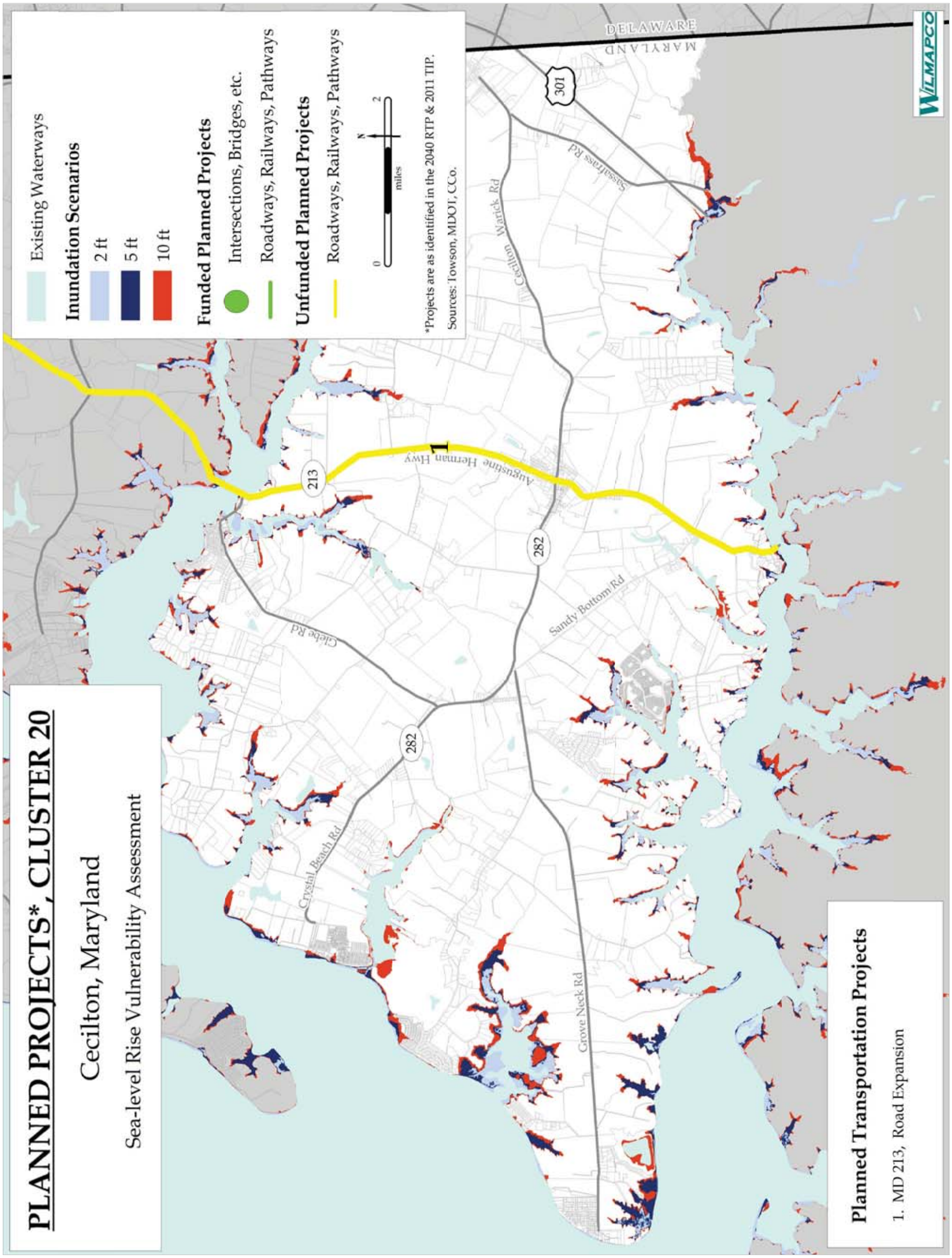


Transportation Infrastructure Impacts

	2 ft	5 ft*	10 ft
Roadways (mi) -	0.02	0.02	.11
Railways (mi) -	----	----	----
Bridges (#) -	2	----	3
Residential (#) -	4	49	135
Commerical (#) -	----	3	13

* 5 ft impacts include those of 2 ft; 10 ft include those of 2 and 5 ft

Map 75: C20 Planned Projects



Chapter 5

Policy Recommendations

Comprehensive transportation policy to address climate change has been slow to develop in the United States. Ongoing public controversy, the lack of scientific certainty, the recent recession and other factors have contributed to this inaction. The absence of a national transportation policy framework regarding climate change has left the policymaking up to states and local jurisdictions, with varying results.

This chapter reviews recommendations to changes in WILMAPCO policy as a consequence of this study. These recommendations are: (1) incorporate climate change policy into the next Regional Transportation Plan (RTP), (2) continually monitor SLR impacts to planned projects, (3) enhance climate change public outreach, and (4) support ongoing climate change adaptation and mitigation efforts. As with any effective policy, performance measures must be identified or developed to measure effectiveness.

Incorporate Climate Change Policy into the Regional Transportation Plan

We should more formally incorporate climate change *adaptation* and *mitigation* policy into our planning process. As noted in the background chapter, adaptation strategies relate to adjustments in the transportation system in response to global warming, such as raising a roadway due to SLR. Mitigation strategies are steps we can take to cut greenhouse gas emissions which result in warming.

The present study represents an important "first step" in planning for climate change adaptation, and we have begun climate change mitigation efforts (more so indirectly than not) during the past few years. Formalizing these mitigation efforts through specific policy objectives—such as a vehicle miles traveled target, support of alternative fuels and technology, and improving the efficiency of freight movement—can be accomplished during the next overhaul of the RTP. Setting these objectives would allow for the deployment of greater staff resources to tackle climate change.

Dave Carter, DNREC, shares an opinion with the SLR Steering Committee.

Our effectiveness of incorporating climate change strategies as a region can be quantitatively measured via the Climate Change Adaptation Tool for Transportation (CCATT): Mid-Atlantic, developed by Michelle Oswald, a doctoral candidate at the University of Delaware. CCATT: Mid-Atlantic is a decision support tool that is repeatable, relevant, user-friendly, and focused on regional impacts including increased temperatures, rising sea-level, and increased precipitation events. The tool includes four main components of transportation adaptation:

- Evaluation of scenarios, adaptive capacity, and impact assessment
- Inventory of existing at-risk infrastructure
- Assessment of proposed at-risk infrastructure
- Evaluation of existing mitigation practices to identify supporting adaptation efforts

WILMAPCO served as a case study application of CCATT: Mid-Atlantic to public transportation planning agencies. In order to apply the tool, data was collected, vulnerable facilities were identified, and future adaptation efforts were, and continue to be, explored. This application provides one measurable method for exploring adaptation efforts and integrating climate change policy into the RTP.

Continually Monitor Sea-Level Rise Impacts to Planned Projects

The coming decades will provide Maryland and Delaware ample time to prepare for SLR. Given the expected lifespan for roadways, railways and bridges, transportation officials should have more than one reconstruction cycle to adjust a given facility to accommodate a rise in sea-level, if the facility is to be preserved. Beyond informing continued investment decisions in given parts of the region, this study provides the basis to identify at-risk planned projects on a rolling basis.

At-risk projects should be flagged (following our methodology found in the Regional Impacts chapter) using the most accurate inundation scenario data annually in the Transportation Improvement Program, or bi-annually in the Regional Progress Report.

The present study should be updated in 2016, unless no improved inundation data are available at that time.

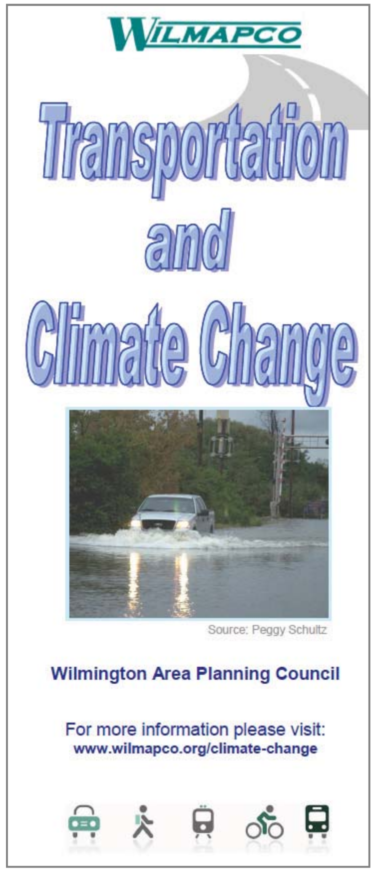
Enhance Climate Change Public Outreach

In step with its incorporation into our RTP, climate change should also figure into our public outreach campaign. Recent studies have shown public awareness of climate change lacking. If we are to take progressive steps towards mitigating and adapting our transportation network to global warming, public acceptance (and indeed pressure to do so) is necessary.

We began the process of raising public awareness of climate change and its associated transportation impacts in late 2010. A pamphlet "Transportation and Climate Change" was developed, to provide a general overview of the linkages between climate change and our transportation system. Further, we created a webpage (www.wilmapco.org/climate-change) which explores these linkages in more depth, while providing our region's latest climate change and transportation news.

The pamphlet also details behavioral adjustments (such as consuming and driving less) that will help reduce global warming.

Working with our Public Advisory Committee, additional steps to enhance climate change outreach, to both the general public and decision-makers, should be identified in 2011 and beyond.



The front cover of our Transportation and Climate Change pamphlet.

Support Ongoing Climate Change Mitigation and Adaptation Planning Efforts

Coordinated adaptation planning is required to address the potential impacts of SLR. It is well beyond the ability of a single agency to tackle the challenges SLR poses to coastal areas. Coordination at all levels of government, along with public and private entities, is necessary to develop response plans. SLR—like traffic congestion and freight movement—is best tackled by linking planning and operations regionally. We must work with operations professionals to better understand SLR impacts to our infrastructure.

As noted in the opening chapter, efforts are underway in both Maryland and Delaware to plan for the broad impacts of climate change. We will become involved, and take an active role in these efforts.

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Appendix

Inundation Disclaimer (from Delaware Coastal Programs)

These inundation maps are a representation of tidal maximum water extents based on local Mean Higher High Water (MHHW). MHHW is calculated for each watershed using the NOAA VDatum software. The watershed reference location for MHHW is at the confluence of the selected watershed's river and the Delaware Bay/River except for the Inland Bays, where the location is the center of the selected bay, the Nanticoke River, where the location is the city of Seaford, and the developed Atlantic Coast, were the location is offshore in the Atlantic Ocean near Indian River Inlet.

These maps represent a constant, watershed based, water level and do not include any changes in water level due to the distance from tidal forcing, downstream flow, or other factors which could possibly change water levels. Any impediments (dikes, dams, etc) to inland flow protect upstream areas until the elevation of the impediment is overcome by either higher water elevation or bypassing the impediment, at which time all land area previously protected is assumed to be inundated up to current water level. Impoundments and other areas protected by dikes where tide gates are installed are assumed to protect the inland areas until the water level exceeds the lowest dike elevation.

The land surface elevations are based on statewide LiDAR data with a statewide average root mean square error (RMSE) of 15 cm (6 inches), however areas of heavy vegetation may have elevation errors exceeding that amount.

The Delaware Coastal Programs makes no warranty and promotes no other use of these maps other than as a preliminary planning tool.