REinvest | CITY REPORT 2015

NORFOLK

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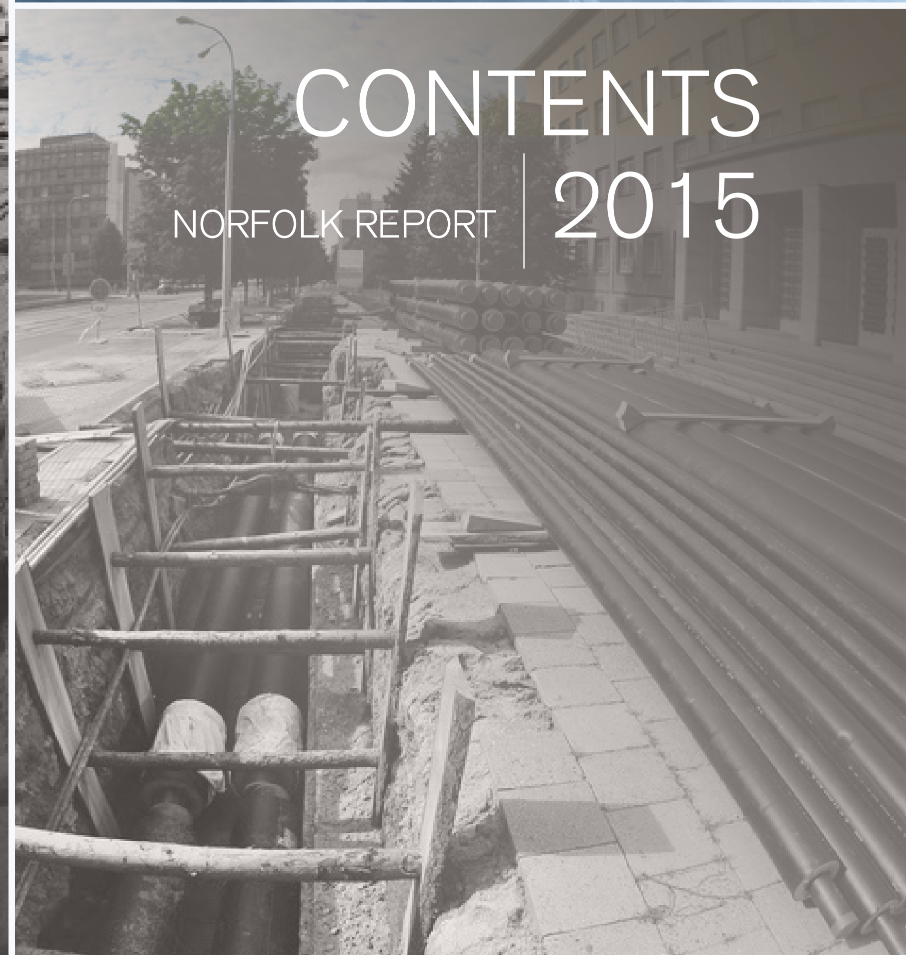
Norfolk has taken major steps to mitigate our flooding challenges through numerous studies and infrastructure improvements. Participating in the RE.invest Initiative helped Norfolk identify strategies for engaging the public and promoting private investment in integrated and comprehensive flood management solutions.

Mayor Paul D. Fraim, City of Norfolk



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RE invest

Introduction

The RE.invest Initiative focused on rethinking city infrastructure systems - including stormwater, energy, and communications among others - to enhance community resilience. By looking beyond individual projects to target city priorities, this initiative was structured to fill the gaps between planning and large-scale project delivery. There has been significant coverage in the national media about chronic underinvestment in urban infrastructure. It is clear that governments alone cannot be expected to meet all future infrastructure needs, especially with increasingly constrained public budgets. This is especially true in the face of emerging climate impacts, like more severe storms, that mean future infrastructure systems will need to look and function differently than our current systems.

In the face of these challenges, RE.invest recognized that designing new types of projects – not just building more of the same – is essential. To this end, RE.invest was based on three core ideas. First, resilience is about systems, not just projects. Careful integration, coordination, and sequencing are essential to make sure that when one structure fails it doesn't take down a whole system. In practice that means that green, resilient, and sustainable infrastructure systems are not made up of a few large projects, but many small pieces and parts. Second, finding new ways to align public and private interests to help cities plan large systems of small projects to invest at scale is necessary. Costs and benefits associated with resilient infrastructure systems are often spread across sectors – therefore coordination among sectors during project design is critical – not just for government agencies, but also for investors. Third, when it comes to green and resilient systems, success is often something that doesn't happen. The city didn't flood, the power didn't turn off, even though the storm hit. Capturing those benefits and savings over time requires thoughtful design and advance planning.

To date, the field of sustainable infrastructure investment has focused largely on developing the financial instruments to deliver resources more effectively. This is essential; however, it is only one part of the solution. Cities and communities must also put forward viable, large-scale projects. To that end, the RE.invest team focused on providing the support necessary to translate city needs to financeable projects through a rapid, structured, and replicable project preparation and delivery process for integrated resilient infrastructure systems.

In Norfolk, the RE.invest team focused on integrated flood management solutions in the Arts District – including cost effective green infrastructure options and seawall upgrades in the project area to address frequent flooding issues that limit economic redevelopment opportunities. Beyond identifying the types of infrastructure solutions that are viable given Norfolk's specific needs, the RE.invest team identified relevant legal and financial mechanisms to support eventual public and private implementation of those solutions.

Overview

In Norfolk, the RE.invest team focused on the Brambleton Avenue-Downtown Arts and Design District (Downtown Arts District) north of Downtown and The Hague[1]. The map included below, shows the Downtown Arts District (outlined in yellow), and the location of The Hague in relation to it. The shaded blue parcels indicate lots that are owned by the City of Norfolk within the Downtown Arts District.

Norfolk has identified the Arts District as an area for redevelopment, which is hampered by existing stormwater and flooding issues. Currently the Downtown Arts District is the most paved area in the municipality with many publicly and privately owned one-story warehouse-style buildings, large surface parking lots and alleyways. In an effort to reduce flooding, the RE.invest team reviewed floodwall systems that could protect the area while maintaining the look and feel of a historical area. To further reduce flooding in hotspots and to prepare the area for redevelopment, the RE.invest team analyzed a variety of green infrastructure implementations – including blue roofs, raised planter boxes, green alleys, permeable pavement, stormwater tree trenches, and surface depression storage - that could be strategically distributed throughout the Downtown Arts District to reduce flooding in streets and buildings. In addition to helping to reduce flooding, these green infrastructure measures would remove impervious surfaces from area watersheds and in so doing help with efforts to meet Total Maximum Daily Load (TMDL)[2] limits set by the recently adopted Chesapeake Bay TMDL Phase II Watershed Implementation Plan (WIP) for the Chesapeake Bay.

While the environmental and economic value of the entire flood management system is very high, so is the cost to implement. In total, the set of integrated infrastructure upgrades is too large an investment for the City of Norfolk to make alone. On the other hand, incentivizing private sector action won't necessarily achieve the scale of results Norfolk needs to solve the problem. Given that, the RE.invest team focused first on identifying the set and scale of benefits an integrated flood management system in the Arts District would produce. Building on that key information, the team assessed the applicability of a variety of legal and financial mechanisms that could do one of two things, either capture and securitize system savings or obligate mutually beneficial public-private-partnerships.

That engineering, legal and financial analysis is presented in this report – along with recommendations to the City to support eventual implementation of any of the outlined solutions.

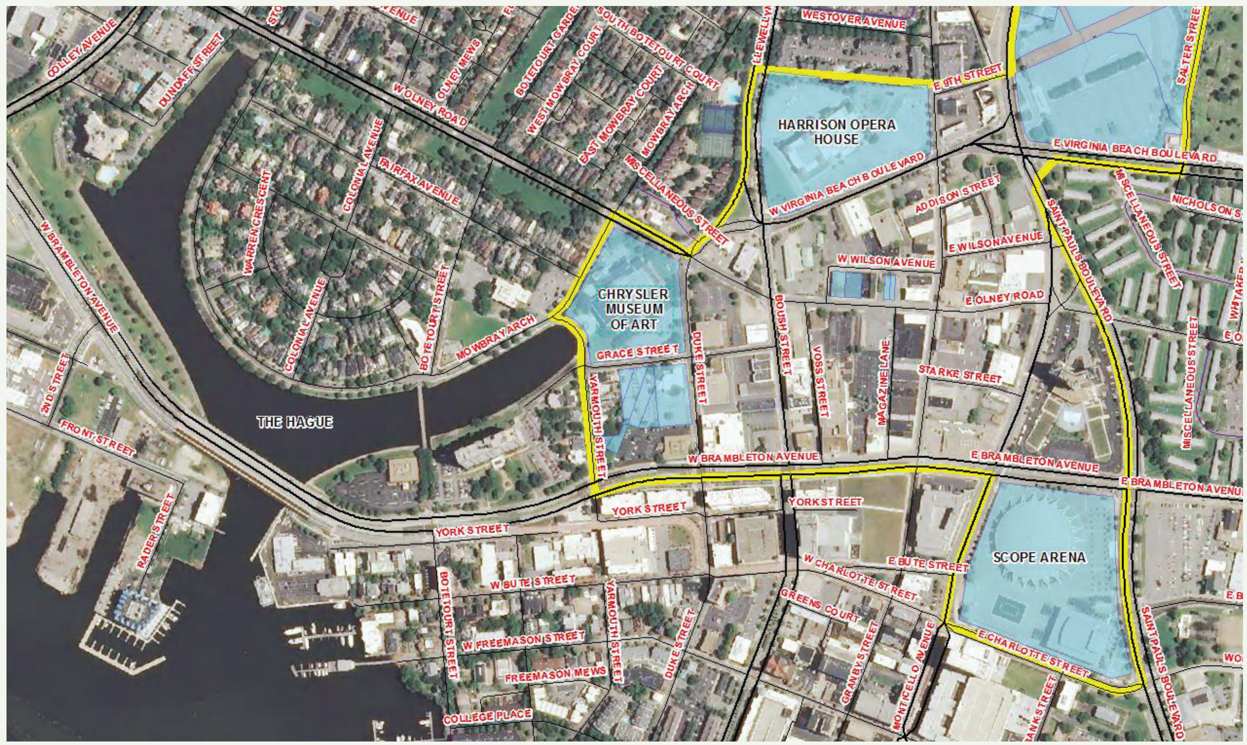

Figure 1 - Downtown Arts and Design District Map

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[1] The Hague is a semi-circular inlet off a tributary of the Elizabeth River located west of downtown Norfolk adjacent to the Downtown Arts and Design District.

[2] TMDL – is a calculation of the maximum amount of a pollutant that a water body can receive without impairing its ability to meet water quality standards. The Chesapeake Bay TMDL sets limits for phosphorus, nitrogen and suspended solids for all states discharging to the Chesapeake Bay.

Existing Conditions

Location

The City of Norfolk is an independent coastal city located at the mouth of the Chesapeake Bay near the southern border of Virginia. Norfolk is located on a series of peninsulas bordered by the Chesapeake Bay, Hampton Roads, the Elizabeth River, and the neighboring cities of Portsmouth, Chesapeake and Virginia Beach. As of 2012, the city had a total population of 245,803. The City of Norfolk is recognized as the central business district of the greater Virginia Beach-Norfolk-Newport News metropolitan area, which has a population of nearly 1.7 million.

The City of Norfolk is home to the largest naval base in the world, Naval Station Norfolk, along with multiple other military installations. It is estimated that 35% of the Gross Regional Product is related to the defense industry, as is 75% of the region's growth since 2001. The City is also home to major commercial port facilities for intermodal, coal, and bulk materials, cruise ships, and shipyards serving both defense and commercial interests. Downtown Norfolk also has a large corporate and university presence.

Geology

Norfolk is part of the Virginia Tidewater, which is a descriptive of the low-land character of the region. About 10 to 12% of Norfolk is underlain by filled wetlands and former submerged areas. Its coastal location at the mouth of the Chesapeake Bay means that it also has to contend with projected sea level rise. According to the USGS land subsidence has been observed in this region of the Chesapeake since the 1940s at rates between 1.1 to 4.8 millimeters per year. Land subsidence coupled with projected and recorded sea level rise increases flooding risk within the City of Norfolk. The map included, provides the location of Norfolk in relation to area subsidence monitoring stations. Reference stations DRV6 (west of Norfolk) and VAGP (northwest of Norfolk) shown on the map experienced subsidence rates of 3.3 mm/year (between 2006 and 2011) and 2.7 mm/year (between 2007 and 2011) respectively.

This region is also said to have been the site of the Chesapeake Bay impact crater 36 million years ago. Figure 2 illustrates the City of Norfolk's location along the Chesapeake Bay impact crater outer rim. It is believed that accelerated subsidence within this region is due to long-term settling of areas within the crater, which continues even today.

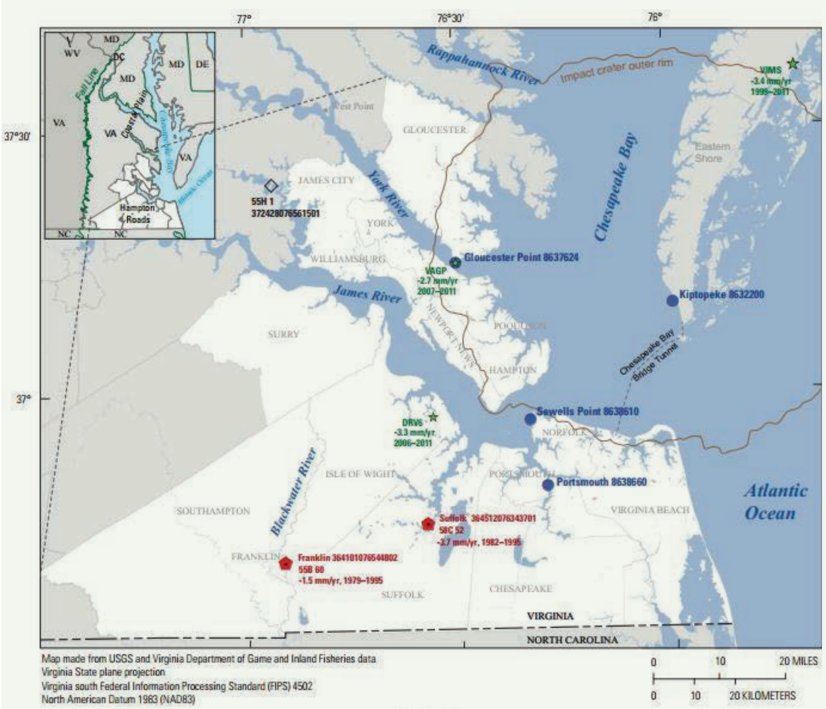


Figure 2 - Norfolk Location in Relation to Area Subsidence (Source: USGS, 2013)

- National Oceanic and Atmospheric Administration, Location, and Identification number (Zervas, 2009)
- Continuously Operating Reference Station (CORS), Name, and Rate of Subsidence for years indencated (National Geodetic Survey, 2013)
- U.S. Geological Survey (USGS) Groundwater monitoring well,Local Name, and Identification Number
- USGS Extensometer Station, Location, Number, Local Name, and Rate of Subsidence for Years Identicated (Pope and Burbey, 2004)

Hydrology

The Norfolk peninsula maintains a shallow depth to groundwater, with City officials estimating that the average depth to groundwater is 3 - 4 feet. This of course limits the amount of sub-surface construction and storage options that could be viable in the area.

Norfolk is also surrounded by water on three sides with the Elizabeth and Lafayette Rivers and their many tributaries traversing the peninsula and discharging into the Chesapeake Bay. Figure 3 included, shows Norfolk in relation to the surrounding water bodies. The Hague and Downtown Arts District, not shown at this scale, are located off a tributary to the Elizabeth River.

The City of Norfolk is located within the Mid-Atlantic coastal plain region at the mouth of the Chesapeake Bay, where the maximum site elevation is approximately 15 ft. The majority of the City is located at an elevation lower than 10 feet. The City is surrounded by water on three sides. The low lying nature of the city's location coupled with heavy rains, the susceptibility to storm surges and the presence of storm water discharges from a large upstream contributory watershed makes Norfolk subject to frequent annual flooding. Where precipitation flooding coincides with tidal flooding and storm surge the existing storm drain infrastructure is incapable of conveying runoff downstream; this exacerbates flooding. Stacking tides, or high tides that accumulate over several cycles coupled with precipitation flooding, can cause more flooding than a hurricane.

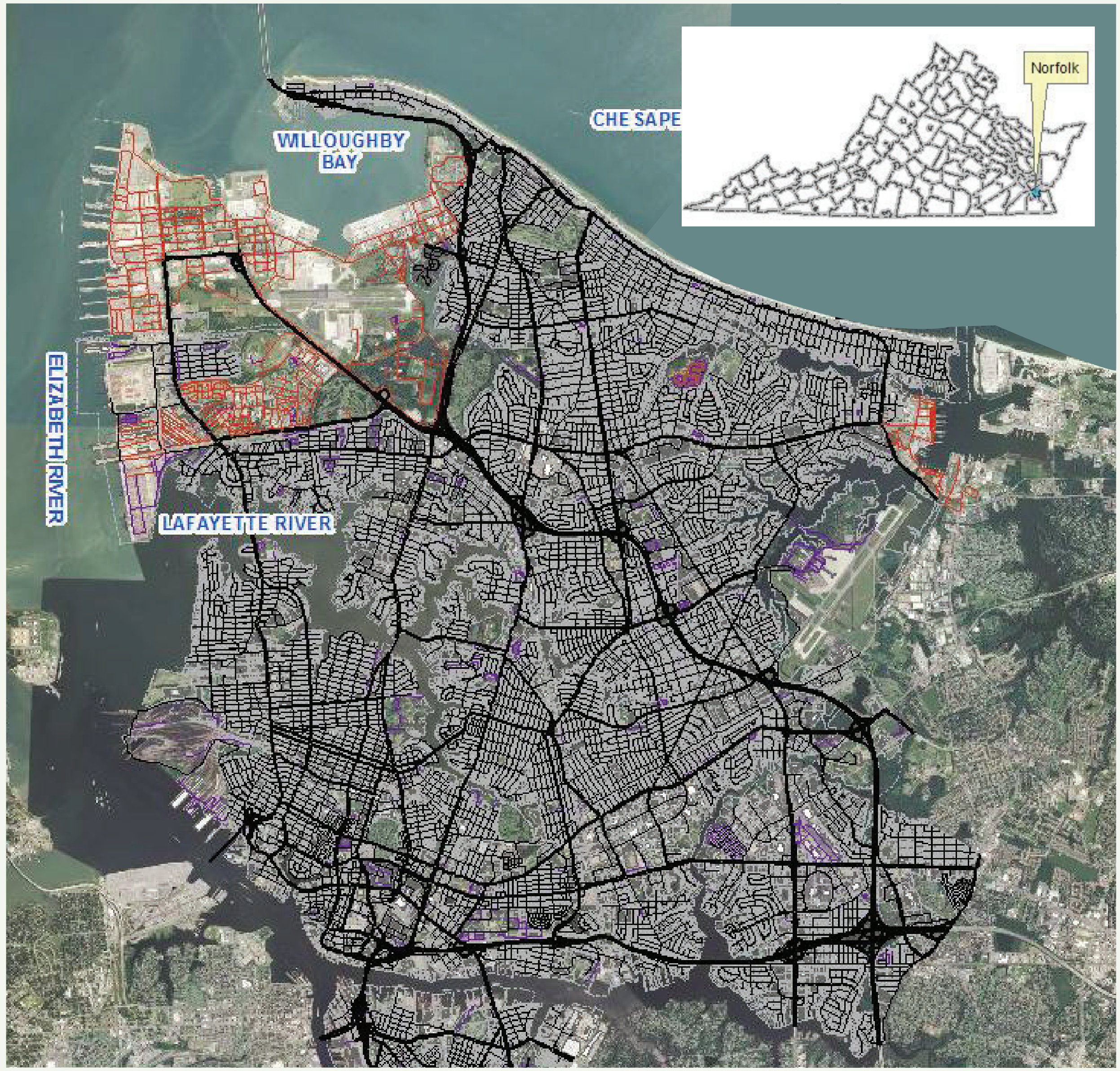


Figure 3 - Map of City of Norfolk Showing Adjacent Water Bodies (Source: ESRI)

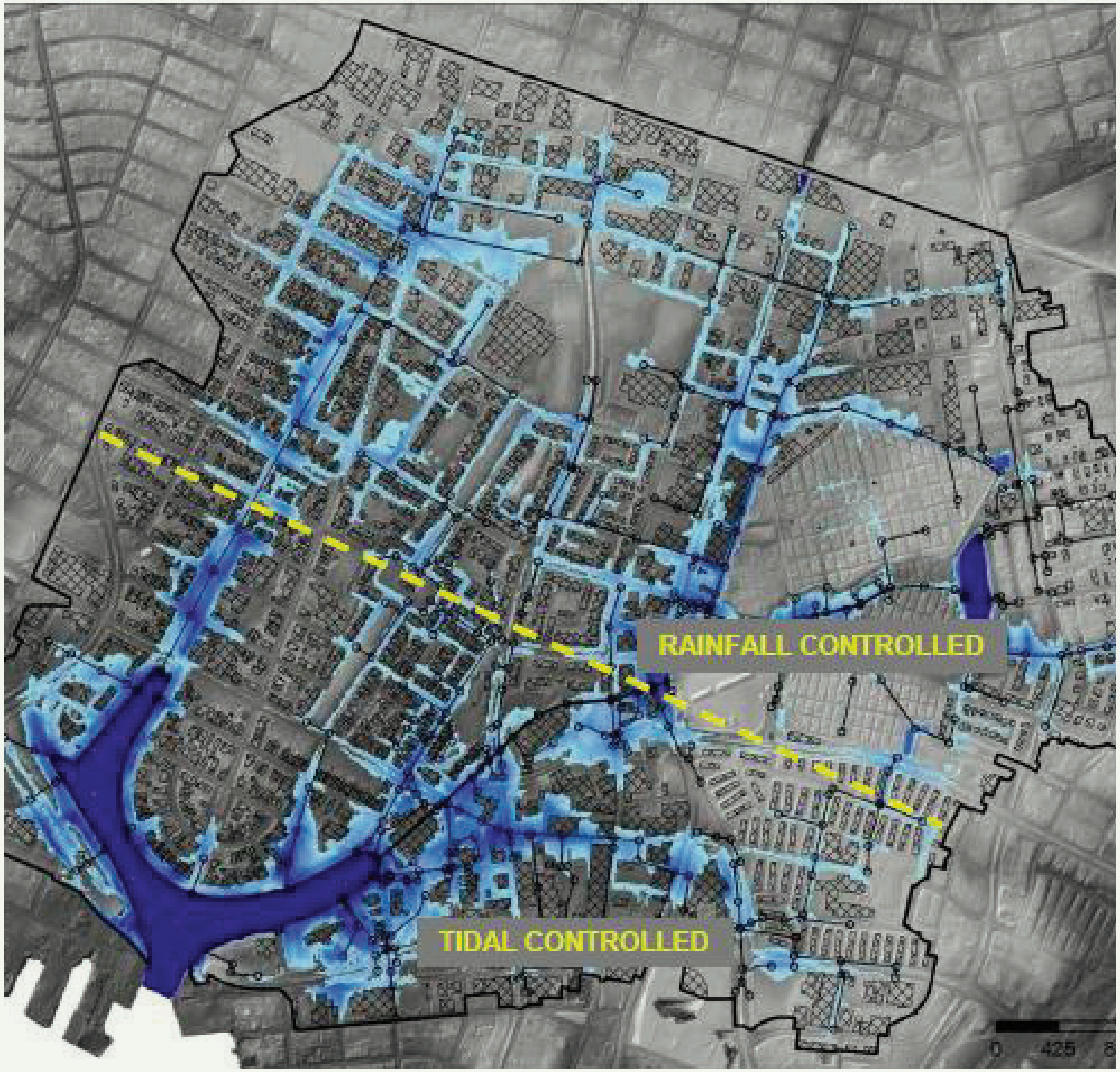


Figure 4 : 10-Year Rainfall & 10-Year Tidal Surge Event Simulation: The Hague (Source: Fugro, 2012)

Climate Impact

With recent increases in flooding incidences, projected sea-level rise, the continuation of land subsidence due to fill settlement, and the prevalence of impervious surfaces, the flooding situation is only expected to worsen as time goes on. Figure 4 shows a simulation of the response of The Hague and Downtown Arts District watershed to the combined effects of precipitation and tidally influenced flooding. The illustration suggests that flooding in the lower elevation waterfront areas are tidally controlled while flooding in the higher elevation areas are precipitation controlled. The intensity of the blue flooded areas provides an indication of the depth of flooding. Darker areas are covered by deeper floodwaters.

Tidal elevations for Norfolk have historically been measured at the NOAA Sewells Point tidal gage located at the mouth of the James River. A summary table of recent storm events and the related water surface elevation (WSE) recorded at the Sewells Point tidal gage can be seen in Table 1. Its important to note that water levels in the waters within and surrounding much of Norfolk are higher than those at Sewell's Point, recent studies by Fugro have reported and evaluated these differences.

DATE	WSE At Sewell's Point (Ft)	EVENT
09/18/2003	6.54	Hurricane/ TS Isabel
11/12/2009	6.32	Nor'easter
08/28/2011	6.18	Hurricane Irene
10/29/2012	5.41	Hurricane Sandy

Table 1 - Recent High Water Surface Elevation (WSE) Recorded at Sewells Point Tidal Gage (Source: NOAA)

Existing Infrastructure

Norfolk is an older colonial city with some original historical infrastructure dating back to the 1800s. Infrastructure improvements were most recently performed in the 1950s due to rapid urbanization. Infrastructure upgraded in the 1950s is currently approaching the end of its serviceable life and due for upgrades.

The existing municipal separate storm sewer system (MS4) is managed by the Norfolk Public Works Stormwater Division and consists of 349 miles of pipe, 137 miles of ditches, 13 storm water ponds, and 10 storm water pump stations. The newest portions of the system have been sized to accommodate a 10-year storm event while portions constructed before the 1950s have capacity for a 2-year storm. The efficiencies of even the new systems are adversely affected by the degraded condition of the old infrastructure. In addition, and most importantly, the difference between tail water elevation in The Hague versus the water elevation at Sewell's Point (which presumably was the basis for the existing storm water system design) imply that the systems are under-designed for their intended design basis. This difference in tail water elevation (actual in Hague versus design based on Sewell's Point), means that the maximum storm that the system can accommodate is about twice as frequent as the intended design storm. Hence, a system intended to accommodate a 10-year design storm in reality can only accommodate a 5-year design storm. This reality is typical of much of Norfolk's storm water system. Sea-level rise and storm surges will further reduce the capacity of the systems relative to their intended design basis.

In addition, extra capacity is needed to handle the additional backwater flows caused by storm surges or

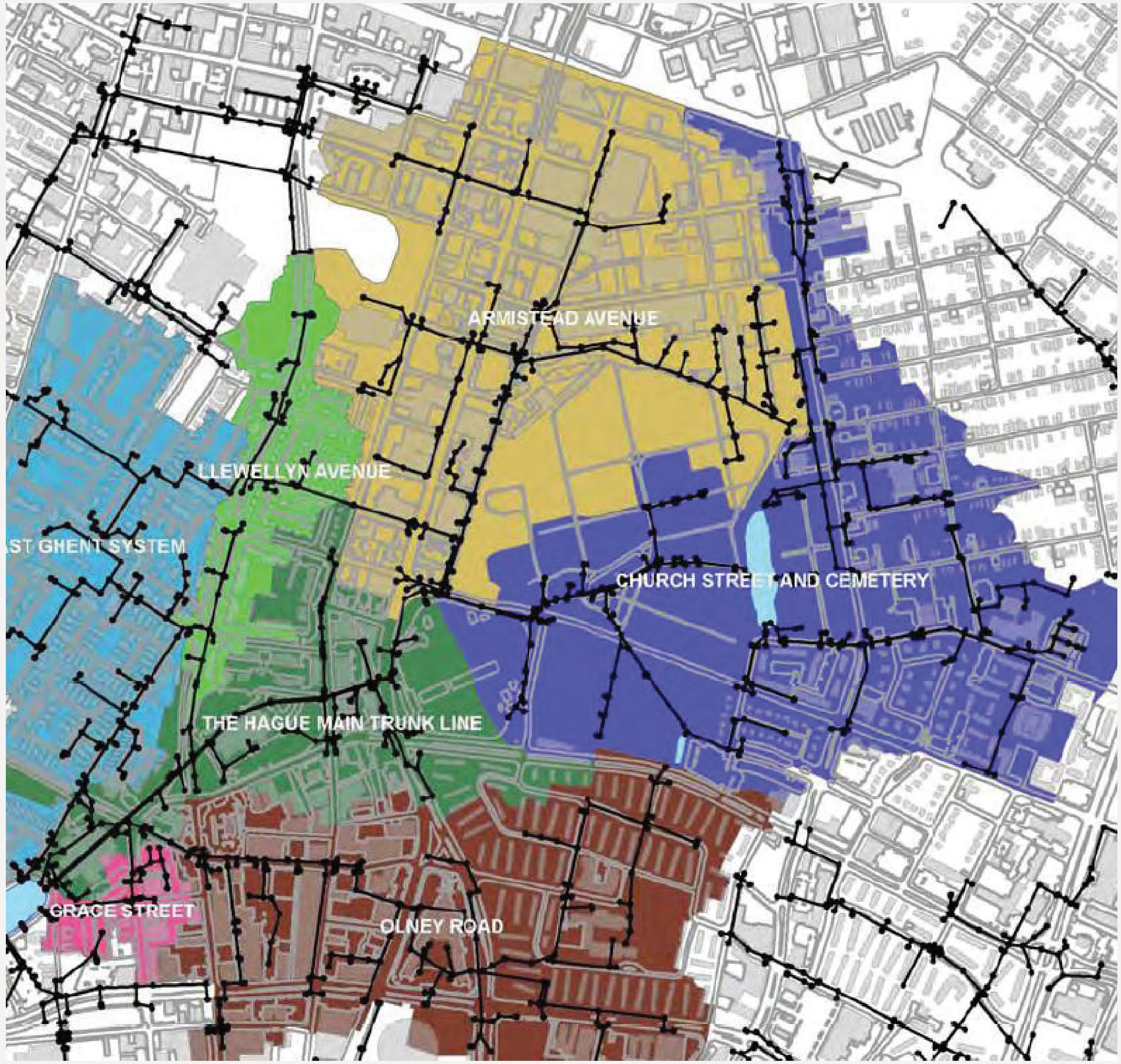


Figure 5 - Downtown Arts District Watershed Existing Stormwater Infrastructure Map (Source: Clark-Nexsen)

high tide, which may occur concurrently. This could be accomplished by either increasing the capacities of most of the storm drain piping or by a number of retention strategies throughout the City. Figure 5 shows a system map of the watersheds that contribute to the Downtown Arts District area within the City of Norfolk. The different colors represent the contributing drainage areas to the different trunk lines within the watershed. Most of the Downtown Arts District contributes to The Hague Main Trunk Line.

Enabling Environment

Norfolk city government consists of a city council with representatives from seven districts serving in a legislative and oversight capacity, as well as a popularly elected, at-large mayor. The city manager serves as head of the executive branch and supervises all city departments and executing policies adopted by the Council. Current Norfolk Mayor is Paul D. Fraim, who supported Hampton Roads district green infrastructure strategy in 2007.

The Mayor and City Council have been historically and continue to be pro- public-private partnership , and have made clear that they intend to pursue public-private development opportunities for the redevelopment of parking lots, outdated buildings, cleared lands and struggling neighborhoods. To support these efforts, the City has developed a very unique performance-based grant that isn't appropriated and payable until 18 month after the City has realized new revenue from a specific project.

Recent reorganization moved the Norfolk Public Works Stormwater division under the Operations Division where it maintains a municipal separate storm sewer system that manages on average 45 inches of rainfall per year with 349 miles of pipes, 137 miles of ditches, 13 storm water ponds, and 10 storm water pump stations – in totally more than 27,000 storm water structures . Prior to 2001, the city focused on integration of their GIS data and their stormwater asset management program and their billing system.

Norfolk's most significant concerns are centered on meeting TMDL requirements in the Chesapeake Bay, and they are currently exploring and implementing green infrastructure strategies to address this perennial challenge. In recent years, the City has launched an Urban Stormwater Workgroup advisory panel to ensure all possible treatment options receive reasonable credit, i.e.. illicit discharge elimination, street sweeping, oyster reefs, education/outreach. In addition, the city is supporting studies of a range of policy and project options ranging from large "pond" retrofits and creek restoration to review of city ordinances and voluntary private-property BMPs for TMDL credit. The City is also exploring opportunities to utilize its stormwater fund, CIP, grants, voluntary efforts, and partnerships to ensure construction of water quality practices continues at an adequate pace in advance of the new MS4 permit issuance.

Most green infrastructure efforts in Norfolk build on the State of Virginia's Southern Watershed Area Management Program (SWAMP), one of the first planning efforts in the State of Virginia to use a green infrastructure based approach to open space preservation, habitat protection and water quality protection. In 2007, the Hampton Roads region developed a green infrastructure strategy focused primarily on land planning and usage.

RE invest

Engineering Solutions

The design concepts in this document are ideas developed by the RE.invest team to creatively address multiple resilience challenges with integrated and implementable solutions. By bringing together project ideas from multiple sectors, these design proposals open up the potential to capture multiple revenue streams and access different sources of financing.

What follows is the proposed design solutions developed specifically for the City of Norfolk based on priority setting discussions and data provided by the City. Recognizing the anticipated future deficiency of current seawall structures in the area, the RE.invest team researched the applicability of seawall upgrades along The Hague waterfront adjacent to the Downtown Arts District project site to determine if these upgrades could more directly solve localized flooding and when complemented with proposed green infrastructure upgrades significantly reduce flood hotspots. More cost effective green infrastructure options to help address existing recurring flooding issues that limit economic redevelopment opportunities were also identified. These green infrastructure practices are aimed at providing runoff volume reduction as well as nutrient removal to meet TMDL reduction targets.

The Hague Site

The Hague is a residential waterfront area west of the Downtown Arts and Design District. An overall map of The Hague is included in Figure 6. The map shows the location of existing storm drain pipes in addition to the extent of the FEMA regulated 100-year flood plain within the area.

As determined in the Coastal Flood Study for Norfolk, completed by Fugro Atlantic, the Downtown Arts District experiences occasional coastal flooding along The Hague waterfront due to the regular daily high tide event. Residents and visitors are forced to refer to tidal charts in order to determine when they can venture out even during sunny dry weather conditions according to a recent Washington Post article. The Hague tidal flooding is very predictable and occurs during high lunar tide period near the full and new moon. Precipitation and/or minor winds extend the depths and duration of flooding associated with abnormal high tides and create additional flooding during periods of lesser tides. Water levels in The Hague have been known to rise close to 1 foot due to these tidal fluctuations. A tidal gage monitoring system while providing information on water levels within The Hague would do little to alleviate the problem and a manual system dependent on human deployment of flood barriers is labor intensive and could endanger lives.

The installation of a self-raising flood barrier along the waterfront area can potentially eliminate this problem. Initially developed in the Netherlands, this solution has been deployed in the Netherlands, Belgium, the United Kingdom, and most recently in a small scale outside of the National Archives in Washington, DC. This passive flood defense system, through hydraulic principles, uses the rising floodwater to automatically raise the flood barrier. As the floodwaters recede the barrier automatically retracts. The beauty of this system lies in the fact that it is virtually invisible allowing residents to keep their unobstructed waterfront views when not in use and does not require human intervention or a regular power source for deployment. As this is expected to be a costly undertaking, the recommendation is for the flood barrier to be constructed in two phases in order to make the cost of the installation of the system more manageable. Phase 1 of the system could extend along the waterfront from the two ends of the existing footbridge connecting Botetourt Road. Super strength transparent plexiglass can be installed along the concrete barricade in front of the museum in order to save on costs and in order to use the existing wall configuration in this location. Phase 2 of the system installation could extend the self-closing flood barrier along the remainder of The Hague waterfront to the west of the footbridge. An image illustrating the principle behind the hydraulics of the proposed system is shown in Figure 7.

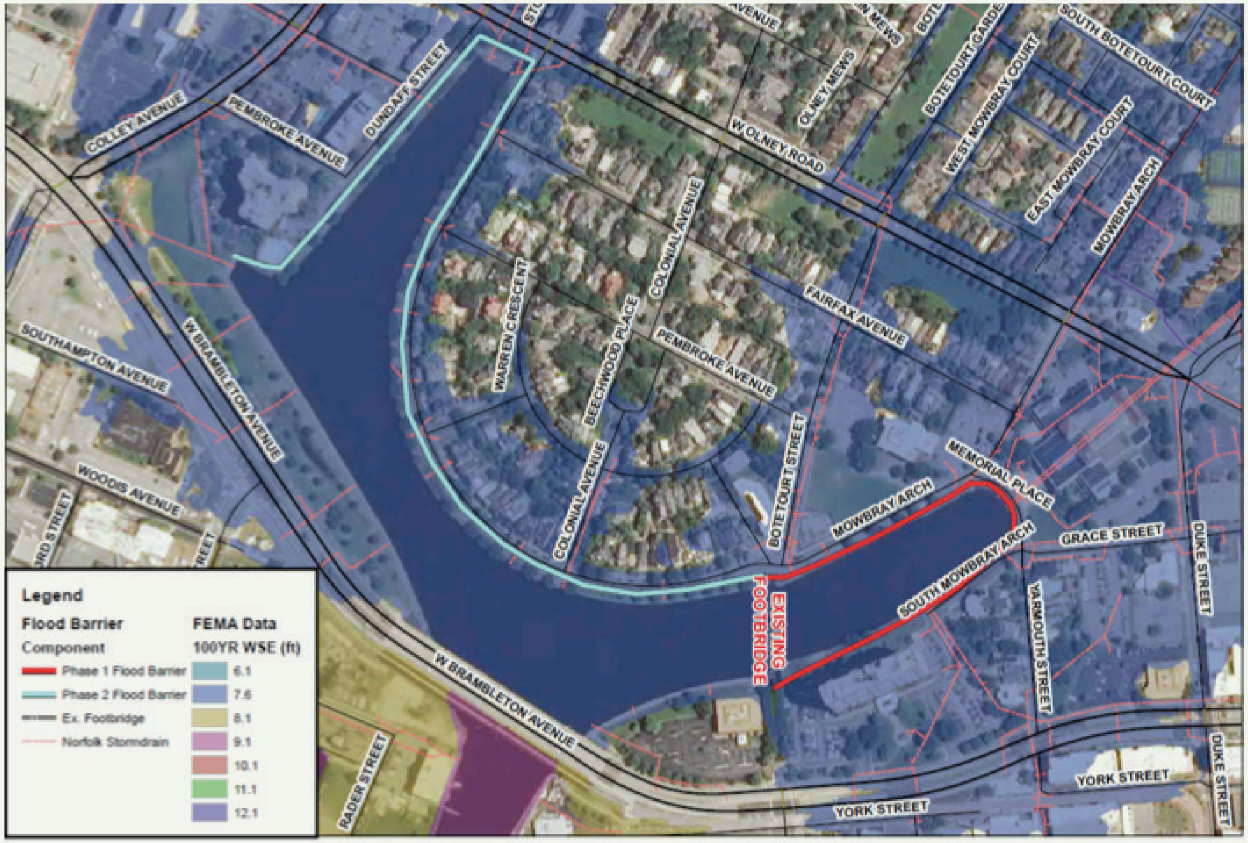
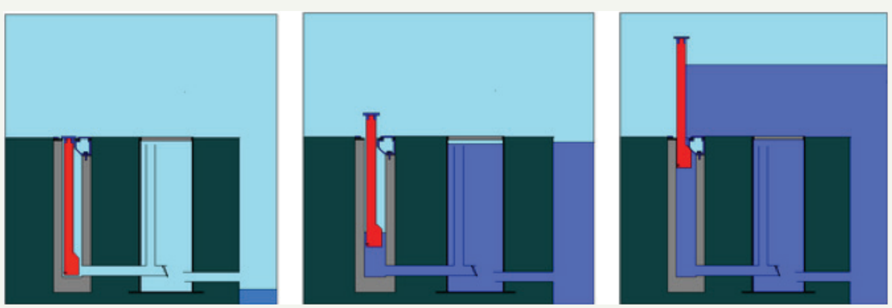


Figure 6: Map of The Hague Showing Proposed SCFB Location



Self ClosingFlood SCFB™

Side view working principle of the self closing flood barrier

Figure 7: SCFB Working Principle (Source: Aggeres Flood Solutions)

An overall map of The Hague showing the existing 100-year level of flooding is included in Figure 8. The number of structures flooded by the 100-year floodplain without the protection of the flood barrier is included for comparison purposes. The shaded blue areas indicate the extent of flooding while the pink shaded building outlines indicate flooded structures. The 100-year base flood elevation (BFE) is defined as the elevation that water is anticipated to rise to during a 100-year flood. For the City of Norfolk this elevation is 7.6 feet. The buildings indicated in red are either partially or entirely located within the 100-year flood plain. The flood barrier system being proposed within The Hague would deploy to a maximum height of 3.28 feet (100 cm). This would not provide protection from the 100-year flooding but will provide protection from more frequent smaller nuisance flooding events.

A hydraulic model was initially created in HEC-RAS to simulate the expected flooding reduction from deployment of the self-closing flood barrier. Issues encountered with the model included the lack of bathymetry data within the Hague waterfront and the complexity of the model due to the interaction of precipitation and tidal processes and inaccuracies with the area flow data. The RE.invest team overcame these issues by mapping the floodplain in GIS at incremental height increases until the team attained the maximum height proposed for the self-closing flood barrier. Using this method the team was also able to determine the number of flooded building structures with and without the self-closing flood barrier. The volume of flood water was also determined using GIS to determine the volume between the flood barrier elevation and the digital elevation model (DEM) created using the City of Norfolk GIS. A summary of protected buildings and flood volumes held back by the flood barrier during Phase 1 and Phase 2 are included in Table 2.

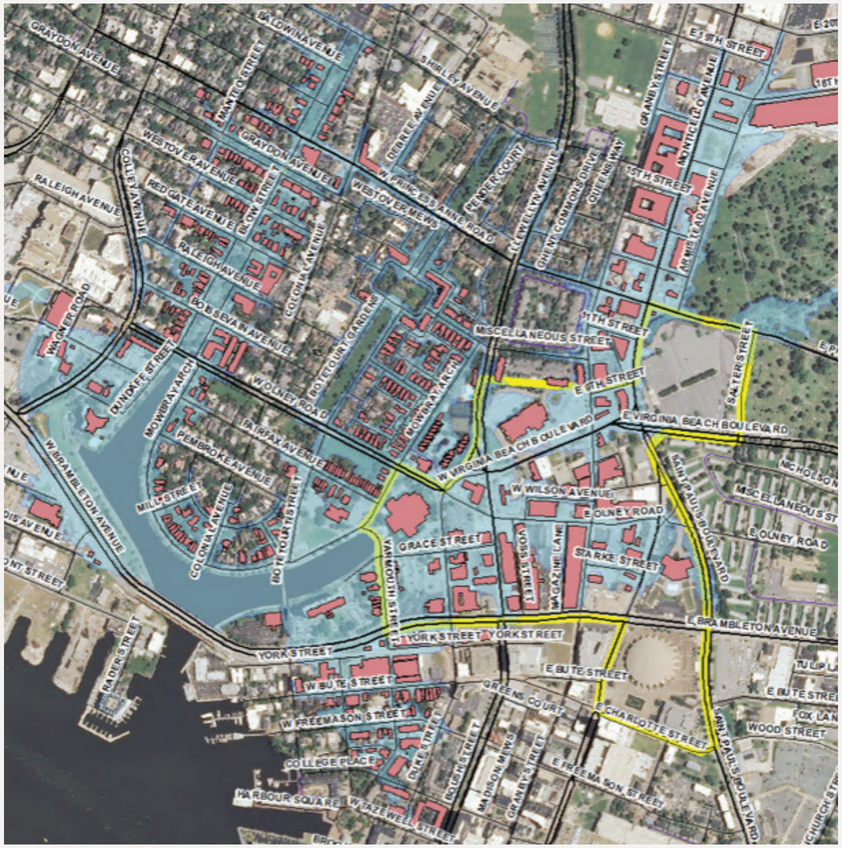


Figure 8: Buildings Currently Flooded by 100-Year Flooding

	NO. OF FLOODED STRUCTURES	AREA OF FLOODED STRUCTURES (SQ. FT.)	NO. OF STRUCTURES SAVED	AREA OF BUILDINGS REMOVED FROM FLOODING (SQ. FT.)	VOLUME WATER HELD BACK (CU. FT.)
100-Year Flooding (7.6')	465	1,997,466	-	-	11,095,891
Phase 1 (4.0')			13	60,026	181,543
Phase 1 (5.0')			31	346,128	1,036,270
Phase 1 (5.75')			50	480,535	2,075,712
Phase 2 (4.0')			13	60,026	223,774
Phase 2 (5.0')			46	389,881	1,322,158
Phase 2 (5.75')			85	647,418	2,738,156

Table 2 - Summary of Flood Reductions due to Self-Closing Flood Barrier

If the self-closing barrier is deployed during an event that coincides with a precipitation event and causes flooding behind the barrier, pumps may need to be used to pump water over the barrier and into The Hague. Conceptual plans for the proposed improvements are included within the Appendix.

It is important to note that flooding in the Hague occurs from both water overtopping the rim of the wall around the Hague perimeter as well as water backing up into and out from the inlets of the many storm drains into the Hague. The proposed self-closing flood barrier will only alleviate the overtopping component of the flooding, and thus is not a stand-alone solution. For that reason, the RE.invest team explored a series of green stormwater strategies that could compliment the tidal solution of the self-closing wall.

Downtown Arts District

The RE.invest Initiative worked to identify a series of green infrastructure strategies that could be deployed within the Arts District to solve short-term flooding needs and complement any longer term flood barrier investment.

The Downtown Arts District is located within the Ghent District of Norfolk and is loosely bound by West Brambleton Avenue, Granby Street, and East Virginia Beach Blvd. It is generally located between the Chrysler Museum of Art, Harrison Opera House, the Scope Arena and the rest of Downtown. A larger map including the sizes and locations of existing storm sewer pipes within the Downtown Arts District is included within the Appendix.

Generally the green infrastructure practices described here will serve to retain stormwater onsite during storm events when storm drains are overtaxed. The storage of this stormwater will delay entry of storm flows into the storm drain system and in so doing this can potentially delay or reduce flooding.

The following features are suggested:

- Blue Roofs,
- Raised Planter Boxes,
- Green Alleys,
- Permeable Pavement,
- Stormwater Tree Trench, and
- Surface Depression Storage

Figure 9 shows the locations for the various types of green infrastructure solutions being recommended. Raised planter boxes locations are not shown on the Green Infrastructure Location Map as siting for these elements is flexible and dependent on property owner preference.

Blue Roofs

Blue roofs are non-vegetated point source controls that detain stormwater in much the same way as green roofs but without the ecological benefits. Blue roofs also have the added benefit of reducing the urban heat island effect and are generally less costly to install and maintain than the more widely known green roof. Modular gravel filled watertight trays (open to the atmosphere) allow water to pond temporarily until the water attains the height of the tray and overflows and drains off the roof at the existing roof drains. Since roof waterproofing is essential, older building may need to have roofs upgraded or repaired before installation of the blue roof system. Structural concerns due to the weight of water are less of an issue as buildings in Virginia are built to accommodate snow loads and this load would be similar to the anticipated 15-20 pounds per square foot anticipated loading on a blue roof from the weight of gravel, other materials and water. A typical blue roof tray section is included in Figure 10.

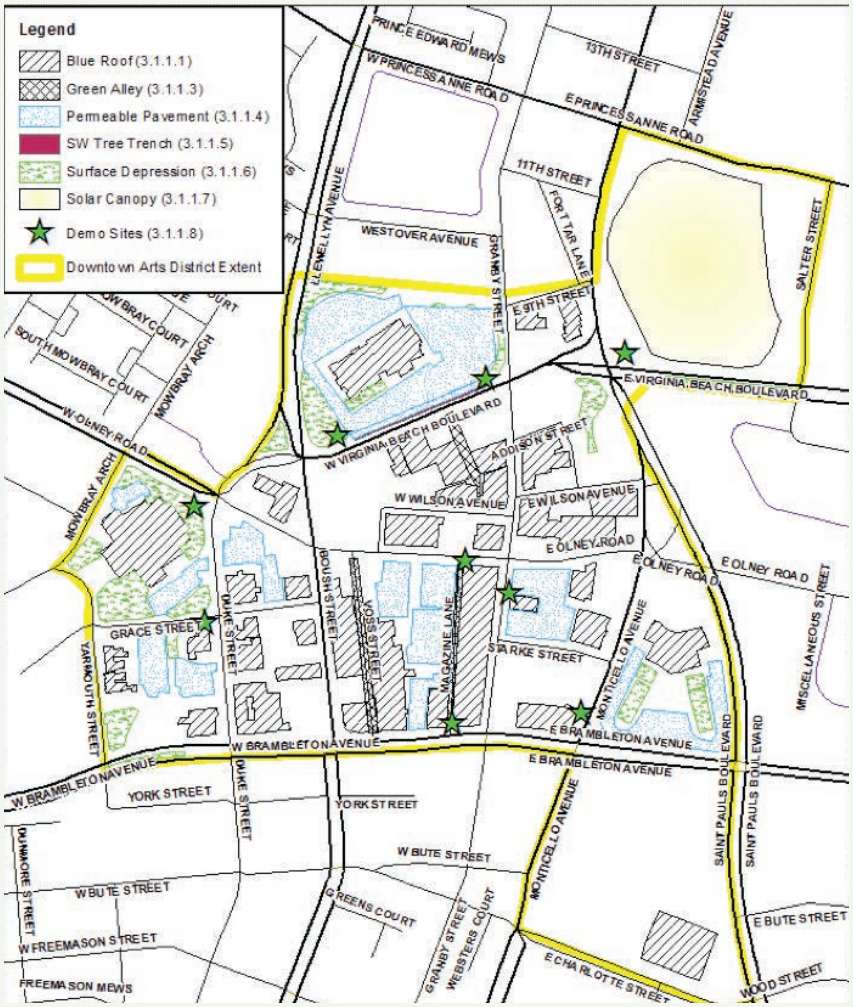


Figure 9: Green Infrastructure Location Map

Blue roofs, along with other green infrastructure strategies have been implemented by New York City as part of its fiscal year 2012-2015 budget in combined sewer areas in order to reduce the incidences of combined sewer overflows. The initial monitoring results were released by the New York City Department of Environmental Protection in a document entitled "NYC Green Infrastructure Plan: 2011 Preliminary Pilot Monitoring Results." Data for the blue roofs within that report indicates that blue roof trays provide retention of at least half of the storm volume. This data is of relevance to the City of Norfolk as New York City has in excess of 70% impervious cover and has an annual rainfall of 44 inches per year.

There are a total of 64 buildings within the Downtown Arts District area. Of these, the sports arena has been excluded since its domed roof would be incapable of retaining water for any period of time. Using a minimum building roof size criterion of 5000 square feet, a total of 37 buildings which can potentially be retrofit with blue roofs were identified within the

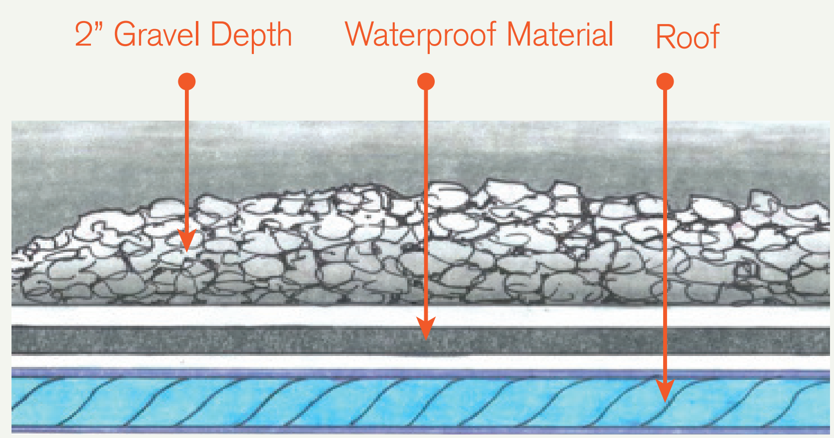


Figure 10: Typical Blue Roof Tray Section (Source: www.arcsa-edu.org)

Downtown Arts District. This 5000 square foot criterion was used to ensure that a minimum of 1000 cubic feet of water would be retained by each of the roofs by implementing this green infrastructure practice. A site plan showing the locations identified for potential blue roofs is included in Figure 11. The shaded blue areas indicate roofs on publicly owned buildings while the shaded areas outlined in teal are privately owned buildings.

A summary of the potential storm water volume captured by the use of this green infrastructure and delayed from entering the storm sewer system is included in Table 3.

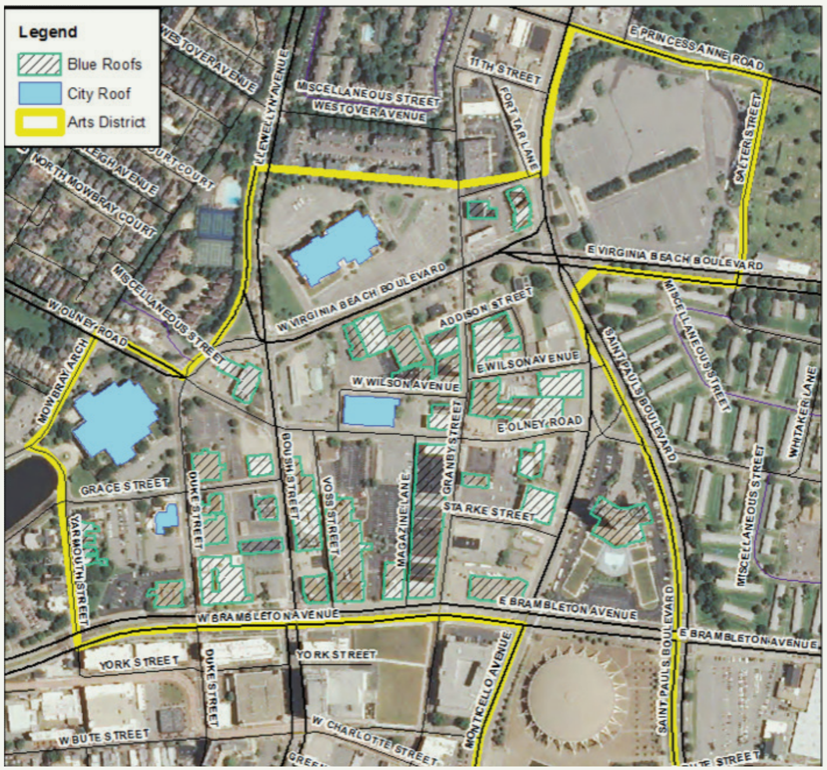


Figure 11: Blue Roof Site Plan

Three-inch deep watertight trays were used for these initial calculations. If deeper or more shallow trays are used the volumes captured would be impacted. Although these volumes appear small, the area of the Downtown Arts District at approximately 4,722,380 square feet represents less than 1% of the City's surface area. Based on our projections, if blue roofs are implemented on a citywide basis we estimate that it could delay the entry of millions of cubic feet of water into the storm sewer system and reduce the magnitude and frequency of flooding within the City of Norfolk.

	NO. OF BUILDINGS	ROOF SURFACE AREA (SQ. FT.)	VOLUME OF WATER CAPTURED(CU. FT.)
TOTAL	63	816,586	204,147
BUILDING FOOTPRINTS LARGER THAN 5000 SQ. FT.			
All Arts District	37	761,282	190,321
Public Buildings	5	199,561	49,890
Private Buildings	32	561,721	140,430

Table 3 - Summary of Storm Water Captured by Blue Roofs Within Arts District

Raised Planter Boxes

Planter boxes are flow-through stormwater treatment facilities adjacent to buildings and disconnected downspouts, which can be used to provide temporary retention during storm events. A raised planter box serves the same function but has the added benefit of providing additional retention volume due to its raised sides. These are ideally suited for areas where underlying soils are not ideal for infiltration and where the retained stormwater will be ultimately discharged to the storm drain system. These systems work well on small sites and can be placed adjacent to buildings. A typical system cross section is included in Figure 12.

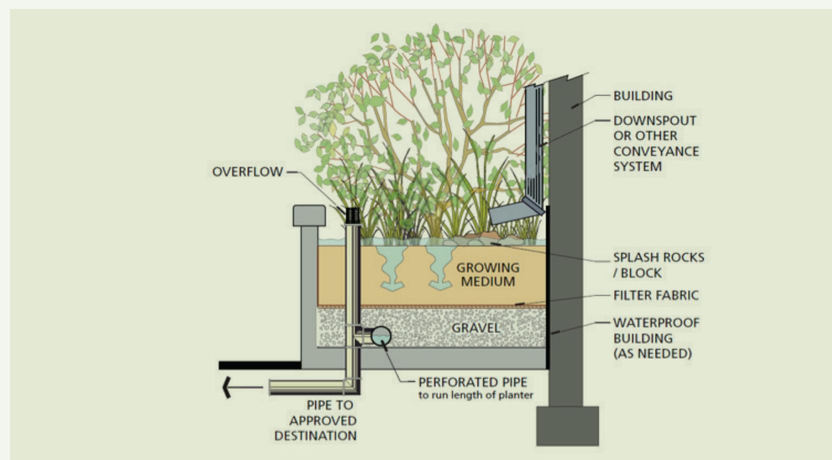


Figure 12: Typical Raised Planter Box Section (Source: City of Portland, Oregon)

The raised planter box configuration suggested for the City of Norfolk consists of a minimum 100 foot long box, 3 foot wide and 3.5 foot deep box. This minimum footprint will capture and detain 1,050 cubic feet (7,854 gallons) of water. These planter boxes can be sited in conjunction with the blue roofs identified previously so that additional retention of stormwater can be provided and delayed from entering the storm sewer system. An overflow pipe at the top of the raised planter box connected to the storm sewer system allows for drainage. Table 4 included provides a summary of the potential storm water volume that can be captured by the use of raised planter boxes. For every 100 linear feet of raised planter box provided, the City can expect to delay the entry of approximately 7,800 gallons of stormwater into storm drain system. If the raised planter boxes are strategically located adjacent to the blue roof installations and if blue roofs are installed on all of the previously identified roofs larger than 5000 square feet this would delay the entry of over 1 million gallons of stormwater into the storm drain system. Sections and details for the raised planter boxes are included within the Appendix. A location map has not been provided since the siting of these features is best placed in conjunction with the Blue Roofs and with downspout disconnections to the planter.

	LENGTH (ft)	WIDTH (ft)	DEPTH(ft)	VOLUME (CU. FT.)	VOLUME (Gallon)
Minimum Typical Box	100	3	3.5	1,050	7,854
Downspout from Blue Roof to Raised Planter	-	-	-	190,321	1,423,700

Table 4 - Summary of Storm Water Captured by Raised Planter Boxes

Green Alleys

The City of Norfolk has alleys that are seldom used except for rear property access by the businesses adjacent to them or by pedestrians. As part of its revitalization plan, the City of Norfolk has identified alleys as a means of creating more connectivity within the Downtown Arts District. Conversion of alleys within the Downtown Arts District such as Magazine Lane into a green alley is an opportunity to do this.

Green alleys are alleys that have been designed in order to help manage storm water, reduce urban heat island effects and conserve energy. The proposed improvements along Magazine Lane include the replacement of the existing asphalt surface with a permeable pavement treatment in order to allow stormwater runoff to the alley to be temporarily retained by the underlying storage media. As infiltration into the surrounding ground is not feasible due to the presence of shallow groundwater the green alley and underlying storage media will be underlain by an impermeable liner. A perforated polyvinyl chloride (pvc) pipe near the bottom of the storage media could be connected to the existing City storm sewer system at an existing inlet/manhole where Magazine Lane intersects East Olney Road. This additional storage within the watershed and the delay in entry of stormwater in the storm drain system could potentially reduce flooding in this area. Magazine Lane is highlighted in Figure 13. A Typical plan, profile and section for the Green Alley are included in the Appendix.

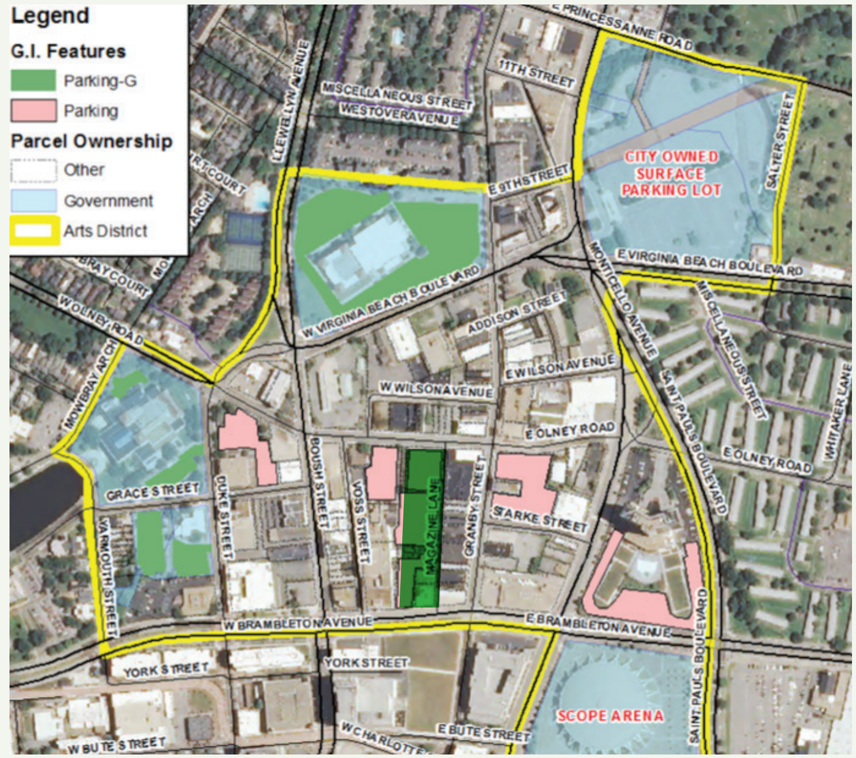


Figure 13: Locations for Permeable Pavement Application

Permeable Pavement

Permeable pavements are non-traditional pavement surfaces that allow stormwater runoff to filter through voids in the surface into a stone reservoir below where this water can either be temporarily retained to delay entry into the storm drain system or allowed to infiltrate and replenish ground water. The three permeable pavement surfaces examined for application in the City of Norfolk were pervious concrete, porous asphalt and interlocking pavers.

The City has several surface pavement improvement projects planned within the Downtown Arts District. These include sidewalk replacements and roadway resurfacing projects. Due to a lack of adequate infiltration and a high water table, only storm water retention is planned for the areas identified for possible permeable pavement application. To alleviate the City's challenges related to street floding, the concept envisioned for the Downtown Arts District includes the installation of demonstration areas alongside conventional pavement surfaces. This will give The City an opportunity to observe and compare the performance of the different surface materials.

The Downtown Arts District has a total surface area of 4,722,380 square feet with more than 90% of this area being impervious. A site visit carried out by the RE.invest team revealed an abundance of surface parking lots and few green spaces for infiltration or retention of stormwater runoff. Figure 13 included shows locations identified for possible permeable pavement applications. The green areas show existing surface parking lots on government owned properties while the pink areas are large surface parking lots identified from aerial photography where this green infrastructure measure might also be implemented with private owner consent. The Scope Arena was not identified for potential permeable pavement application as it has a large underground parking garage. This green infrastructure application has also not been suggested for the large city owned surface parking lot identified to the north east as this is a capped landfill where the application of permeable pavement strategies would not be possible.

A summary of the potential storm water volume delayed by the use of this green infrastructure practice is included in Table 5. Although these volumes appear small, the area of the Downtown Arts District at approximately 4,722,380 square feet represents less than 1% of the City's surface area. If permeable pavement is implemented on a citywide basis it could potentially delay the entry of millions of cubic feet of water into the storm sewer system and may reduce the magnitude and frequency of flooding within the City of Norfolk.

PROPERTY TYPE	SURFACE AREA (SQ. FT.)	STONE RESERVOIR DEPTH (in)	VOLUME (CU. FT.)	VOLUME (Gallon)
City Owned	247,012	8	164,675	1,231,852
Private	249,692	8	152,256	2,801,739

Table 5 - Summary of Possible Stormwater Captured with Permeable Pavement

Stormwater Tree Trench

A stormwater tree trench is a subsurface trench with a stone reservoir for stormwater runoff retention and conveyance along with sections of engineered soil for growth of trees. It manages stormwater runoff by collecting surface runoff via inlets and overland flow and conveys these surface flows to the subsurface trench. The runoff is stored temporarily between the voids in the stone reservoir and provides needed water to the street trees. As soils within the City of Norfolk are ill suited for infiltration, the sides of the subsurface trench would need to be wrapped in an impermeable liner. A perforated underdrain 2 inches from the bottom of the stormwater tree trench would collect and convey the stormwater to the existing storm drain system at the intersection of Llewellyn Avenue and West Virginia Beach Boulevard. This system was envisioned by the RE.invest team along West Virginia Beach Boulevard fronting the Harrison Opera House. A typical section through the system is included in Figure 14. This recommended stormwater tree trench was designed to be 550 feet long, 6 feet wide and 1.5 feet deep. Based on projections, the team estimated that almost 5,000 cubic feet (~37,000 gallons) of storm water could be captured and detained by the storm water tree trench. Although only one location was identified for this green infrastructure practice within the Downtown Arts District, the concept can be applied in other locations within the City of Norfolk where the shade provided by the new tree canopy and the stormwater storage features of the underground reservoir would be beneficial. Typical plan, profile and section for the Stormwater Tree Trench are included in the Appendix.

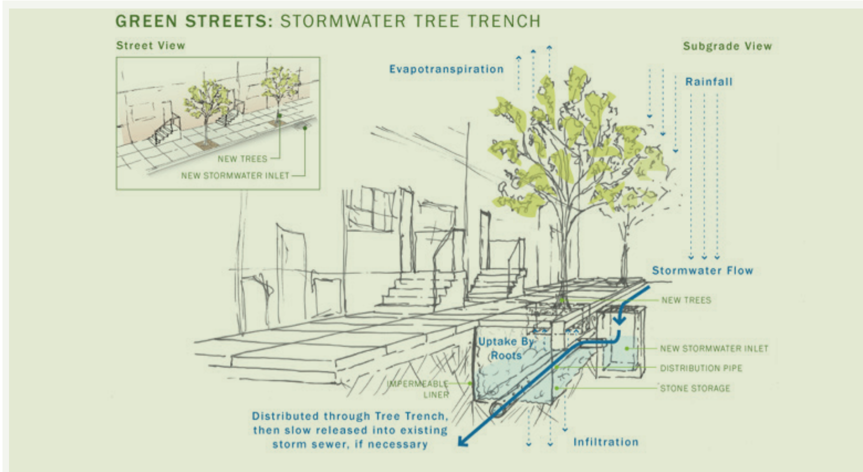


Figure 14: Stormwater Tree Trench Section (Source: PWD Green Streets Design Manual)

Surface Depression Storage

Surface depression storage within the Downtown Arts District could delay the timing of flows to the storm sewer system, which is often overwhelmed during storm events due to surge and tidal effects at discharge points. Currently, grassy areas within parking lots and medians appear to be elevated, vegetated and are likely compacted, offering few opportunities for storm water retention. In order to make use of these storage areas, medians and grassy areas should be excavated to approximately a 6-inch depth. This would allow stormwater runoff the opportunity to pond temporarily in medians and grassy areas delaying the timing for stormwater entry into the storm drain system. In areas where grassy areas already drain to roadways and ultimately to inlets and the storm drain system, this can be facilitated by reversing the slopes on existing drain pipes between the grassy areas and roadways to allow runoff to the roadways to drain to grassy areas and be temporarily retained. A map showing the areas identified for potential surface depression storage within the Downtown Arts District is included in Figure 15.

A summary of the potential stormwater volume delayed entry to the storm drain system by this practice is included in Table 6. Although these volumes appear small, if surface depression storage became a standard practice it would significantly reduce the magnitude and frequency of flooding within the City of Norfolk.

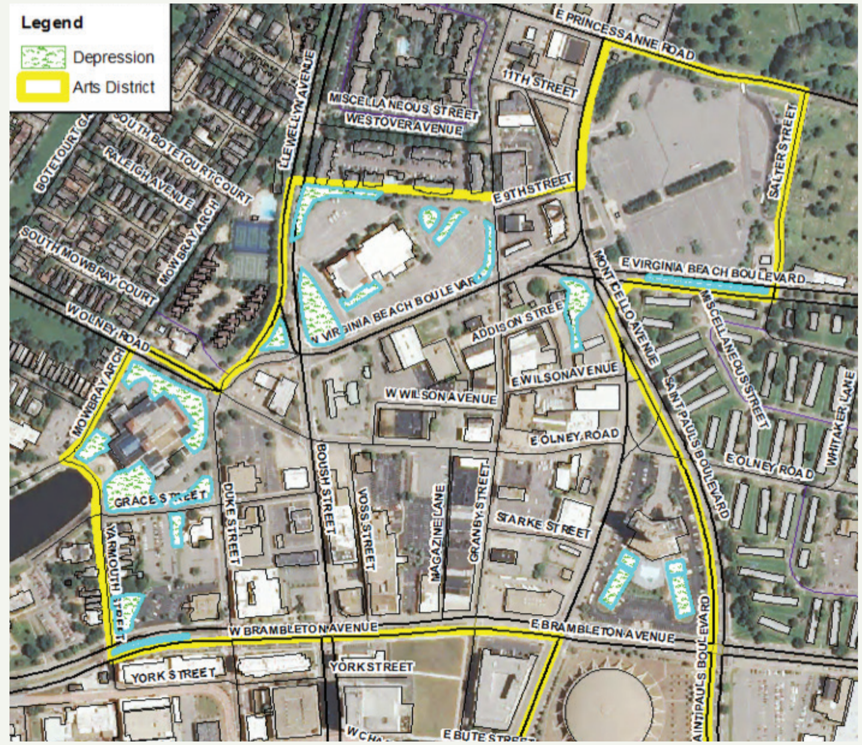


Figure 15: Surface Depression Storage Locations

	AREA (SQ. FT.)	VOLUME (CU. FT.)
Surface Storage	150,000	75,000

Table 6 - Summary of Stormwater Captured by Depression Storage

Solar Covered Parking Canopy

The Norfolk Downtown Arts District has many privately owned surface parking lots. These tend to be large, provide little shades and concentrate heat. One of the few publicly owned surface parking lot is along East Virginia Beach Boulevard. Currently underutilized, this parking lot could be used as an anchor renewable energy source while also providing a covered parking facility for patrons. A percentage of the lot's approximately 390,000 square feet area could be left open for vehicle drive aisles while the rest of the area can be covered by solar panels. Ten to twenty watts of solar power could be generated by every square foot of solar panel canopy provided.

This lot overlays a closed landfill which restricts the type of development that can be done on site. As penetration of the landfill cap is prohibited the drilling of foundation piers would not be possible, and larger above ground anchoring would have to be provided.

The power generated could be used to power overhead lighting within the parking area, to power charging stations for electric vehicles, or for electronic device charging stations so that cell phones and other personal devices to help maintain communication in the event of major prolonged power outages. Additionally stormwater runoff from the solar canopy could be captured and retained to delay entry into the storm drain system.

Although the large existing surface parking lot along East Virginia Beach Boulevard would be ideal as its size would allow for the generation of relatively large amounts of power in one contiguous area, solar canopies can be placed within any of the many surface lots within the City.

Cost Estimation & Benefits Assessment

Preliminary quantities and costs were developed for the various elements suggested within this document. These estimates are intended to give a basis for how financing of the proposed systems could be achieved. Cost estimates include environmental review and permitting costs, engineering design costs, construction supervision and inspection costs, and a 20% contingency allowance. Detailed background information on the development of costs and the various assumptions used are included in the Appendix. In addition to the development of capital costs and operations and maintenance costs, every effort has been made to develop unit benefit costs in order to quantify direct and indirect revenue and savings anticipated for the City by implementation of the recommended green infrastructure practices. The summary of construction and annual operating and maintenance costs are included in Table 7.

DESIGN ELEMENT	CONSTRUCTION COST ($M)	ANNUAL OPERATIONS & MAINTENANCE COST ($M)	TOTAL ($M)
The Downtown Arts District			
Blue Roofs (750,000 SF)	2.0	0.3	2.3
Raised Planter Boxes (2,500 LF)	2.0	0.2	2.2
Green Alleys (45,000 SF)	1.0	0.2	1.2
Permeable Pavement (7,500 SF)	0.2	0.03	0.23
Stormwater Tree Trench (3,300 SF)	1.0	.02	1.02
Surface Depression Storage (150,000 SF)	0.7	0.01	0.71
Solar Covered Parking (150,000 SF)	15	0.05	15.05
Technology Demo Areas (9 sites)	0.2	Negligible	0.2
The Hague Site			
Phase 1 - Flood Barrier	7.5	0.1	7.6
Phase 2 - Flood Barrier	17.5	0.2	17.7

Table 7 - Green Infrastructure Elements Construction and Operating Costs

In order to structure a financing and implementation plan for the proposed comprehensive flood management system, the team worked to define the direct and indirect beneficiaries of the proposed investment in order to monetize the value of these benefits. In the case of Norfolk, the following categories of beneficiaries would need to be involved in the project implementation and financing

Private Property Owners

Rising sea levels, tidal surges, and unmanaged stormwater flooding impact individual commercial and residential property owners within the City of Norfolk most directly. These property owners already have and will continue to see rising flood insurance premiums coupled with increasing costs for individual property upgrades. However, because of the high cost of flood insurance premiums and a lack of coordination, most property owners are investing in temporary protection (e.g. sandbags, sump-pumps) and regular damage cleanup rather than comprehensive upgrades. Providing investment incentives based on property value increases and insurance benefits could provide property owners with capital to invest in preventative upgrades and maintenance and realize greater savings.

City Government

The City of Norfolk is the primary party responsible for building and maintaining local flood management infrastructure, ranging from pumps to keep water off the streets and out of local businesses, to raising the height of seawalls to protect against rising seas and eroding shorelines. Given the projected costs of these investments, the City does not have the public funding available or sufficient revenue from their tax base to support all of the necessary infrastructure upgrades. However, the City would be a direct beneficiary of coordinated upgrades to private property that reduce risks and prevent flood damages to public property. In addition to providing direct flood management benefits, comprehensive green infrastructure upgrades also help to catch water where it falls, preventing discharges that exceed recently adopted Chesapeake Bay TMDL rules and regulations. Given that reductions to Total Nitrogen (TN), Total Phosphorus (TP) and Total Suspended Solids (TSS) are now mandatory for new developments and for redevelopment projects such as those planned with the revitalization of the Downtown Arts District, the RE.invest team reviewed each recommended green infrastructure strategy to estimate runoff reduction and calculate the pollutant removal efficiency on any remaining runoff volume. A summary of the pollutant reduction rates are included in Table 8[9].

[9] *Supporting data to accompany these values are included within the Appendix.*

BMP	AREA (Acres)	TN LOAD REDUCTION (lb/yr)	TP LOAD REDUCTION (lb/yr)
Blue Roof/Downspout Disconnection (D.A.A)	17.45	172.91	20.77
Permeable Pavers/Green Alley (D.A.B)	12.59	115.66	16.14
Surface Depression Storage (D.A.C)	3.44	7.01	0.98
TOTAL	33.48	295.58	37.89

Table 8 - Summary of Nutrient Load Reduction due to Green Infrastructure Practices

State/Federal Governments

In many cases, State and Federal governments are the primary source of funding following a disaster. For example, since Hurricane Sandy hit the eastern seaboard in October 2012, FEMA has provided nearly $3.9 billion in federal disaster assistance to affected areas. Given the increase in federal disaster declarations and the vulnerability of coastal cities, State and Federal agencies have a direct interest in protecting and increasing the resilience of a coastal city like Norfolk to reduce national disaster risk and financial liabilities.

Insurance & Re-insurance Firms

The public flood insurance market across the country is saturated and seeing annual double-digit increases in premiums. Private insurance companies see this as an opportunity to enter a new market, which they are doing slowly because they cannot at this point offer a better rate that the heavily subsidized existing insurance market. In the absence of infrastructure investments, current flood and storm risks are simply too high for insurers, and therefore the premiums they can offer are too high for most consumers. Many of the largest insurance and re-insurance companies have publicly expressed interest in supporting risk reduction measures that could allow them to actively diversify and manage risks—reduce damage payments—and reach new markets and policy-holders.

Translating these benefits into real sources of revenue requires adequate data to define cost allocations between parties and projected current and future savings, and also structures that make those cash flows more secure. Described below are a series of legal and financial structures that can be put in place to leverage those projected cash flows help to reduce financial risk.

Value Capture Mechanisms

While capital expenses for the proposed integrated flood management system are estimated to be large, the potential value created through reduction of local flooding, and protection against storm damage could conceivably justify the costs. Just like many large infrastructure projects, the proposed green infrastructure projects generally have greater economies of scale and higher resilience benefits when constructed in large segments versus as piecemeal investments by various private owners. Given that, the RE.invest team focused on structures to support financing the system as a single structure or a series of larger deals to capture the distributed benefits these projects en masse would create throughout the Arts District. The most important factors in securing this type of large-scale project finance are clearly defined ownership and management responsibilities that can capture benefits from green infrastructure and coastal protection systems as cash flows. Below is a set of models relevant to Norfolk. Each of these models would need to be adapted to match the City's administrative and financial needs and local resident and property-owner preferences.

Special Assessment Districts (Subheading that is the same size as "Public-Private Partnerships"). The City of Norfolk could structure a special assessment district that encompasses all existing properties within the Arts District with the aim of dedicating collected funds for flood-management investments throughout the area. Coupling those assessments with a portion of captured insurance savings would feasibly provide the City of Norfolk with sufficient revenue to capitalize major infrastructure investments like the ones described here.

If pursued, the RE.invest team would recommend the city consider a “pull-mechanism,” such as a competition, that creates market incentives for private properties to join the special district. Structuring a local competition that encourages individual blocks within the Arts District to collectively pursue green infrastructure strategies in return for a tax break could be a viable option.

Public-Private Partnership

Another option the City of Norfolk could explore is a public-private partnership (PPP) model structured in the United Kingdom. In the case of UK Coastal Management Partnerships, local governments were authorized to partner with non-profit, philanthropic and private entities to aggregate sufficient funds for investment in coastal protection infrastructure. In East Anglia, the British Marine Aggregates Producers Association (BMAPA), the Crown Estate, and the Centre for the Environment, Fisheries and Aquaculture Science (CEFAS) partnered to test the affects of aggregate dredging. In Pevensey Bay, the British Environment Agency tendered a 25-year design, build, operate and maintain public-private partnership to invest in coastal defense systems that would protect a 50-km2 area of low-lying land behind the coast. While at the outset of structuring this partnership there were legitimate concerns that capital costs of the project would be higher by using a PPP than if the public sector had secured a low-interest loan on its own, the concern proved to be unfounded. Instead, because of the careful focus on operational specifications and pre-negotiated cash flow conditions, the UK Environment Agency realized a better risk allocation than it would have on its own, created cost-saving innovations throughout the process, and improved the financial security of its position with an overall savings on project cost.

Norfolk could apply similar PPP models to facilitate more a cost-effective and comprehensive approach to flood mitigation infrastructure. By essentially 'privatizing' the self-deploying flood barrier and green infrastructure systems for a period of 30-50 years, both public and private entities could benefit.

Coordinating Corporate Investment (iPark)

The City could also explore a third-party investment strategy that leverages corporate interest in testing and demonstrating new green and/or resilient infrastructure technologies and economic development funds. By integrating "park-lets" into planned green infrastructure upgrades, the City of Norfolk would create an opportunity to test and analyze cutting-edge micro or household level water, energy and telecom technologies that could be integrated

into future capital improvement plans and system retrofits while also revitalizing public spaces for new community uses. Funds collected from companies for the right to demonstrate on these sites could be directed towards implementation and long-term maintenance of high-priority green infrastructure upgrades throughout the Arts District and beyond.

Given this opportunity, the RE.invest team considered how to integrate small platforms for corporate technology demonstrations into green infrastructure designs to make the entire system more attractive to private sources of capital to finance green infrastructure construction, operations, and maintenance, while attracting new economic development to the City. Within the Downtown Arts District there are abandoned lots already serviced by utilities, which could be set up as demonstration areas for various technology minded firms to showcase their projects. A typical site could be a 10-foot by 10 -4-6" thick concrete platform. These installations could rotate annually and be geared toward whatever themes the City of Norfolk is interested in showcasing. Power to these sites could be generated by small independent solar panel systems at each location.

Included in Figure 16 is a Demonstration Area Siting Map with proposed locations for Technology Demonstration Areas. These have been located in areas expected to have large volumes of pedestrian traffic to enjoy the installations. Major businesses or area features in close proximity to the sites have been identified as patrons from these establishments would be expected to get the opportunity to take advantage of the technology demonstration areas.

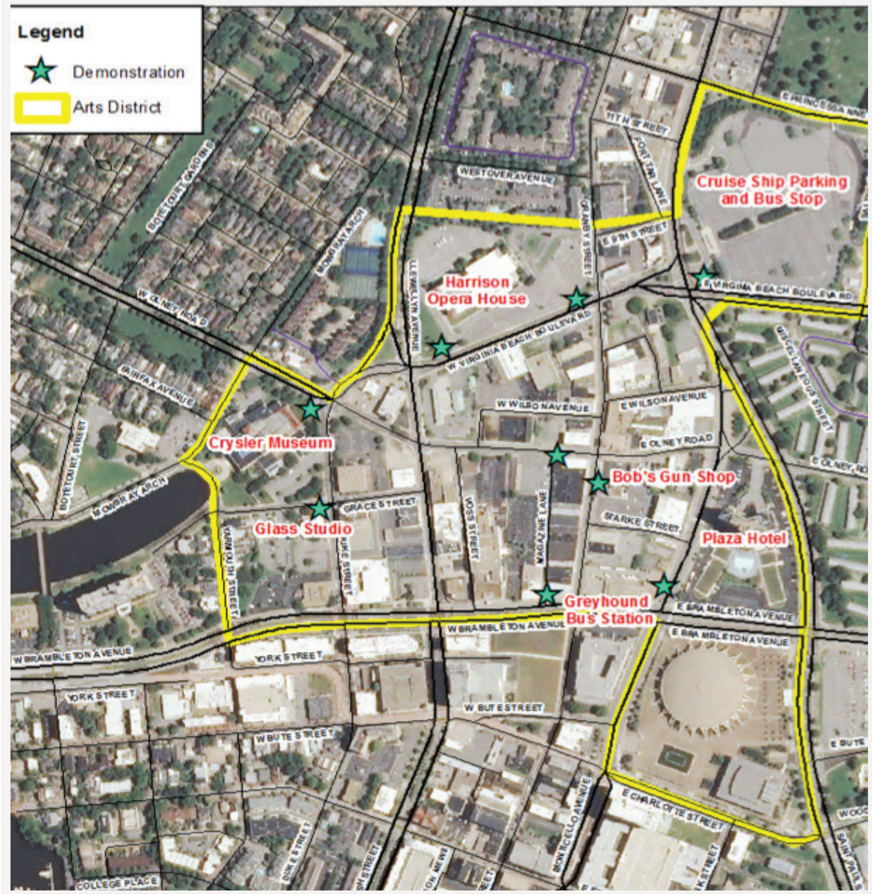


Figure 16: Demonstration Area Siting Map

RE invest

Implementation Strategies

The City of Norfolk's ability to create a special assessment authority or district that can levy taxes and/or fees as described, offers a unique opportunity for financing comprehensive resilience upgrades like the proposed floodwall and green/blue infrastructure solutions. Across the country, local governments have used these value capture mechanisms and borrowing against future tax revenues (i.e. tax-increment financing, TIF) to incentivize, if not directly finance, investments in areas with high private investment risk. These value capture mechanisms use special district-level taxes and community improvement fees to capture a portion of the value created for private property owners and developers as a result of public investments.

The same mechanisms used to capture value created for private entities by public investment in transport or drainage systems could, in principle, be applied to public or, if restructured, private investments that reduce disaster or insurance risks. Tax-increment financing is a form of value capture based on borrowing against future increases in market based land values and associated increases in tax revenues in order to finance investments in higher-risk areas. In Norfolk, by establishing that climate and/or disaster risks are directly impacting property values - TIF or similar types of value capture mechanisms should be available to finance flood management solutions on both public and private properties that would reduce those risks.

More generally, other value capture and savings based financial instruments such PACE bonds for energy efficiency retrofits and upgrades have been deployed with great success to support large-scale investments in private property, such as rooftop solar energy systems. In contrast to TIF mechanisms, PACE and similar instruments do not require the designation of any specific geographic area or district for funding eligibility, giving a city more flexibility to administer a broad program of upgrades.

The legal and financial structures described above are strategies the City of Norfolk could pursue today. At present, there is not sufficient density and/or household level data to compel third-party investors to invest. Given this, the RE.invest team has identified a series of partnerships that the City could pursue to increase the viability of private financing for flood management infrastructure projects. These strategies are described below.

Data Collection & Public Participation

In order to pursue any of the green and blue infrastructure options included above, the RE.invest team developed the following high-level implementation strategy for the City of Norfolk. The activities described offer a roadmap to streamline data collection, engage property owners, and ensure cost-effective design and construction of a comprehensive package of infrastructure designed to protect city residents.

To successfully implement any comprehensive resilient infrastructure projects, the City must systematically engage and get approvals from hundreds of private property owners and managers. The RE.invest team has explored models of participatory engagement that can support coordinated action but also participatory data collection and investment, and the following steps are offered as a model for Norfolk to creatively engage its residents in the planning, implementation, and financing of new resilient infrastructure protection projects.

Partner with technology firms and local businesses to build a new platform for local data collection on unreported flood-related costs and losses (short-term)

Crowdfunding and crowdsourcing platforms have been used for over a decade to successfully engage individuals in projects and causes. Some examples are Wikipedia (collaborative encyclopedia), Kiva (microfinance), Kickstarter (project funding), FoldIt! (games for health and science), and Kaggle (data analysis prizes and competitions). Government agencies including NASA have also used crowdsourcing tools to engage communities in participatory monitoring and citizen science programs to creatively fill budget shortfalls.

Because there are few property-level sources of data on Norfolk's current and historical losses from storms and flooding, the RE.invest team recommends that the City explore partnerships with one or more small technology firms, that have been successfully crowdfunding small scale community projects, to crowdsource data on flood related costs and losses, such as sand bag purchases, mold clean-up services, and wet-dry vacuum rentals or purchases. Using technology to engage residents on local priorities, the City can gather data on existing conditions of their flood protection infrastructure and their experiences with flooding. By constructing a detailed profile of losses, the City can then pursue savings based financing such as a social impact bond, mini-bond, or catastrophe bond. Other options include partnering with local flood protection or clean-up related small businesses to aggregate data and assess patterns of flood risk and loss or even working with large companies and corporate foundations, such as the Mastercard Foundation, to track local expenditures on "indicator" products associated with clean-up or flood related repairs.

Set-up a system of prizes and rewards to encourage participation (short-term)

In order to maximize local participation in data reporting, the City can also consider working with local businesses to offer incentives to participating residents. For example, residents who share information can register to serve as local "resilience champions" or receive updates on public meetings, and in exchange, they could get discounts with participating merchants selling products to improve their resilience (e.g. emergency preparedness supplies, free sandbags, solar chargers, etc.). Rewards can also be tiered based on the level of participation or environmental monitoring that residents provide over time.

Launch a competition or a "Race to Resilience" to get public buy-in, accelerate local approvals and construction schedules, and reduce costs (medium-term)

After a final design is selected and approved, the City should also consider implementing a competition to get residents to sign-up to be first "block" to upgrade their flood management infrastructure. A competition organized around predetermined segments could encourage residents to sign-up with their neighbors to be the first in line for implementation. The blocks with all residents who "approve" the project and agree to start construction first can also be offered other financial incentives. If a design-build or public-private partnership approach is pursued by the City, then this type of competition could be integrated into the public outreach and community engagement components of the project.

Involve residents, schools, and local universities in evaluating the system and reporting benefits (long-term)

Similar to highway clean-up volunteer organizations, the City can consider how to also engage residents in ensuring the long-term health of the local coastal protection system. Schools could be engaged to "sponsor" sections of the wall to regularly conduct environmental monitoring and visual inspections. For more complex analyses, local universities can provide additional capacity for monitoring hydrological conditions and evaluating risk reductions over time.

Together the steps above offer a cost-effective roadmap for implementing infrastructure solutions that require local property-owner participation and approvals.

Innovative Financing

Redesigning Catastrophe Bonds

Traditionally, insurance instruments do not create new streams of capital for reinvestment in risk reduction measures. However, in recent years a number of insurance models have emerged in the healthcare industry that can be applied to climate and disaster risk management. For instance, in 2006 ICICI Prudential launched a specialized insurance policy for people with Type 2 diabetes and pre-diabetic symptoms. The policy covers not only treatment, but also the cost of a preventative wellness program, and reduces insurance premiums for individuals who demonstrate good control of their condition. Applying this approach to risk management in coastal cities like Norfolk, offers a model for how insurance policies and premiums can be structured to create special funds for investment in upfront risk reduction measures in addition to covering potential losses.

Based on these models, and the fact that insurance is an instrument for reducing the extent of losses for those holding assets in city systems – its clear that insurance mechanisms can be an important financial instrument to mobilize capital for urban infrastructure. In the case of Norfolk, the proposed set of flood management infrastructure options are likely to reduce both the rate of insurance premium increases and total damage claims. This combination of benefits provides an opportunity to assess and capture savings to both individual property owners and to local and international insurance firms.

One of the tools that the insurance industry has developed to hedge their financial risks is a catastrophe bond. Currently passive financial instruments, where proceeds are held in managed funds and payouts occur only when eligible catastrophic losses can be claimed. In years where such an event does not occur, the invested funds generate a return that is paid out to private investors willing to assume the risk. These investment interests are very attractive to investors seeking to diversify their portfolios since disaster risks are generally uncorrelated with other market-based investment risks. An actively structured catastrophe bond would function more like a social impact bond, which is designed to generate funds to finance specific projects that reduce a social ills, costs, or risks over the long-term.

Generally catastrophe bonds are issued by reinsurance firms and/or large public entities (i.e. Mexico's national government or the World Bank) to provide diversification of risk across geographies or sectors. However, re-insurance companies are now exploring their ability to issue private catastrophe bonds that would allow them to build a diverse portfolio of specific kinds of catastrophic risk across a large number of cities. In this structure, private re-insurance companies have an incentive to use a portion of the proceeds to finance resilience upgrades and risk mitigation measures in participating cities in a way that establishes predictable reductions of the risks and damages covered by the bond.

Given the current market appetite, the RE.invest team recommends that the City consider options for partnering with the Navy and/or State of Virginia to explore a catastrophe bond similar to Mexico City's current bond structure or the World Bank's June 2014 issuance covering 16 Caribbean islands for storm and flood risks. An important prerequisite for the City is having baseline data that definitively documents not only predictable losses and damages from rising sea-levels and storm surges, but also shows anticipated future savings based on planned resilience investments, such as the self-deploying flood barrier.

Creating Pooled Funds

The challenge with investing in any structural retrofit as is proposed will all of the RE.invest engineering solutions, is that working within existing properties and building stocks is complicated. Beyond that, often the financial savings are distributed and can only be accrued over a long period of time. Traditionally public financing has leveraged taxing authority, through TIF and other structures, to capture distributed benefits. And since the 1970s, the private sector has created other mechanisms to capture sector-specific savings effectively – particularly through the energy efficiency and renewable energy sectors via ESCOs and the PACE program. Now that the practice is well understood it is starting to be applied more broadly to support infrastructure investments that generate significant longer-term financial value, and the City of Norfolk could leverage this market interest to support green and blue infrastructure upgrades the produce flood management benefits.

In California, the City and County of San Francisco has leveraged this expanding market interest to structure a pooled fund to support seismic retrofitting private buildings to implement their Community Action Plan for Seismic Safety – a $1 million study to understand the areas earthquake risk. The CAPSS is similar in many respects to the investments Norfolk has made in flood management studies by Fugro, and outlines a series of important steps that must be taken by the City and residents to prepare for the worst impacts.

One of the first steps taken by San Fransisco under the Earthquake Safety Implementation Program was to sign into law the Mandatory Soft Story Retrofit Ordinance, which requires evaluation and retrofit for multi-unit soft story buildings. To support both mandatory and voluntary retrofits, the City created a grant fund to support earthquake retrofit upgrades, but learned quickly that funding, even when coupled with an ordinance was not enough to compel action. Because any retrofitting comes with high up-front analysis and transactions costs, the grant funds to support construction were seen as too little too late for many private property owners. Interested in motivating both mandatory and voluntary retrofits, the City of San Francisco approached Alliance NRG, an energy service company, and Deutsche Bank to restructure their grant funds into a public financing option.

Launched in the Fall of 2014, the program is has a simple structure – Deutsche Bank provides the upfront capital guarantee to Alliance NRG, who then accepts applications from individual property owners and manages the upgrade process from design through construction. Alliance NRG has a contractual relationship with the City to recoup their investment plus interest via an additional line item on each participating property owners' regular property tax invoice from the city.

In order to pursue this financing model to support green and blue system upgrades, the City would need to first define relevant project types, structure a mandate that covers those upgrades, and coordinates relevant contractors who could provide the upgrade services. In addition, the City

For an easy-to-read overview and history of the Cat Bond market from Hurricane Andrew to Hurricane Katrina, see Michael Lewis' In Nature's Casino (New York Magazine, August 2007). In anticipation of the 2015 UN Conference of the Parties in Paris, the International Council on Science (ICSU) has released a "Road to Paris" series. For a current summary of the Cat Bond market landscape, see Leigh Phillips' Cat Bonds: Cashing in on Catastrophe (ICSU, November 2014.)

must be able to credit those private property owners investing in green and blue upgrades with savings via property tax assessments. Unlike on-bill savings, which accrue to property owners directly in the form of reductions to bills, the savings created in this model would accrue to the wastewater utility and the system more broadly. While any single property may not make a large impact, the collective impact has the potential to be significant for the City.

Like the soft-story pooled fund in San Francisco, the selected green and blue infrastructure contractor(s) would need to accept applications from property owners, and manage the upgrade process from design through construction. The contractor(s) would require a series of contractual relationships to recoup their investment plus interest. The first contract would obligate property owners to pass-through water bill savings, and a second agreement with the City and/or local utility would ensure the contractor receive an annual or semi-annual payment that scales based on system-wide savings accruing to the City. This pooled fund would go beyond providing financing to help streamline the upgrade process and reduce transaction costs in a way that can also increase project uptake.

While none of the proposed strategies will produce wholly private financing options for green and blue infrastructure upgrades in the short term, when combined they can offer a menu of options for the city to support long term resilient infrastructure investment.

REinvest Innovations

To address frequent flooding issues that limit economic redevelopment, the City of Norfolk should invest in integrated flood management solutions in the Arts District and beyond – including green infrastructure options and seawall upgrades.

- Integrate gray and green infrastructure solutions
    - Consider how flexible flood barrier investments can be incorporated into wider redevelopment plans
    - Integrate green infrastructure into development plans and incentive programs for private developers
- Consider financing options, such as tax-increment finance (TIF), to capture real estate value increases from flood protection measures and green infrastructure upgrades
- Calculate "avoided losses" and potential financial savings due to reduced chronic flooding
    - CSO Capacity Payments – Fees and/or Long-Term Lease Agreements
    - Parking Revenues – Rates and/or Long-Term Contracts
      Surface recreational areas with green infrastructure for stormwater capture
    - Avoided Flood Damages – Reduced damages and/or insurance premiums
- Partner with technology firms and local businesses to crowd-source data on unreported losses, such as flood damages or mold clean-up, to quantify potential savings and monetize projected benefits to accrue to residents and small businesses
- Create public programs and local competitions to encourage community-based action on a menu of green infrastructure options

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APPENDIX
iPARK NORFOLK

The Challenge

Green space is a public good. But cost effective maintenance of these community spaces has traditionally been a fixed cost for local governments. Even in cities that have prioritized flood management investments, major and necessary upgrades like flood barriers and expanding and maintaining productive green and open space is a challenge.

Cities across the country, like Norfolk, have been exploring new ways to increase investment in green infrastructure and other flood management technologies that protect their residents, local businesses and street infrastructure from regular damage. At the same time, private companies looking to test and deploy innovative technologies have struggled to demonstrate their municipal and household solutions in the face of multi-year environmental review and permitting processes. Rather than targeting US markets that have the greatest infrastructure upgrade needs, these companies have set-up testing sites in friendly R&D environments. For example, Israel has become a hub for innovative US water technology companies, while cities like Norfolk struggle to access and finance cutting-edge green infrastructure and flood management solutions.

This proposal is designed to address these two very different challenges by designing and structuring educational and interactive technology demonstration spaces in and around Norfolk's developing Arts District to support not only the cities flood management, but also economic development goals.

The Opportunity

To complement ongoing flood management efforts, iPark Norfolk is a proposal to develop a set of interconnected "park-lets" on municipally-owned parcels to serve as demonstration sites for innovative technology installations. Similar to a World's Fair or an interactive museum, a set of carefully curated resilient technology exhibits can serve both community and local government needs, while creating channels for private sector engagement in infrastructure upgrading.

Through this series green infrastructure investments that double as park-lets, the City of Norfolk will have an opportunity to test and analyze cutting-edge micro or household level water, energy and telecom technologies that could be integrated into future capital improvement plans and system retrofits while also revitalizing public spaces for new community uses. By developing these sites as museum-quality demonstration spaces, the City can take an alternative approach to attract leading companies from around the world, engage residents and tourists alike in building local resilience, and promote sustainable economic growth.

Funds collected from companies for the right to demonstrate on these sites can be directed towards implementation and long-term maintenance of high-priority green infrastructure upgrades throughout the Arts District and beyond. Additionally, these funds could be directed to support educational programs focused on the impacts of sea-level rise on coastal communities. In any case, a public-private partnership structure to govern the park and exhibit spaces would be designed to provide maximum public benefit.

The Proposal

Based on guidance from the City of Norfolk, the RE.invest team would suggest the city utilize small parcels associated with identified green infrastructure upgrades in the Arts District. Specific municipal and/or utility owned parcels to be determined. Depending on size and underlying characteristics of the selected sites, each parcel will be developed using the following criteria:

- Maximize green infrastructure. Coordinate with the broader green infrastructure plans in an effort to create a trail of breadcrumbs across a series of areas within the City that is both walking friendly and can serve as a productive flood management system.
- Maximize education and interaction opportunities. In an effort to make the space productive for both sponsoring companies and visitors, it will be important that all demonstration sites include educational and interactive components.
- Prioritize a mix of short-term prototype and longer-term installation demonstrations. In an effort to meet the anticipated funding needs for green infrastructure upgrades, the structure will prioritize an equal mix of temporary and longer-term demonstrations.

iPark Norfolk management structure could be based on the following parameters:

Legal Consideration	Available options
Management	An entirely separate management entity established as a Non-Profit or B-corp offers the greatest flexibility in managing the site operations and finances, capturing value, establishing partnerships, and curating the demonstration spaces. The City could also choose to establish authority within an existing local entity, for example within the Department of Economic Development. Regardless of structure, the entity should be responsible for managing incoming cash flows, distribution of funds to partners and for the community benefit (via contribution account, enterprise fund, etc.). The City should also determine the level of formality of its relationship with the management entity – options range from an informal but close working relationship to a more formal role as an Executive partner or Board member, through an MOU or formal agreement.
Land Ownership	Several ownership options can be considered based on city development priorities. The City can maintain ownership of individual parcels outright and cover any liability issues. The City can also maintain ownership of individual parcels but pass liability onto the demonstrator by signing a lease with the managing entity that includes clauses that facilitate site development. The City could also sign a low-cost transfer to the management entity that includes a cancellation clause should the City determine a more productive use of property after a certain time-period.
Community Benefit	The City can define a range of required community benefits that the management entity must meet. For example, the City could require funds support system upgrades in accordance to pre-determined plans including capital to support construction and/or O&M of green infrastructure. In addition, the City can designate funds to support various education or redevelopment efforts (i.e. Better Block).

Type of Partner	Financial Interest	Target[s]*
Demonstrator	Based on the sponsoring partners, the management entity would secure an initial set of companies to deploy either prototypes or in-system installations. Depending on the relationship established between the sponsoring partners and the management entity, demonstrating partners may be asked to contribute financially to the site either via equity or a lease fee.	• Consumable goods (i.e. energy efficiency, renewable energy, water efficiency products for households) • Coastal management products
Sponsor	The management entity would secure 1-2 site sponsors to contribute funds that support site operations and maintenance in exchange for either first look rights at demonstrated technologies (i.e. MIT Media Lab) or access to demonstration sites (i.e. San Jose Environmental Innovation Center & Demonstration Center).	• Fortune 500 companies with large R&D arms t • Venture capital firms actively investing in (1) consumable sustainability or efficiency focused technologies, (2) coastal management products • Coastal management products

* Should not be considered a comprehensive list of options for the City, but rather as a point of departure for discussion of some of the pathways available for consideration.

RE.invest INITIATIVE
NORFOLK, VA

DRAWING INDEX

SHEET NO.	DRAWING NO.	DESCRIPTION
GENERAL		
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2	G-2	ABBREVIATIONS, LEGENDS & NOTES
CIVIL		
3	C-1	ARTS DISTRICT - CONCEPTUAL PLAN
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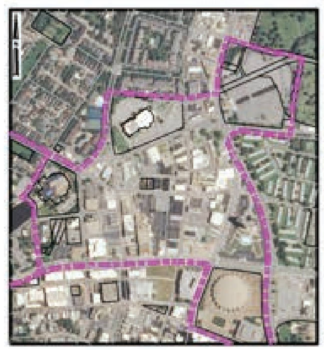
SHEET NO.	DRAWING NO.	DESCRIPTION
CIVIL		
8	C-6	ARTS DISTRICT AREA PLAN 4
9	C-7	THE HAGUE - FLOOD BARRIER PLAN
10	C-8	DETAILS - PERMEABLE PAVEMENT
11	C-9	PLAN / PROFILE - GREEN ALLEY
12	C-10	PLAN / PROFILE & SECTION STORMWATER TREE TRENCH
13	C-11	PLAN / PROFILE & SECTION - SURFACE DEPRESSION STORAGE

PROJECT SITES

VICINITY MAP
NTS



ARTS DISTRICT
NTS

THE HAGUE
NTS

NOT FOR CONSTRUCTION

RE invest investing in resilience. investing in communities.

GENERAL

TITLE SHEET, LOCATION MAPS & DRAWING INDEX

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Drawing No. G-1
Date 04/04/2014
Sheet 1

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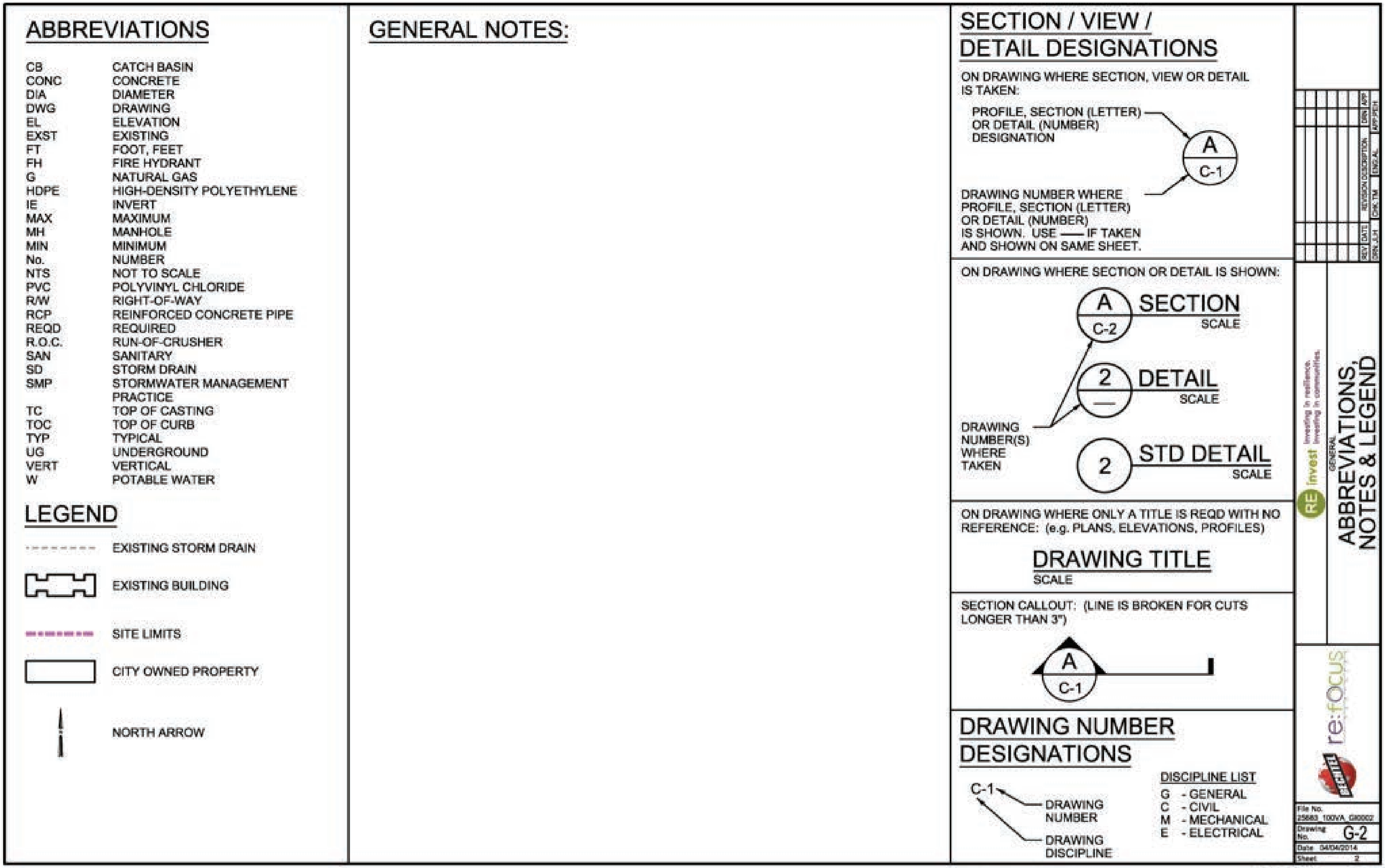

ABBREVIATIONS

CB	CATCH BASIN
CONC	CONCRETE
DIA	DIAMETER
DWG	DRAWING
EL	ELEVATION
EXST	EXISTING
FT	FOOT, FEET
FH	FIRE HYDRANT
G	NATURAL GAS
HDPE	HIGH-DENSITY POLYETHYLENE
IE	INVERT
MAX	MAXIMUM
MH	MANHOLE
MIN	MINIMUM
No.	NUMBER
NTS	NOT TO SCALE
PVC	POLYVINYL CHLORIDE
R/W	RIGHT-OF-WAY
RCP	REINFORCED CONCRETE PIPE
REQD	REQUIRED
R.O.C.	RUN-OF-CRUSHER
SAN	SANITARY
SD	STORM DRAIN
SMP	STORMWATER MANAGEMENT PRACTICE
TC	TOP OF CASTING
TOC	TOP OF CURB
TYP	TYPICAL
UG	UNDERGROUND
VERT	VERTICAL
W	POTABLE WATER

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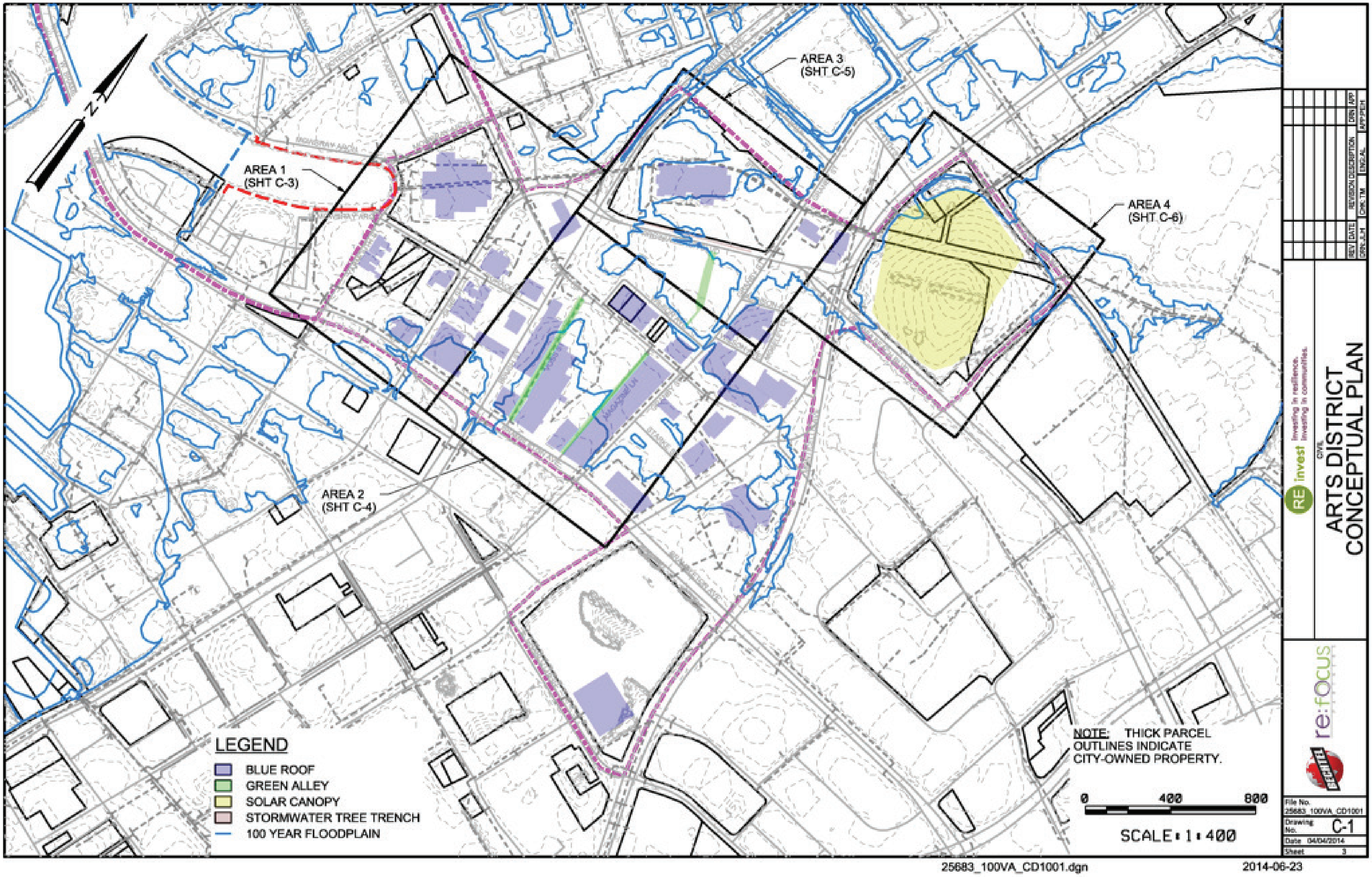
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AREA 4
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GREEN ALLEY
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STORMWATER TREE TRENCH
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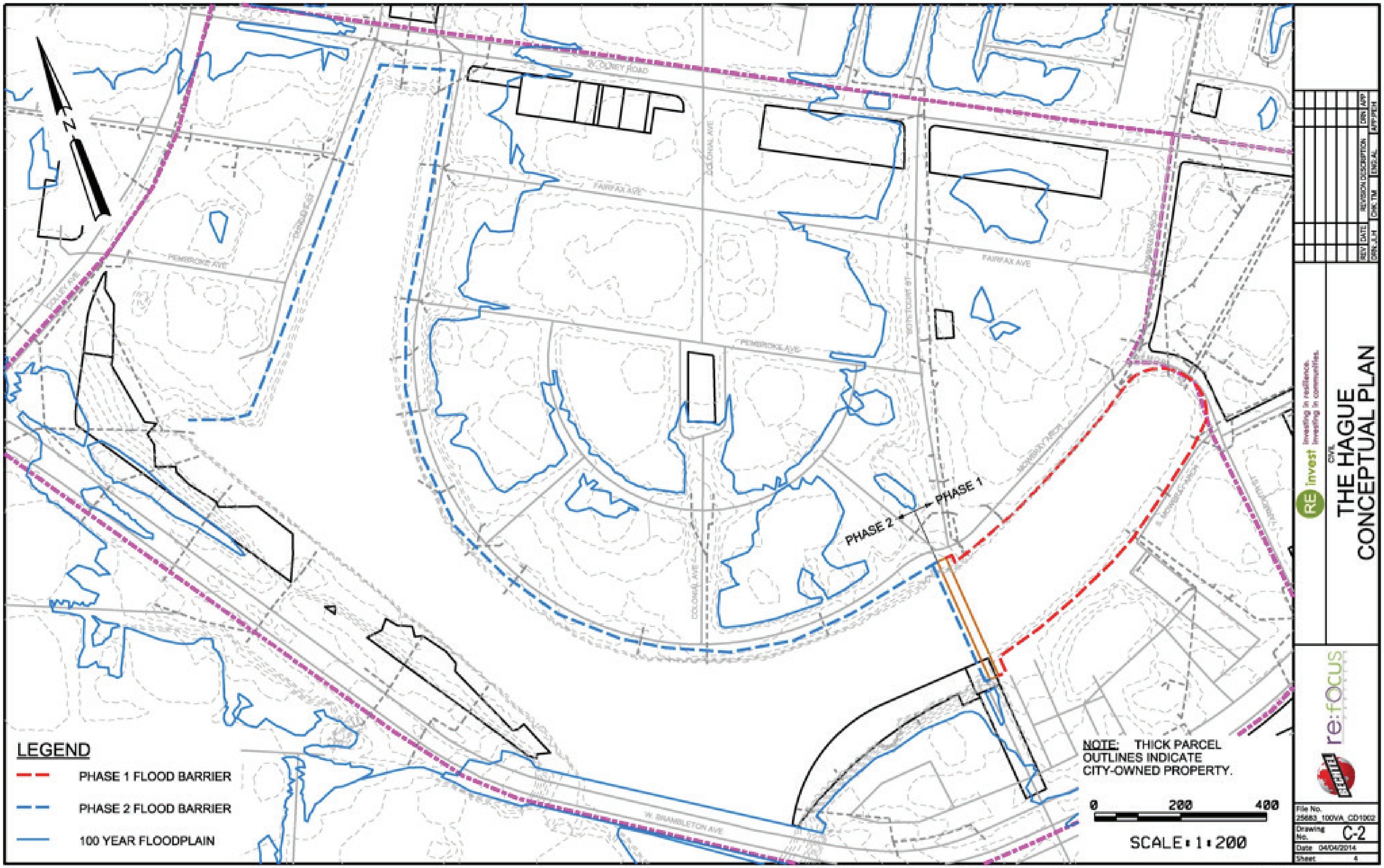

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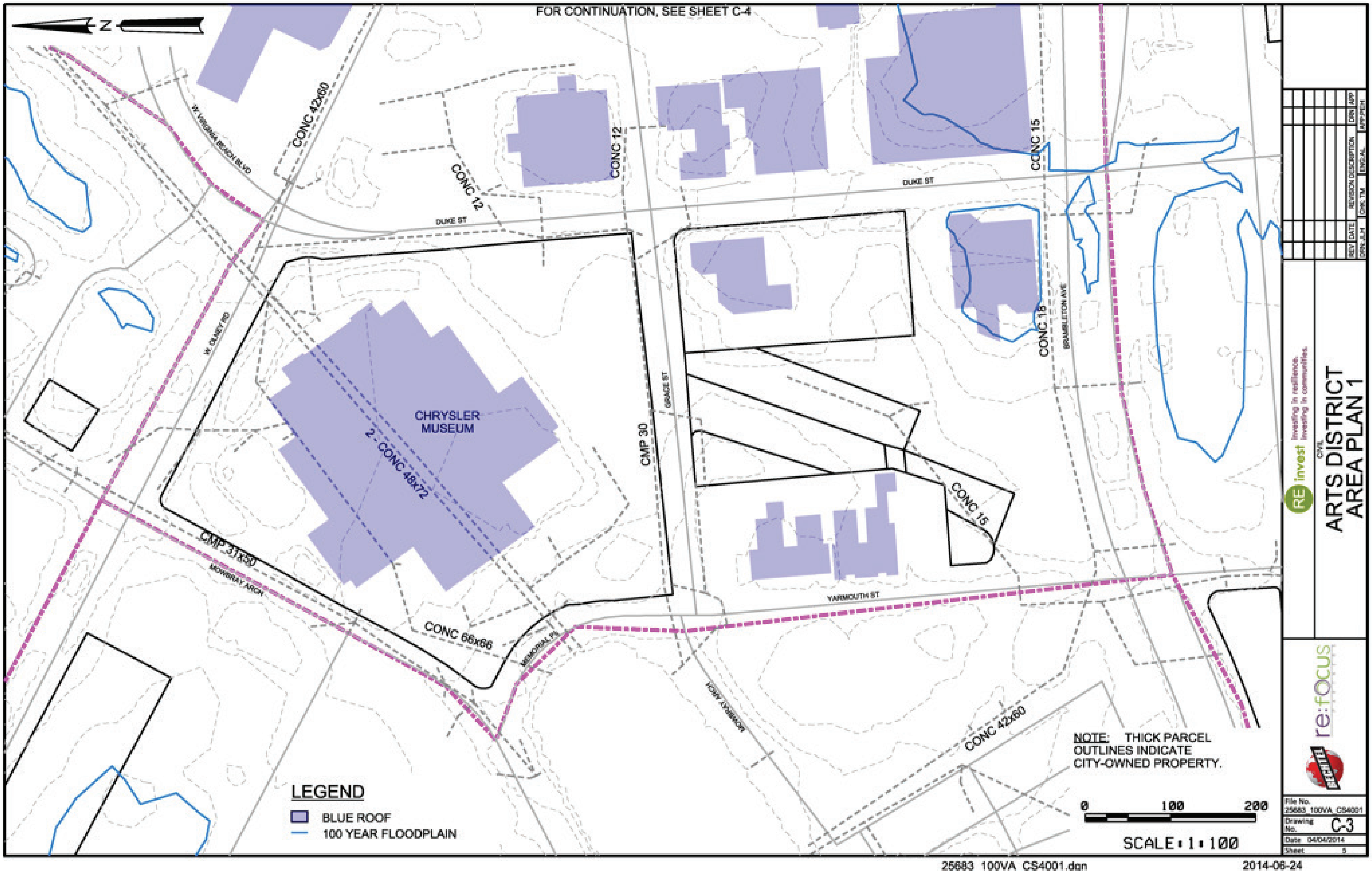
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YARMOUTH ST
GRACE ST
BRAMBLETON AVE
W. OLNEY RD
W. VIRGINIA BEACH BLVD
MOWBRAY ARCH
MEMORIAL PL
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Date 04/04/2014
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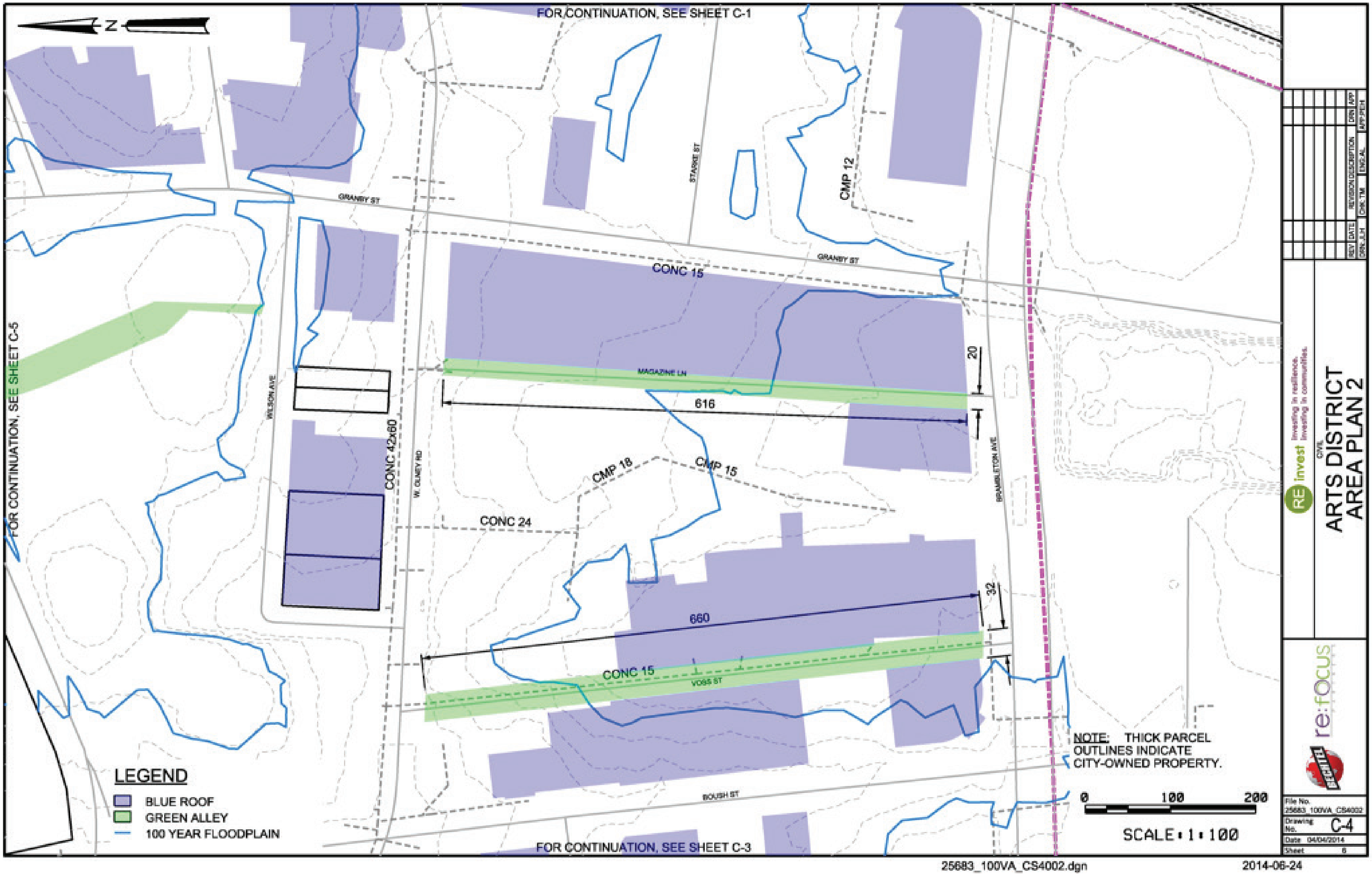
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FOR CONTINUATION, SEE SHEET C-5
FOR CONTINUATION, SEE SHEET C-3
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VOSS ST
BOUSH ST
LEGEND
BLUE ROOF
GREEN ALLEY
100 YEAR FLOODPLAIN
NOTE: THICK PARCEL OUTLINES INDICATE CITY-OWNED PROPERTY.
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CIVIL
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Date 04/04/2014
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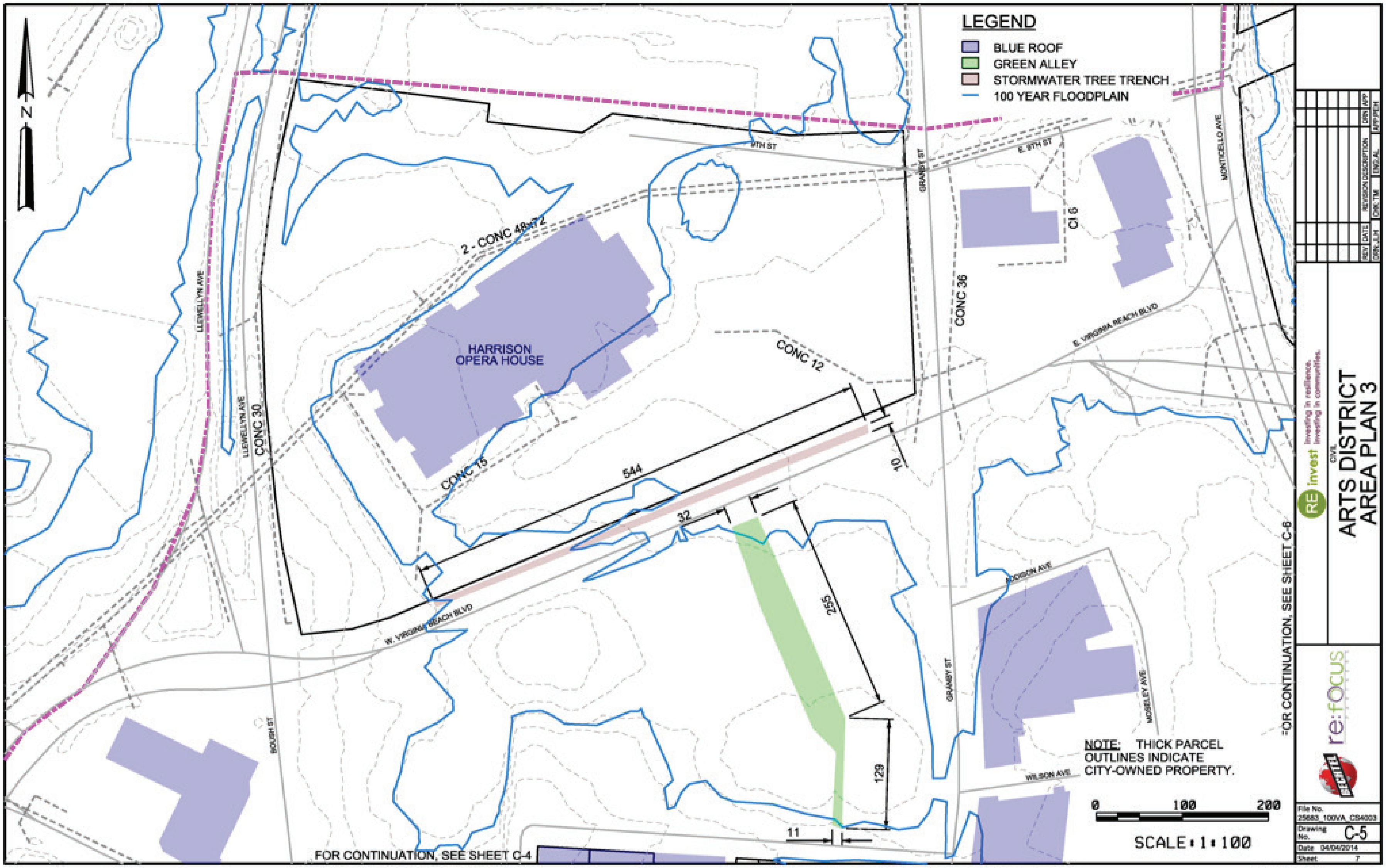

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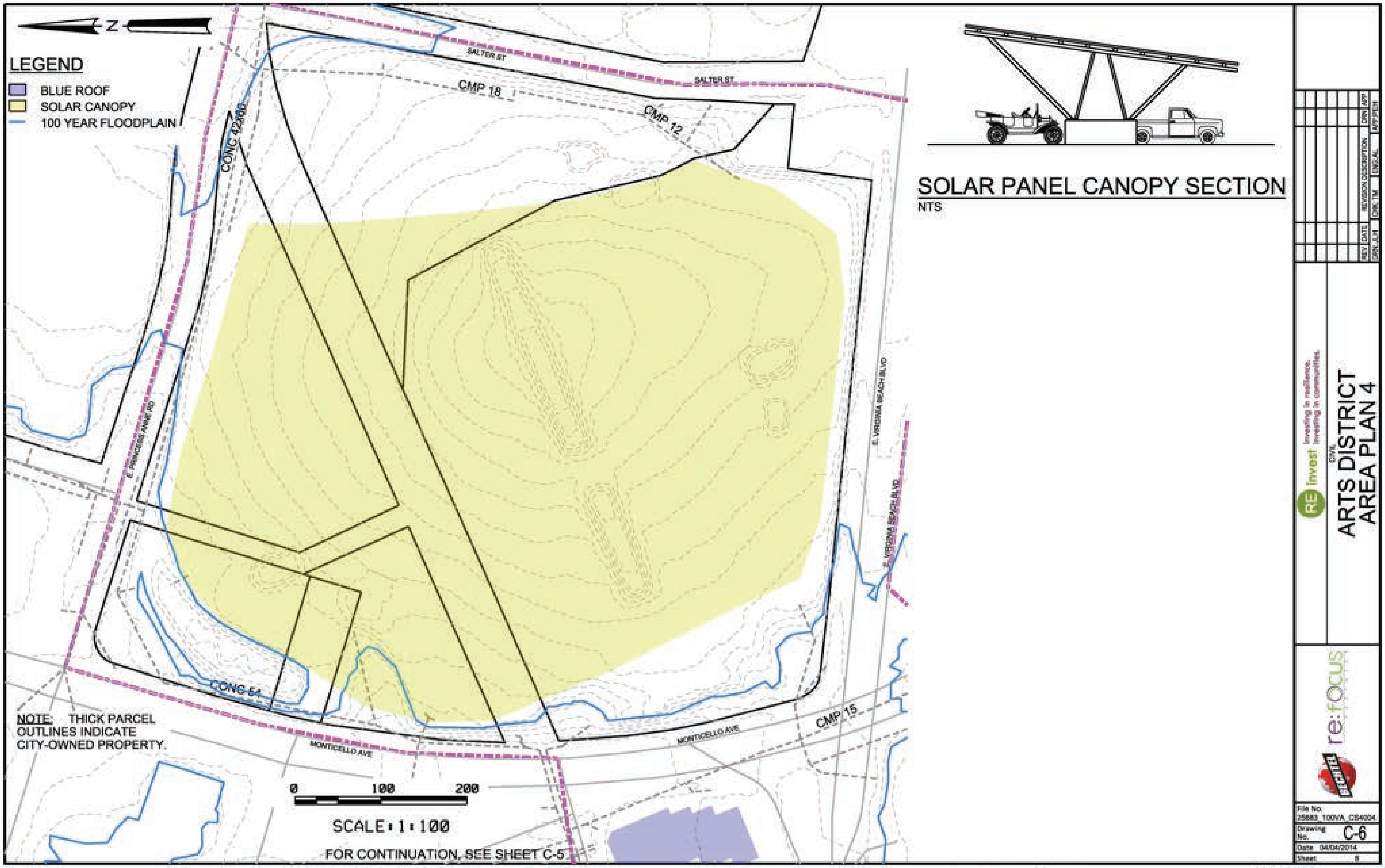

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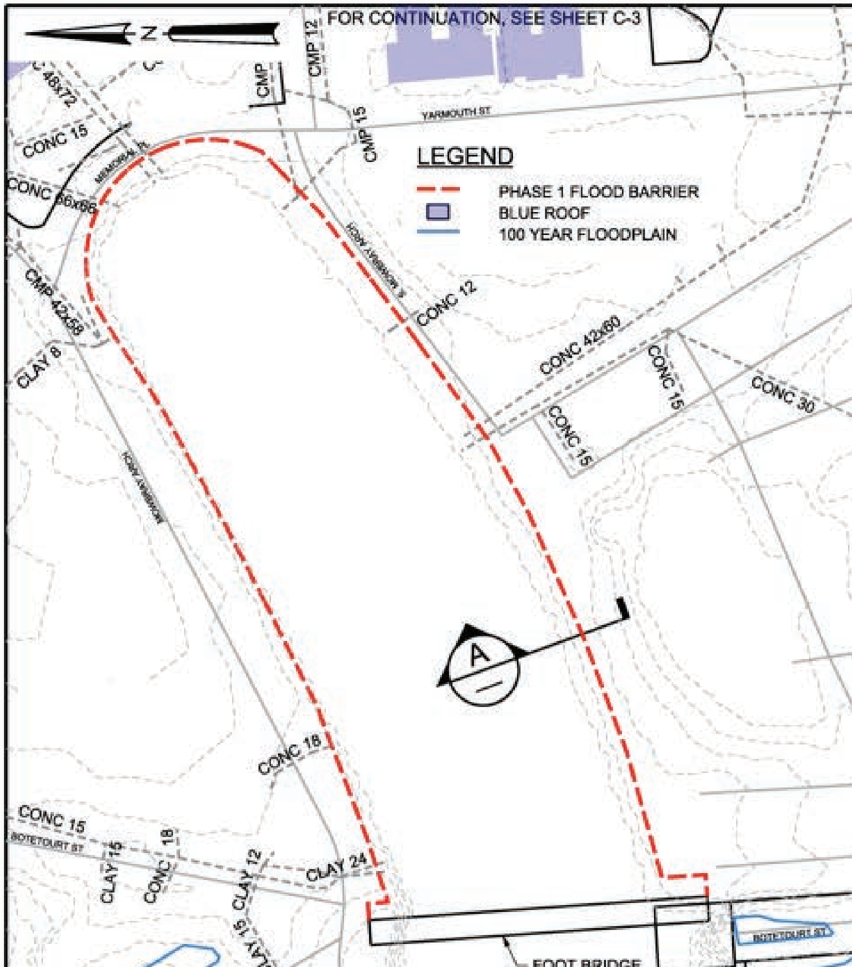
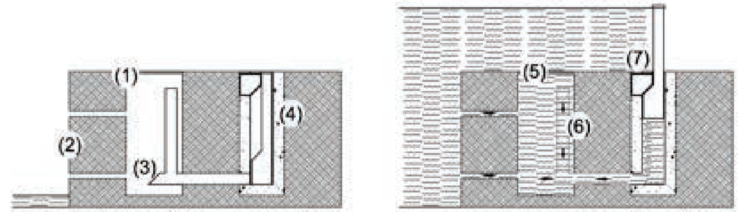


PHASE 1 HAGUE FLOOD BARRIER

1" = 100'



All components are hidden below the surface. The activation basin or service pit (1) will follow the tides through one or more inlet pipes (2).

A one-way check valve in the drainage outlet (3) prevents incoming water from flowing into the main basin containing the floating wall (4).

When the water reaches flood level (5), the main basin will fill up through a vertical inlet pipe (6) in the activation basin. The barrier will automatically rise to its full height.

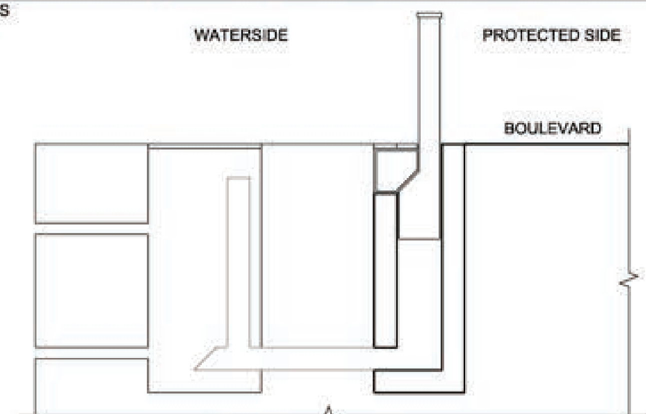
Once raised, a steel cap or block (7) will lock the barrier into position making it watertight.

The barrier is raised before the floodwater crosses the quay and will remain in place until the water subsides.

The floodwater can continue to rise without flooding the protected area. In riverside locations, the service pit can be drained through gravity drainage when the floodwater recedes. On sites where gravity drainage is not possible, a pump is needed to lower the barrier to its resting position. In all other cases, the barrier operates 100% without the need for an energy source or human intervention. Once lowered, the top of barrier seals itself to prevent inflow of waste or debris.

OPERATION OF THE SELF CLOSING FLOOD BARRIER

NTS



A SECTION

NTS

THE HAGUE - PHASE 1
FLOOD BARRIER PLAN

CIVIL

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Drawing No. C-7

Date 04/04/2014

Sheet 9

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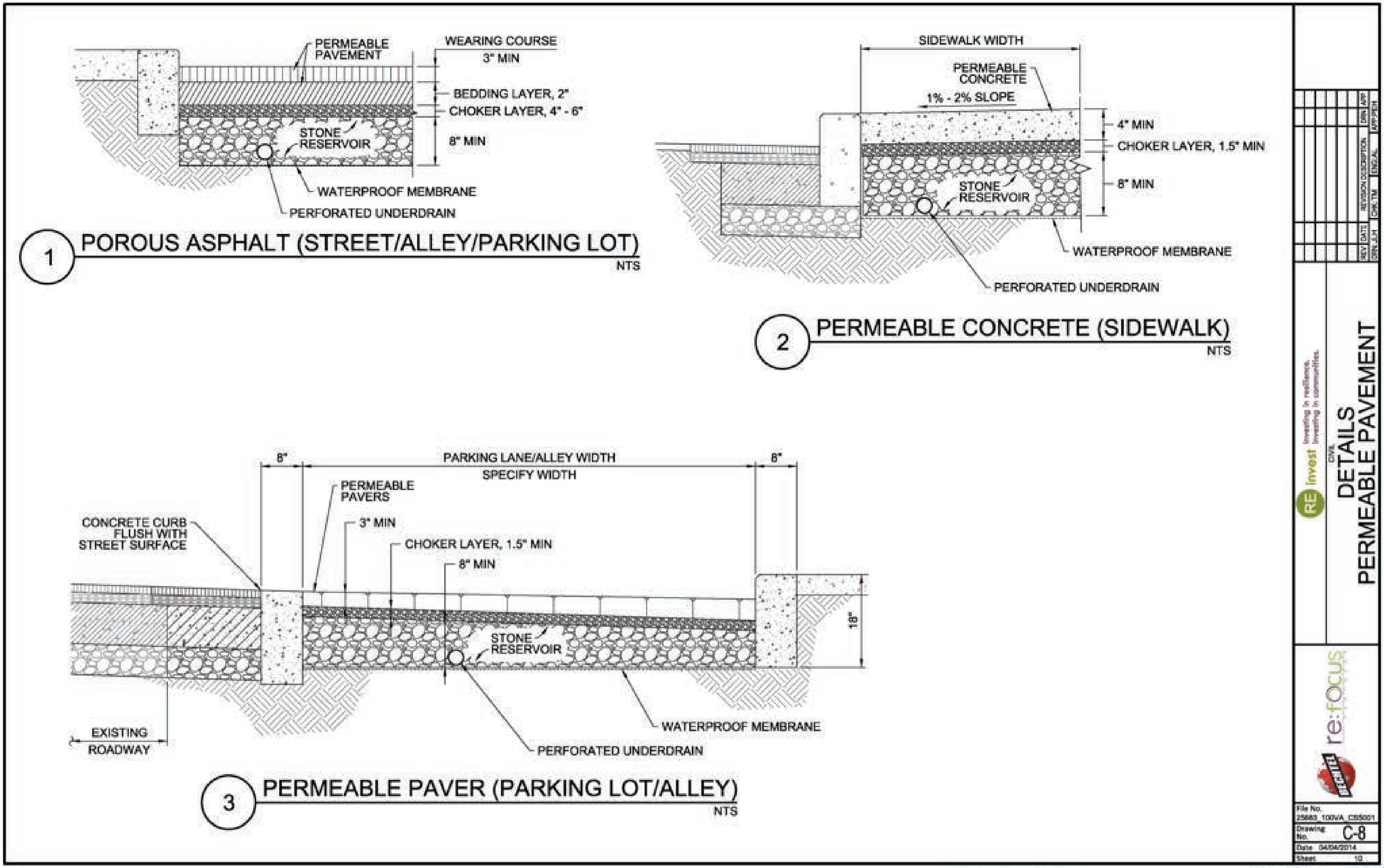

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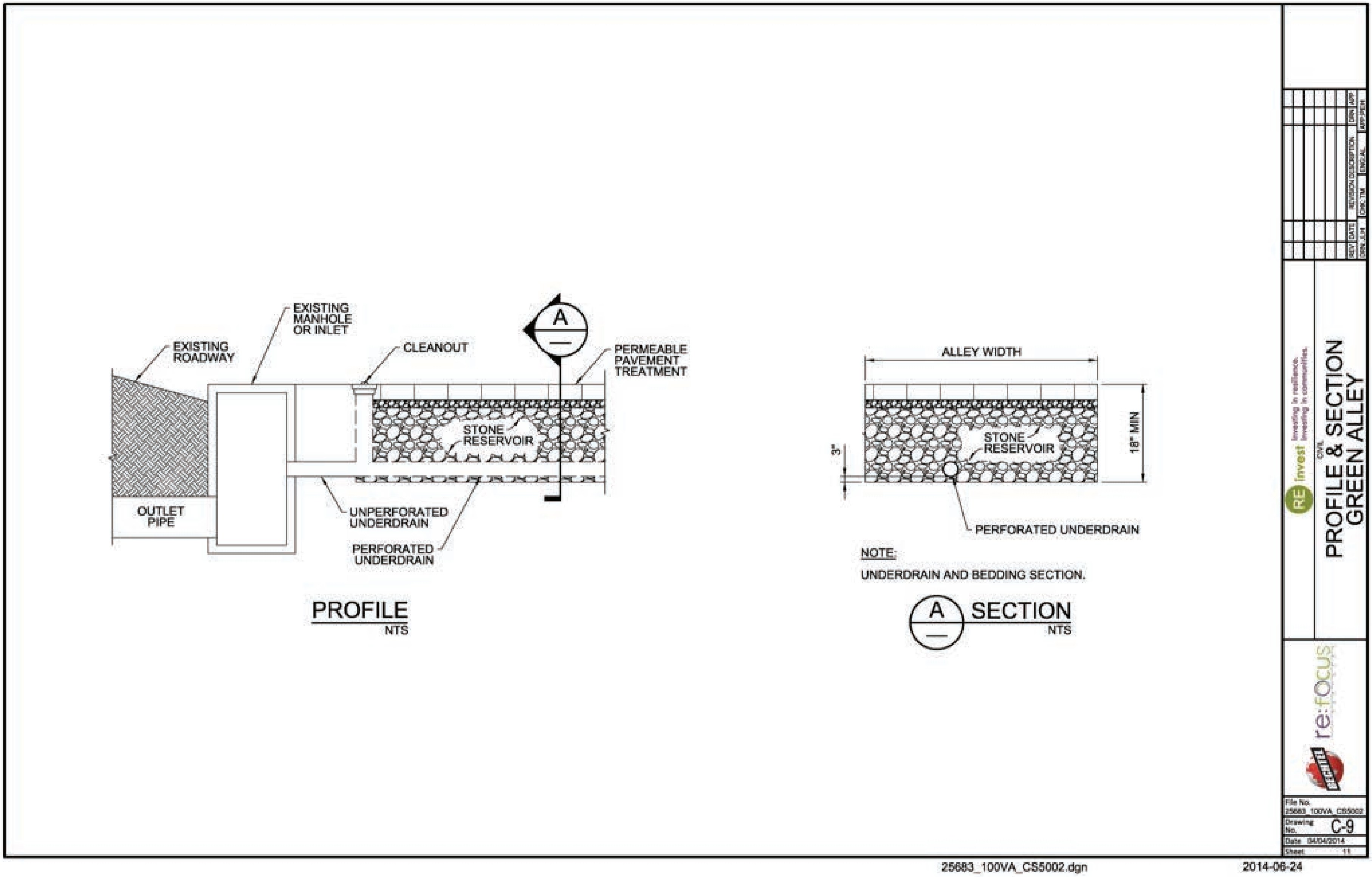
EXISTING ROADWAY
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A
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OUTLET PIPE
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UNDERDRAIN AND BEDDING SECTION.
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PROFILE & SECTION GREEN ALLEY
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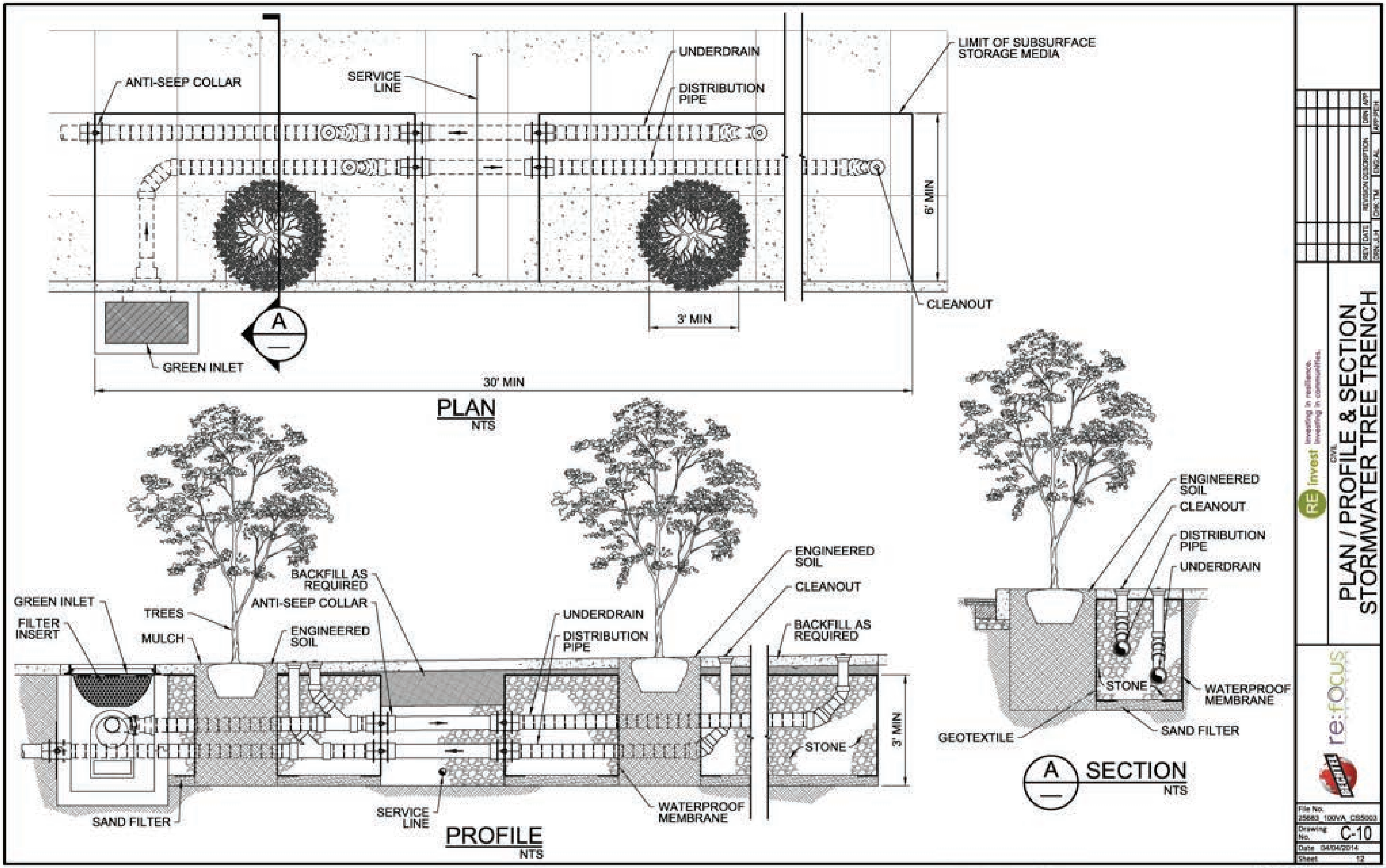

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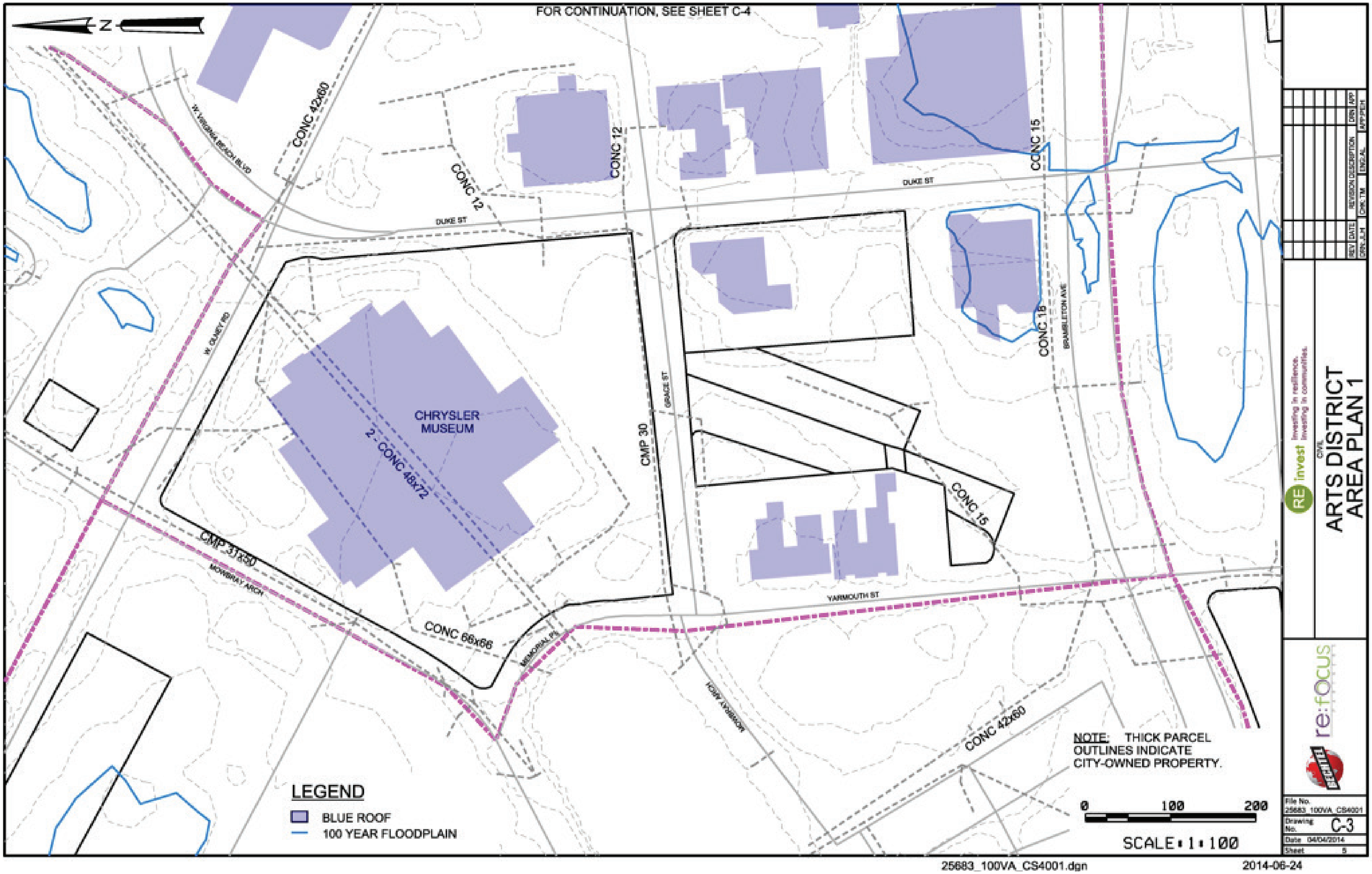
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YARMOUTH ST
NOTE: THICK PARCEL OUTLINES INDICATE CITY-OWNED PROPERTY.
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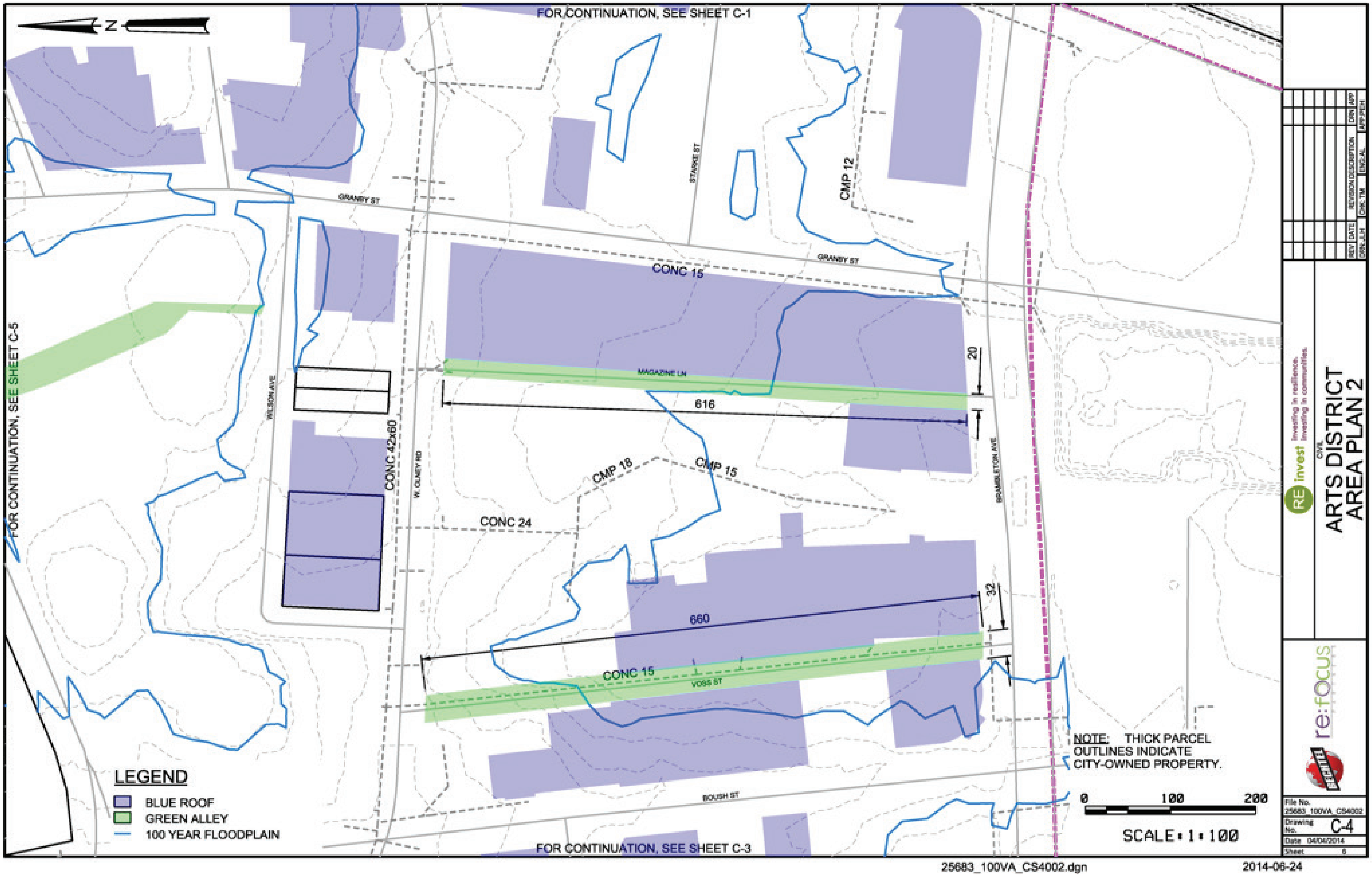

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VOSS ST
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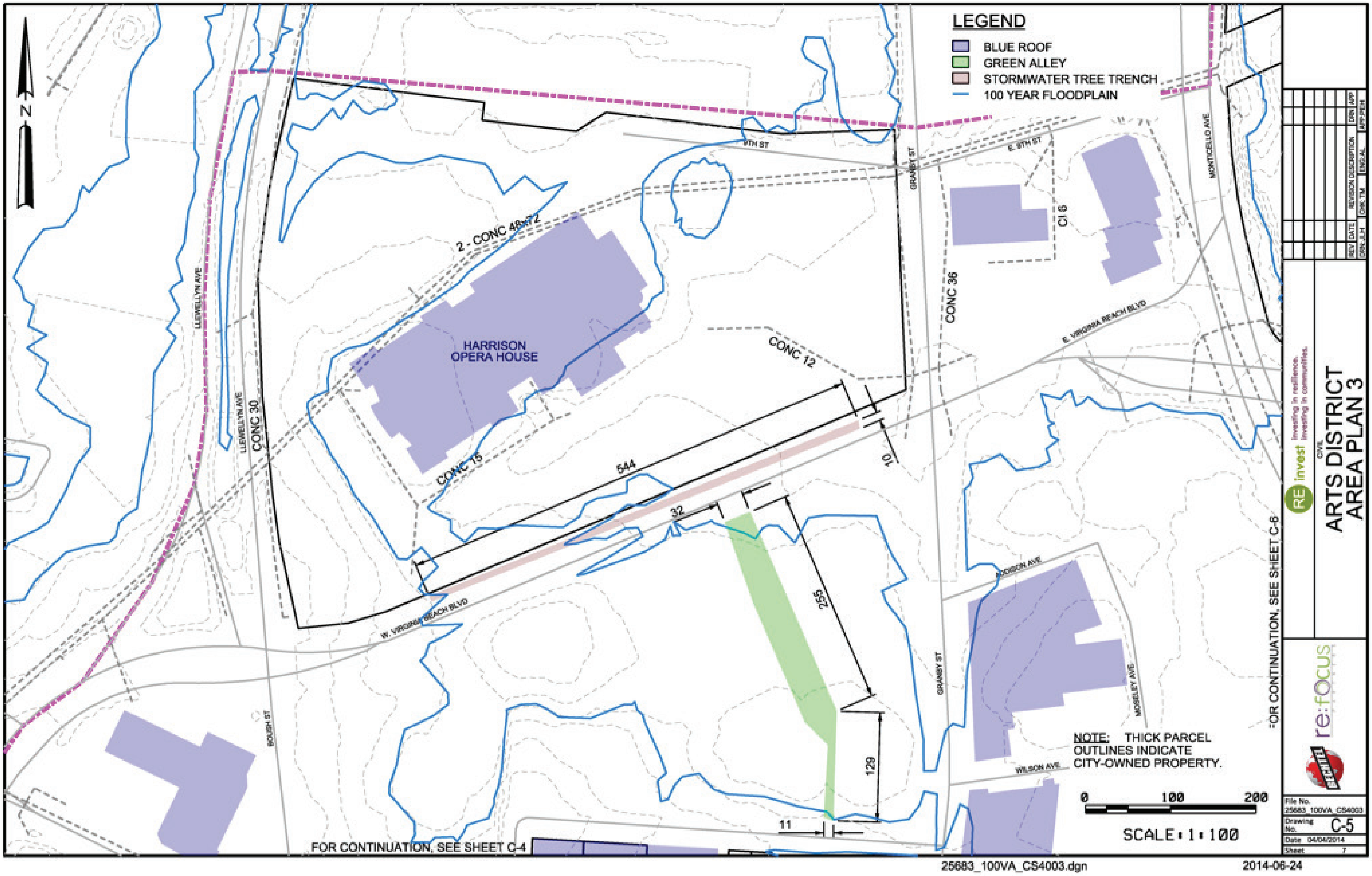
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E. VIRGINIA BEACH BLVD
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LLEWELLYN AVE
BOUSH ST
MONTICELLO AVE
ADDISON AVE
WILSON AVE
MOSELEY AVE
9TH ST
E. 9TH ST
NOTE: THICK PARCEL OUTLINES INDICATE CITY-OWNED PROPERTY.
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FOR CONTINUATION, SEE SHEET C-6
ARTS DISTRICT AREA PLAN 3
RE invest
Investing in resilience. Investing in communities.
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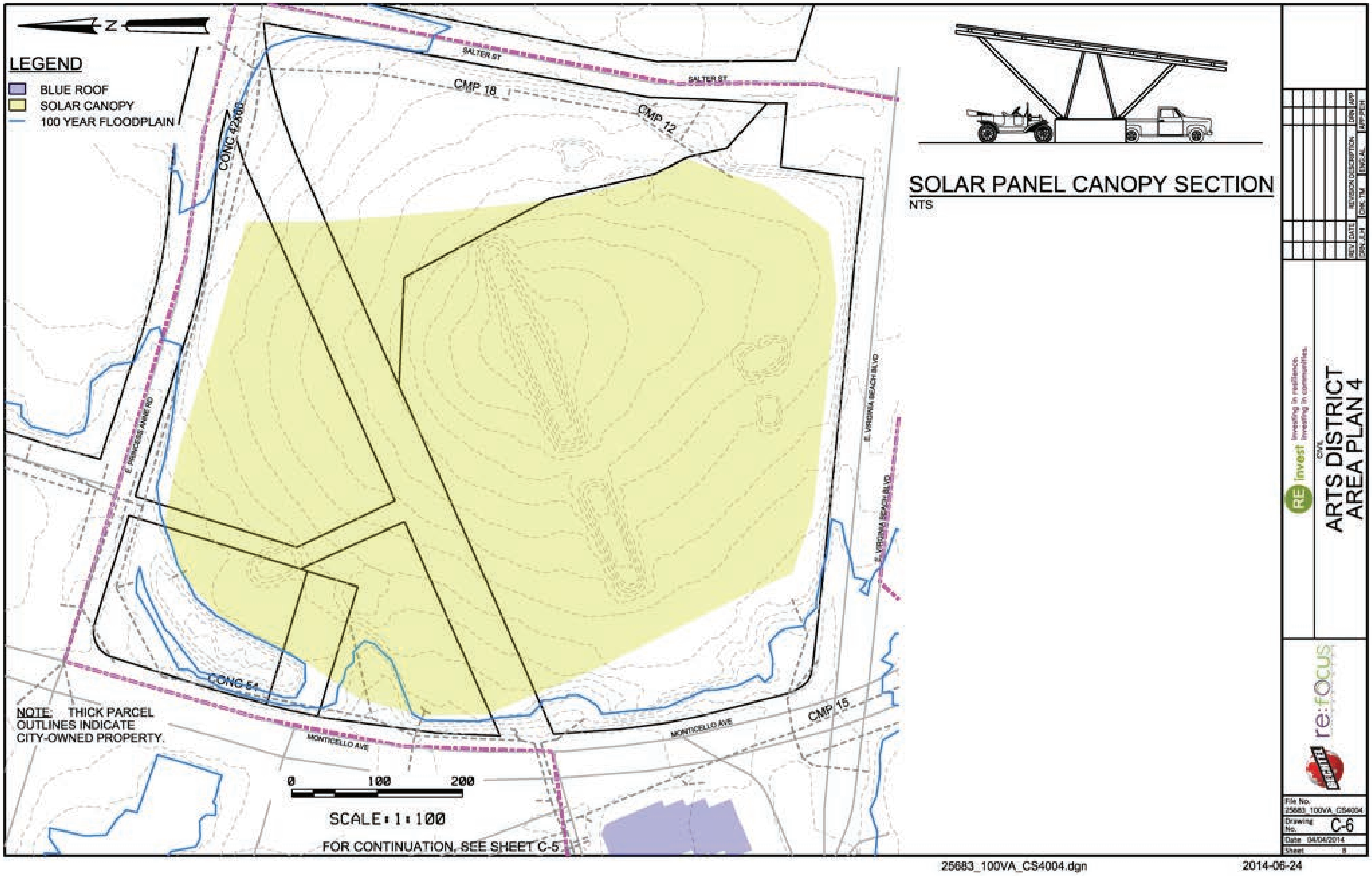
Date 04/04/2014
Sheet 7
25683_100VA_CS4003.dgn
2014-06-24


N
LEGEND
BLUE ROOF
SOLAR CANOPY
100 YEAR FLOODPLAIN
SALTER ST
CMP 18
CMP 12
E. PRINCESS ANNE RD
E. VIRGINIA BEACH BLVD
CONC 54
MONTICELLO AVE
CMP 15
NOTE: THICK PARCEL OUTLINES INDICATE CITY-OWNED PROPERTY.
0 100 200
SCALE: 1:100
FOR CONTINUATION, SEE SHEET C-5
SOLAR PANEL CANOPY SECTION
NTS
ARTS DISTRICT AREA PLAN 4
re:focus
Drawing No. C-6
25683_100VA_CS4004.dgn
2014-06-24