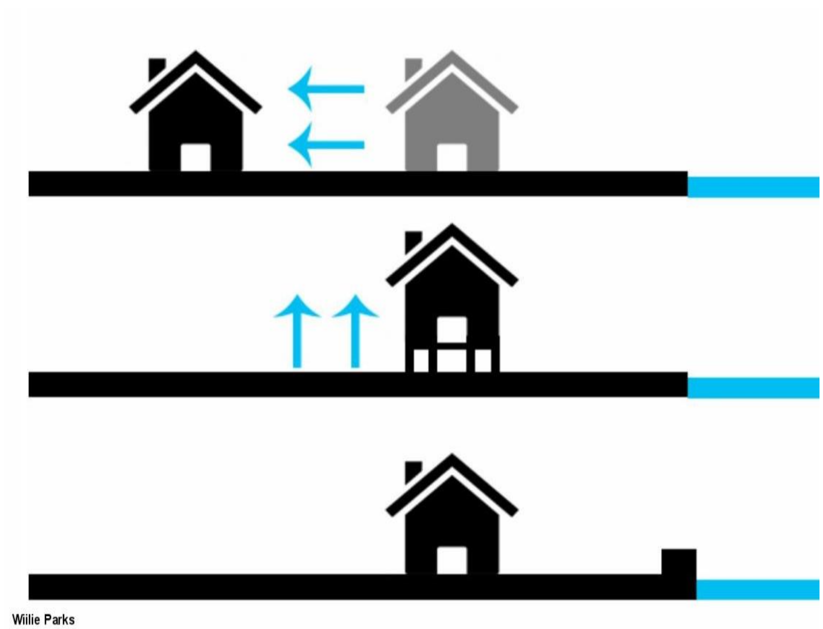
January 2016

Tidewater Rising Resiliency Design Challenge



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Sea Grant Virginia

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Sea Level Rise

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Background

Southeastern Virginia is a flat, tidal region with the highest measured rate of relative sea level rise on the Atlantic Coast at 4.45 mm/yr., with a predicted rate of between 4 and 6 feet over the next 100 years. The region has been ranked by the Organization for Economic Cooperation and Development as 10th in the world for assets at risk from sea level rise in port cities. Most of the region's economy is water-dependent (military bases, ship building, ship repair, shipping, ocean tourism) and at high risk from the sea level rates we will experience.

There is high awareness of the problem in the region, due to increased flooding events and due to studies issued by Virginia Institute for Marine Science, the Hampton Roads Planning District Commission, as well as individual cities such as Norfolk, Hampton, and Virginia Beach. Some cities (Norfolk and Virginia Beach) are already designing projects to address current and future inundation threats. Norfolk is seeking funding for two storm surge barriers in Norfolk (Hague and Pretty Lake), and two rainfall inundation projects (Mason Creek and Spartan Village). Virginia Beach has embarked on a major inundation mitigation project at Lynnhaven Colony. Norfolk has raised Brambelton Ave at a cost of $2.4 million as a flood control measure to protect its light rail project and guarantee access to its hospital center. Total adaptation needs in the region have not been estimated but will run into many billions of dollars.

However, most of tidal Virginia is still at the start of the sea level rise/flooding adaptation planning phase, with few robust plans in place. The full range of possible adaptation approaches has not been fully explored or developed and most of the approaches being considered are larger infrastructure projects that do not reach down to the neighborhood level. What the region's communities need are designs for smaller, distributed solutions that can become part of the fabric of our region.

We have both a need and an opportunity to engage the public, businesses, and local governments in a conversation about designing for adaptation, to begin to think about the kind of adaptation we want, identify the community needs and goals we want the designs to serve, and to begin to develop the professional design and engineering capacity in this region to address our needs. The challenge is to use the urgency of our situation to drive the innovation needed to stay ahead of the impacts that are coming and fit innovative solutions into our neighborhoods.

For Wetlands Watch, an added challenge is to find adaptation solutions that are protective of ecosystem services along the shoreline. Without nature-centric adaptation designs "on the shelf," the tendency will be to armor shorelines, dooming wetlands and the shoreline ecosystem.

Concept

The concept for the "Tidewater Rising Resiliency Design Challenge" was developed over a number of years, during Wetlands Watch's local government work on adaptation. We were constantly being asked by local governments and communities, "Has anyone actually implemented adaptation approaches that we can use here?" We have seen a number of conceptual ideas and plans from the various adaptation design work that has been done elsewhere (partial list at end). We saw design ideas that were developed post-Katrina and post-Sandy in areas impacted by those storms. However these designs were not appropriate to the communities we were working in. Some were too conceptual, too long-term, or at too large a scale to be applicable. The post-disaster designs were likewise difficult to envision applying to intact communities without "benefit" of post disaster funding and political will. Finally, we couldn't find many designs that applied to the topography of Virginia's coastline, especially the coastline in southeastern Virginia which is extremely flat.

We discussed the idea of conducting a design effort with the Virginia Sea Grant Program and they asked us to expand on the concept at a half-day workshop at the Virginia Sea Grant's 2014 annual symposium. At that session, a group of stakeholders helped frame the design process and refined our thinking on the scope, focus, and operation of the design effort.

The overall goal of the work was to conduct a flooding/sea level rise adaptation design process in a shoreline community, at the street/parcel level, with full community involvement, focusing on adaptation *before* significant storm and flooding damage occurred, with a central goal to maintain or expand ecosystem services in any designs developed. We also wanted to work in a community that displayed the complex hydrologic conditions that reflect the challenge of adaptation in built-out communities in Southeast Virginia: development atop old creek beds and wetlands, groundwater close to the surface, restricted and constrained drainage due to sea level rise affecting infrastructure, etc.

A secondary goal involved developing interest for adaptation design and engineering within southeastern Virginia's professional community so that a community of practice and expertise could be developed. We wanted to involve academic institutions with relevant departments of design, architecture, engineering, and policy in order to develop tomorrow's expertise.

We also envisioned this design work informing the range of challenges in the adaptation process, exposing needed work in legal, policy, economic, social, and other fields. We have partnerships with the William and Mary Law School's Coastal Policy Clinic and the Virginia Institute of Marine Science's Center for Coastal Resources management and we hoped that the design process would expose needed areas of inquiry for those and other institutions. We hoped that these inquiries would produce solutions that we could feed back into the design process in a subsequent cycle. This can be visualized as an expanding spiral coming from a central design focus but encountering other disciplines and areas of need [Figure 1].

With an award from the Virginia Sea Grant Program in 2014, Wetlands Watch started work on this community-scale, street level design work for sea level rise adaptation.

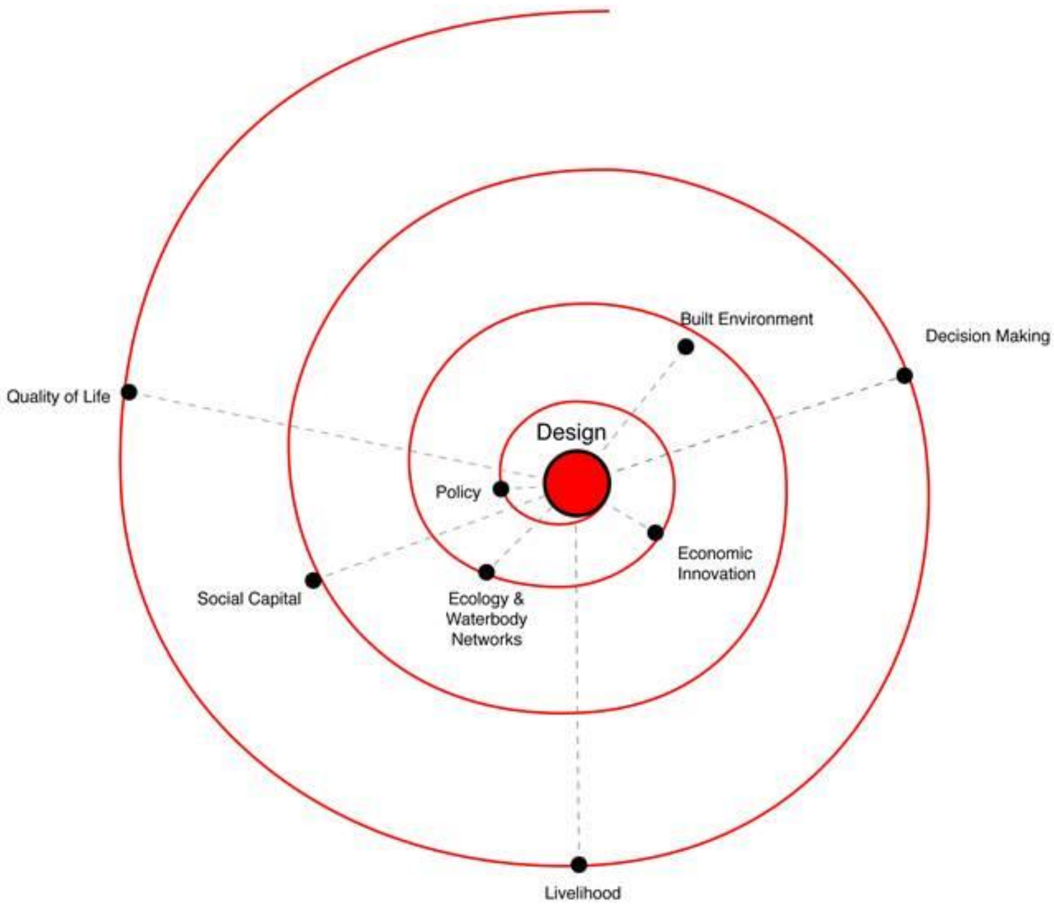


Figure 1 (Illustration by Shelly Jules Plaag)

Organization of Design Effort

The organizing process involved assembling a multidisciplinary, core team of professionals in design and engineering, development, historic preservation, planning, and ecosystem restoration. The primary partner in this effort was the Hampton Roads Green Building Council, which helped promote involvement with this work among their members. In addition, Wetlands Watch reached out to individuals who had special talents and perspectives to bring to this effort. In all there were nearly 30 professionals involved at various levels with this project.

The team of advisors helped rough out the design, focus, elements, and goals of the design process, using the Sea Grant Symposium recommendations as a start. With this advice we made a number of refinements to our original plans. For example, we originally anticipated having the design process evolve into a competition between cities with a "request for proposals" to go out to the local governments in Hampton Roads, asking cities and counties to "bid" for the design process to come to their locality. The core team advised against that approach, feeling there was too much time and energy taken up in this process and some level of disappointment on the part of the localities not chosen. Using this advice, we then switched to an internal review process, identifying potential sites and then selecting down to the final candidate.

We also envisioned a process involving early community involvement, so that community values could be identified and protected during the design process. We were depending upon the residents of the community to identify the specific and detailed impacts of flooding to guide the design process.

We winnowed the site selection criteria to a few central items:

- **Motivated and Willing Participants and Partners** – Local staff, elected officials, and citizens are aware of current risks, motivated to change, and willing to participate in the design process with an interest in/plans to ultimately developing, funding, and implementing a Sea Level Rise adaptation plan.
- **Opportunities to Incorporate Natural Infrastructure and Ecosystem Services into the Adaptation Plan** – Sea Level Rise Adaptation plans/designs must maintain or expand ecosystem services on the selected site through measures such as incorporating the use of natural infrastructure (wetlands, trees/forests, "green" stormwater management practices, green/open spaces and conservation easements, riparian buffers, coastal dunes, wetlands or stream mitigation banks or land trusts, restoration or reconnection of floodplains to streams and creeks, living shorelines, etc.) as a adaptation strategy, but also plan for the resiliency of green/natural infrastructure over time(retreat zones, etc.).
- **Availability of Critical Planning/Design Information** – The resources needed to inform the design process (land use and hazard mitigation plans/site analyses/maps, etc.) are readily available and will be provided (without charge) in digital and printed formats.
- **Opportunities to Address Architectural, Engineering and Planning Challenges** – Core partners indicated a preference for residential properties to which we would apply adaptation, resiliency, and sustainability strategies. Where appropriate we would incorporate needs for historic buildings and landmarks, new building design, existing building retrofits, infrastructure, broader community plans, etc.
- **Part of Existing Local Hazard Mitigation and Post-Disaster Recovery Plan -** Locality already has plans for relocation, acquisition, and re-use of certain high-risk properties and/or infrastructure. Locality has identified at-risk communities/neighborhood blocks/properties/infrastructure/public facilities located in a 100-year flood plain or high-hazard zone and targeted them for mitigation and adaptation.
- **Availability of Existing Master Plans and Community Plans -** Locality has already targeted (and plans to fund) communities/neighborhoods/corridors for change that can be modified to incorporate this resiliency and adaptation work. These plans would have enhanced availability/analyses of site-specific data and characteristics that could inform the design process and enable us to tackle a larger area. Plans might be redevelopment/revitalization of brownfields, grey fields and vacant properties, natural, historic or cultural resource protection, economic development, public housing projects, infrastructure/transportation, stormwater management/Chesapeake Bay or Local TMDL action plans, community character, parks and rec, etc.
- **Presence of Special Overlay or Tax Districts** – Locality has areas which are zoned for or incentivize change, revitalization, or protection/restoration (historic, conservation and

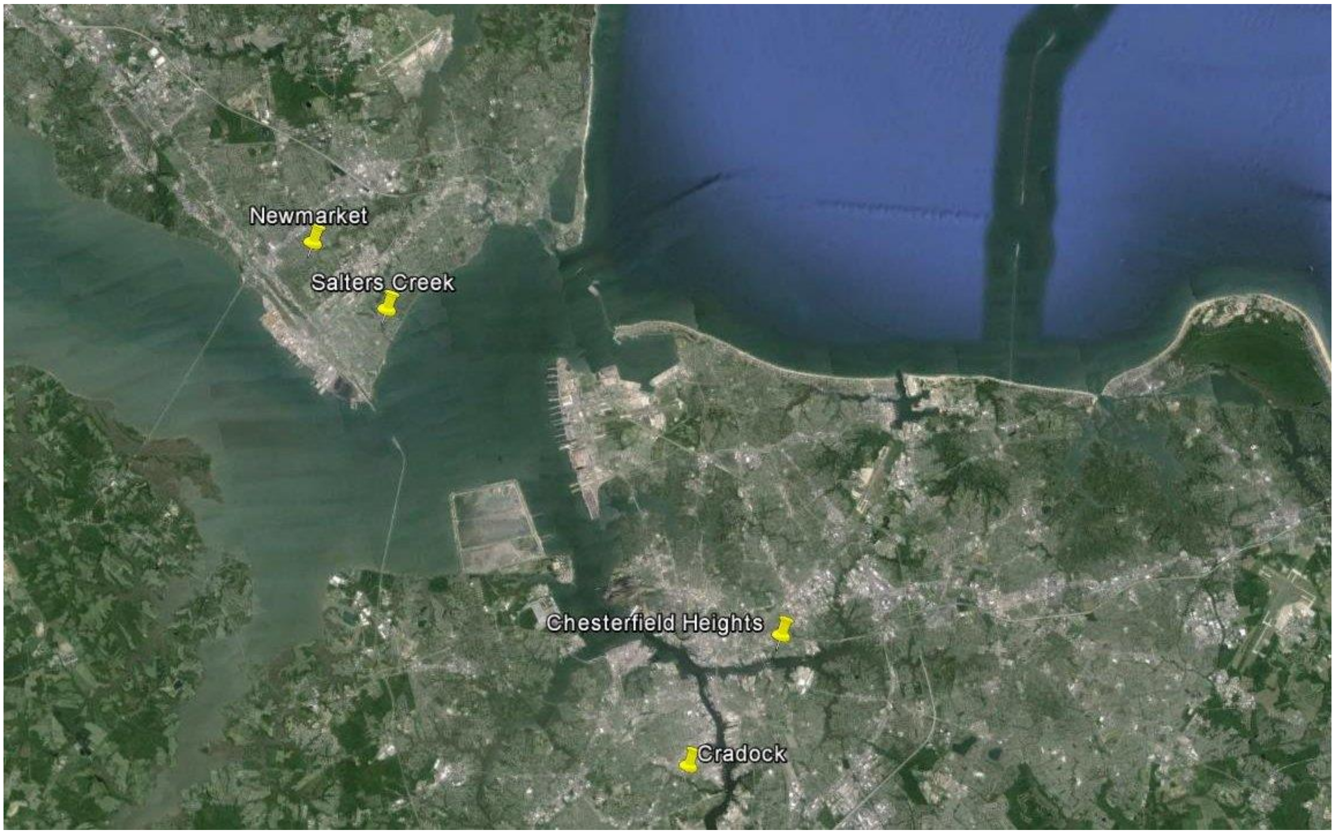
hazard/floodplain management, economic or socio-economic revitalization, mixed use, cluster)and are intensely studied with detailed analysis of existing resources and area characteristics, and include specific design standards, ordinances, and restrictions.

- **Revenue Sources or Sinks for Locality** – Areas identified by locality or steering committee as subject to "flight" by existing residents due to cost and quality of life factors:
    - rising cost of insurance (both Flood and Homeowner insurance) putting financial pressure on homeowner;
    - high incidence of property owners who wish to sell and move but can't because the house is a repetitive loss structure or in a high risk zone(Special Flood Hazard Area);
    - frequency of flooding is wearing on residents, causing vehicle damage, causing employment disruption, generally eroding the quality of life;
    - lower-income/ minority/social justice areas where existing challenges to community resiliency are being exacerbated by frequent flooding.
- **Optimum Site Scale –** Area is large enough to display a range of impacts and problems but not so large or complicated as to tax the limits of the design teams.

We discussed a planning threshold for the project and decided that we should initially look to adaptation designs that will be effective through mid-century. That seems to be the threshold that is being used in regional planning with expectations that sea level will increase an additional 1.5 feet by then. The centennial rate is estimated to be between 4 and 6 feet, however, according to the study produced by the Virginia Institute of Marine Science and designs needed to be mindful of the longer term trends.

Candidate Sites

We looked at four potential sites:



Newmarket Creek in Hampton/Newport News - This area along the Newmarket Creek watershed starts in the Newmarket Creek community and runs through other communities on its way to the Hampton Coliseum. This is a mix of apartments and single family homes and the area floods worst from a combination of rain during high tide events, when Newmarket Creek no longer drains to the Back River because of the tidal surge coming upstream. The Creek is a typical constricted urban headwater that has hydrologic problems. The neighborhoods along the creek are working class/disadvantaged neighborhoods.

Salters Creek in Newport News - This is a lower income neighborhood with flooding problems. As with many constricted urban creeks, this area floods during rain events tied to high tides (Nor'easters) as rainfall cannot escape the neighborhoods. The city has a program for purchase and razing of repetitive loss properties along this watershed – both to deal with recurrent flooding and blight.

Cradock/Paradise Creek in Portsmouth - One of the earliest planned communities built to support WWI shipyard workers. Single family homes dominate this historic neighborhood, which has fallen on rougher times in recent years. The northern edge of Cradock is influenced by flooding from Paradise Creek. The community is surrounded by Superfund/RCRA sites containing industrial waste and toxic contaminants from 200 years of the Portsmouth Naval Shipyard's operations. Tightly knit community that has been the subject of much work by the Elizabeth River Project.

Chesterfield Heights in Norfolk – An historic community of middle/lower income single family residences on Eastern Branch of Elizabeth River, built starting in 1915. The western end of the community is built on old filled in creek (Ohio Creek) which complicates flooding. Eastern end of neighborhood is Grandy Village – Norfolk public housing community. Chesterfield heights is a focus area by the Elizabeth River Project for River Star Homes, RiverFest, etc.

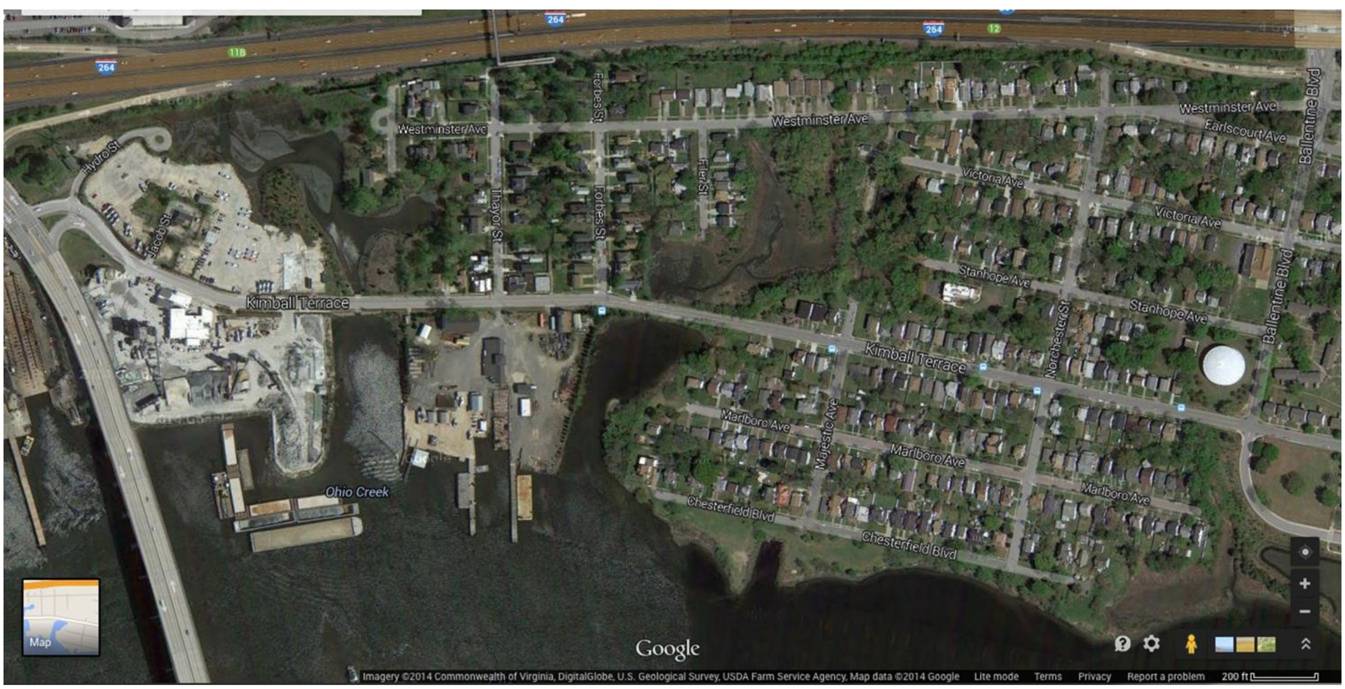
In the end we selected Chesterfield Heights because of the active involvement of the Elizabeth River Project in the neighborhood, the presence of a vibrant civic league, the mix of homes (both historic and later in-fill), and the mix of tidal and rainfall flooding.

Chesterfield Heights Conditions

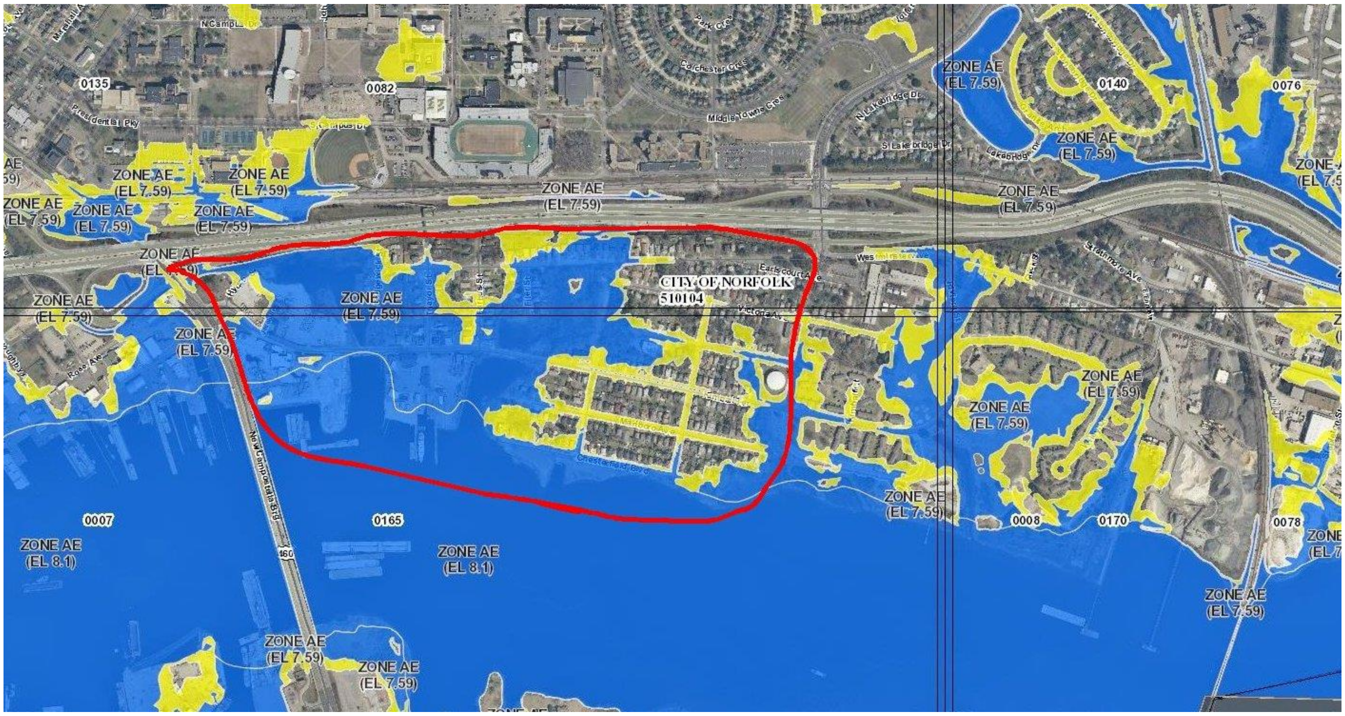
Chesterfield Heights is a community of nearly 900 people living in 500 structures, mostly single family homes, on the northern shore of the Eastern Branch of the Elizabeth River, a tidal estuary with impaired water quality. The community was platted in 1904 and the first homes were built in 1915 along the riverfront. It was added to the National Historic Register in 2003. Chesterfield Heights is predominantly African-American and has a median household income of about $32,000.

It has approximately a 2,200 foot long riverfront shoreline experiencing increasing erosion from barge wakes. It has two creeks/inlets that convey water deep into the neighborhood and are a source of storm surge flooding. The older homes along the riverfront and in the central part of the community are built well above the river levels and have basements. Newer construction tends to be buildings on slabs.

Chesterfield Heights has an active civic league and the neighborhood exhibits a strong sense of place.



Satellite Map of Chesterfield Heights



Flood Zone map of Chesterfield Heights (blue=100-year flood plain)

Chesterfield Heights Elizabeth River Shoreline

Design Team/Partners

We sought to involve young professionals and students in this work and wanted to combine the talents of architects, landscape architects, and engineers in looking at the same project/set of problems. We contacted Mason Andrews of the Hampton University Architecture Department, and Mujde Erten-Unal with Old Dominion University's Civil and Environmental Engineering Department, the faculty leaders in past innovative design/build efforts. The Hampton University students had collaborated with engineering students from Old Dominion University on prior Solar Decathlon projects and a partnership on this adaptation design effort seemed a natural fit.

We engaged the Hampton Roads Green Building Council (HRGBC) and its member firms and individual professional members to be part of a professional advisory group. This advisory team consisted of architects, engineers, landscape architects, commercial developers, historic preservation experts, and other allied professions. The HRGBC held three events involving this advisory team and the student design teams over the course of this work. In addition many individual professionals served as advisors and mentors to individual students and student teams. Also, the Virginia Chapter of the American Institute of Architecture's Emerging Leaders in Architecture program selected Chesterfield Heights as their focus area in 2015, adding additional design depth to this effort.

The student teams worked independently and separately, but came together each Wednesday for a joint information and collaboration session. The project-based learning focus used a series of lectures from the team of experts that helped inform the design process. As well, we were able to bring additional experts to the process as needed (such as a restoration mason who spoke about the characteristics of brick construction ca. 1915). The students also collaborated with some of the professional advisors on specific problem issues they encountered.

Student Presentations by Restoration Brick Mason (seated, center) and Structural Engineer (standing at board) Exploring Ability of Brick Basements to Hold and Store Water.

Due to academic coordination problems, we started initially only with a team of Hampton architecture students in the fall of 2014, later bringing in an informal group of 8 ODU engineering students from the American Society of Civil Engineering's student chapter. The student effort was connected to the pool of talent surrounding this project and relied on their professional expertise as the project developed.

In the second semester, starting in January, 2015, 10 Hampton University Senior Architecture Students and 10 ODU civil and environmental engineering students participated in the Senior Design Course in the Engineering Department and were focused in coordination on Chesterfield Heights.

Design Process/Progress

Civic Engagement

Wetlands Watch and the academic leads on this project met with the Chesterfield Heights civic league and neighborhood leaders on-site. We explained the project, its goals, and outlined what the residents could expect from the project. We warned them that students and other strangers would be coming into their neighborhood to gather information on the community. We obtained their full cooperation on the project.

The Hampton University architecture students began familiarizing themselves with the Chesterfield Heights neighborhood, collecting data on the community and then conducting site visits. During these visits, the students interviewed residents and took pictures of the neighborhood. Students also visited the neighborhood during rain events to witness flooding problems first-hand.

We arranged a community meeting on the project, inviting residents to the Stanhope House community center to relate their experience with flooding and to learn more about the project. During this afternoon, weekend event, students from Hampton and ODU administered a questionnaire on the residents' situation and helped them locate their houses and flooding events on a map.


Resident interviews


Mapping impacts

From this work, we concluded that the neighborhood was better off than many shoreline neighborhoods in Norfolk, with tidal flooding limited to areas adjacent to tidal creeks and rain/ground flooding limited to a smaller number of homes. The owners of houses with basements in the portion of the neighborhood nearest the Elizabeth River indicated that basements were starting to flood with increasing frequency. (The presence of basements is indicative of the relatively high elevation of that part of the neighborhood.) However there was clear evidence that the situation was getting worse and that in some parts of the neighborhood adjacent to the two tidal creeks, the flooding has been significant.

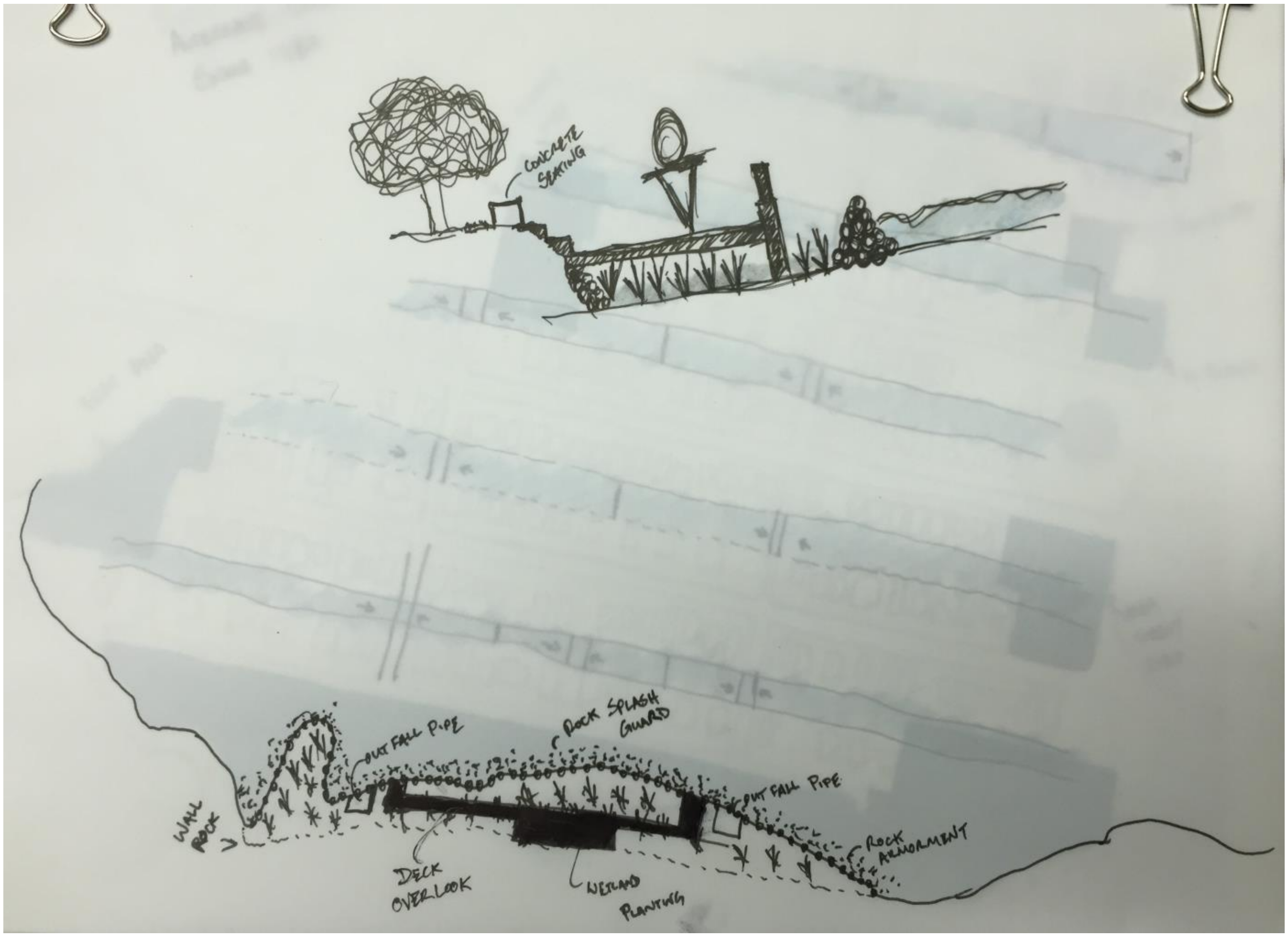
We heard many complaints about flooded streets, especially where the city had installed drop inlets on the storm water lines, which clogged with debris. Residents routinely waded into those intersections and cleared the clogged inlets.

One of the biggest concerns in the community was the continued erosion of the 2,200 foot shoreline. Bow wakes from the barge traffic in the near-shore shipping lane seemed to be the major problem, given that old maps of the riverfront showed little change from pre-development shorelines. At some places, the shoreline is within feet of Chesterfield Boulevard, the street fronting on the water, posing a significant risk to the road.

<u>Framing Concepts</u>

The early design work was focused on a four-phased approach, which the students associated with rough time lines. The first phase, mitigation, was to address today's flooding. The second phase, installing the living shoreline to halt erosion and restore habitat, was seen as providing additional protection ten or more years into the future. The third phase involved installing under-street cisterns, something that would add another 25 years onto the neighborhood's protection. The fourth phase, elevating houses, was seen as a longer term solution, providing useful life to the community 75 years into the future. This was diagramed in the illustration below:

Early Conceptual Diagram of Process and Project



Early Conceptual Sketch of Approaches (Willie Parks)

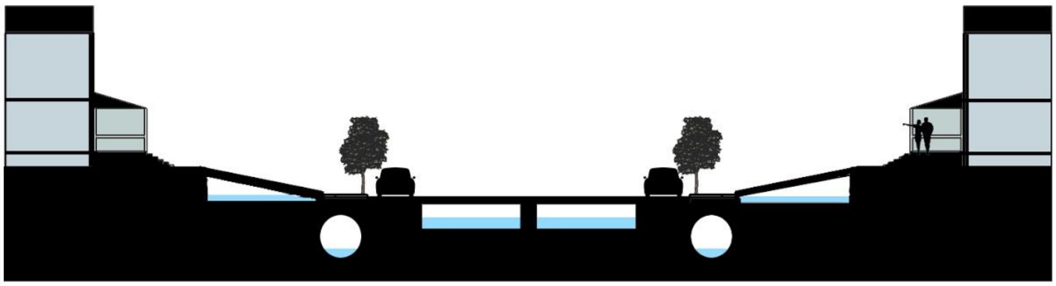
With more information this time line and linkage to adaptation approaches became less rigid as the thinking shifted to more decentralized design and engineering concepts. However, this staged approach still provided a systematic way of thinking about the solutions and the potential to phase them in over time.

In the site visits, the students noticed the unique brick sidewalk along a section of Marlboro Avenue and found that the residents had struggled with the city during a road work project to retain the brick pavers in the street. This started the students thinking about using brick, permeable pavers draining to under-street cisterns to store storm/flood water, to be released slowly after the storm event.

Marlboro Avenue Brick Pavers, Chesterfield Heights

The students were also mindful of the standard practice of elevating houses in the flood plain as a mitigation measure, but worried about how that would affect the community. First, there is the possibility that raising an historic structure, such as the homes along the Chesterfield Boulevard shoreline, would endanger their historic status by changing the relationship of the house to the street: does an historic home elevated 12 feet above grade still retain “historic” status? Second, in community interviews, the students were told of the value of the “porch culture” in the neighborhood which would be sacrificed with a simple elevation of these homes, one-by-one.

In response, the students conceived using a series of under-street cisterns, with permeable pavers on the street. They also proposed cisterns in front of the elevated homes, which would be covered by soil and graded more gradually from street to porch, seeking to maintain the desired relationship of street elevation to front porch elevation. An illustration shows this original plan.



Under-street, front lawn cistern elevation (HU Students)

Through much of the first semester, the students were still collecting basic information on the site: soil, hydrogeology, storm water infrastructure, etc. As with any older site, this information was scattered throughout project data on prior infrastructure work. The city of Norfolk staff, the Norfolk Housing and Redevelopment Authority, and various engineers associated with the project were able to eventually help the students locate the information they needed.

One of the major problems with storm water in the community is the undersized and aging system of pipes. The storm water pipes are nearly 100 years old and were part of a since-disconnected combined storm water/sanitary sewer system. They are 20 – 24" pipes, undersized by today's standards, with outfalls are now covered by water at low tide, due to the sea level rise that has occurred since the system was installed. Pictures below illustrate the problem.

Storm Water Pipe Outfalls Submerged at Low Tide

The challenge became to hold the rainfall water on the land so as to not exceed the capacity of the sea level rise-challenged storm water system. The ODU engineering students developed a “water budget” for the neighborhood using the Environmental Protection Agency’s Storm Water Management Model (SWMM). From this they determined the volume of peak storm water flow they needed to remove in order to minimize flooding impacts and allow the existing compromised storm water system to handle the runoff.

Soil and hydrology data was needed to determine the feasibility of rain infiltration approaches, and here the challenge of working in an older neighborhood emerged. Much of this information was tucked away in appendices of past public works projects or resided in the memories of engineers who had worked in the neighborhood. Finding this information was a task onto itself and delayed the project for a time.

Soil maps were finally located and showed that most of the central part of the neighborhood had type B soils suitable for infiltration. While most of Norfolk’s shoreline had unsuitable soils for infiltration composed of clays and fine grained soils, this area did not. Hydrogeological data was located in plans and documentation for a prior sewer line replacement project and showed groundwater tables 4-5’ below grade. With this information, along with new lidar imagery from the City, the students moved to consider potential solutions using disconnected downspouts, landscaping solutions to water control, and gradual infiltration as a way of dealing with the peak storm surge.

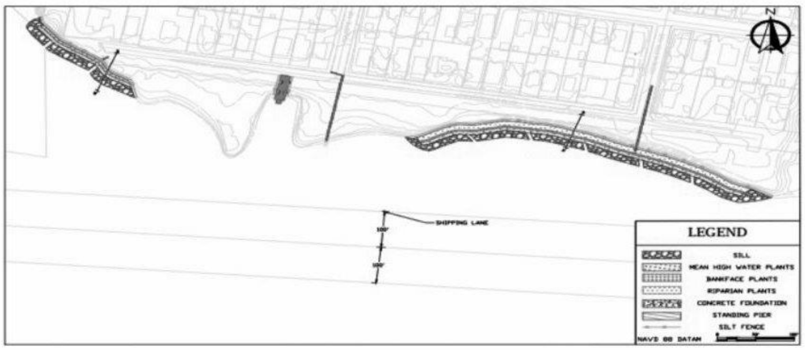
Consequently, the concept of large cisterns under the streets and under front lawns morphed into a low impact development stormwater approach. Urban bio-retention systems, under-street cisterns, basement cisterns, and an innovative system of collecting and holding rain water from rooftop disconnects all were part of the eventual design. In addition, a design proposal was made for a living shoreline to protect the 2,200 foot shoreline and expand ecosystem services. An additional element is the proposed elevation of Kimball Terrace to provide storm surge protection for the interior of the neighborhood.

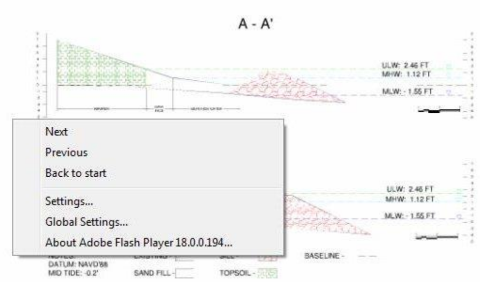
Some additional small fixes were also needed. To prevent backflow up the storm water pipes from rising tidal waters, a Tideflex valve system was proposed to cover the ends of the storm water pipe outfalls. These flexible, one-way valves are already being installed around the city of Norfolk. The students also observed during rainfall event visits that the ends of some of the streets flooded and needed bio retention ponds to collect water off the streets and store it for slow release into the river or infiltration. They also recommended replacing the drop inlets for storm water with standard curb cut inlets.

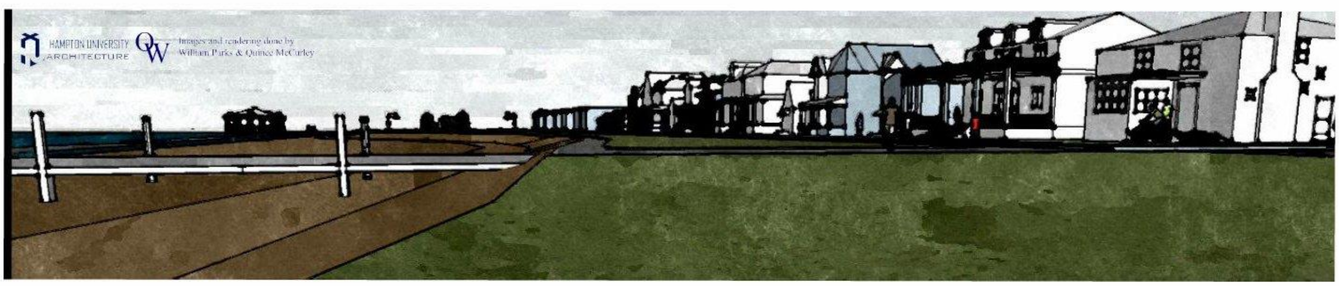
Design/Engineering Solutions

SOLUTION #1

Living Shoreline







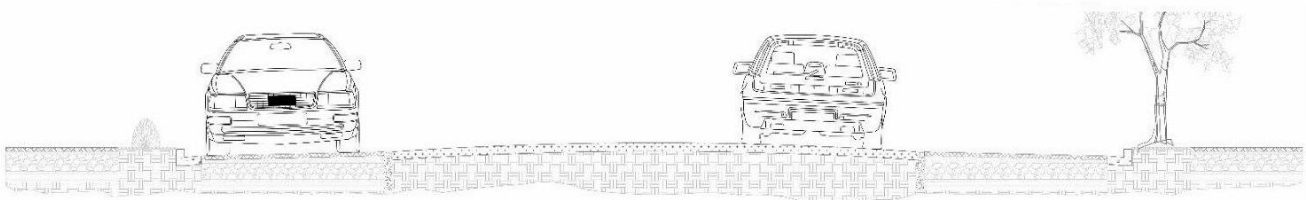
(All illustrations by HU/ODU students)

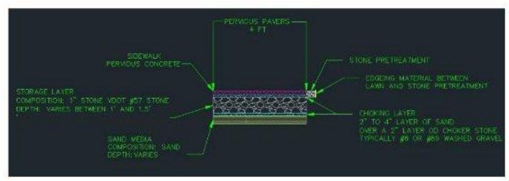
To protect the shoreline from erosion and maintain/expand ecosystem services, a living shoreline was proposed along the 2,200 foot shoreline in front of Chesterfield Boulevard. The shoreline design would allow tidal, vegetated wetlands to repopulate the intertidal zone between the offshore rock sills and the existing shoreline while providing erosion protection. The design took into account the nearshore shipping channel and acccomodated the community's desire for a water access/dock. The community is very concerned about the erosion of the shoreline but want to maintain their connection to and use of the waterfront.

The living shoreline work took advantage of an existing shoreline engineering study on this site and involved the expertise of Norfolk city staff who have installed similar systems in the city. In addition, the expertise of the Virginia Institute of Marine Science's Center for Coastal Resources Management was a key part of the evolution of the design.

SOLUTION #2

Pervious Pavers/Under Street Cistern

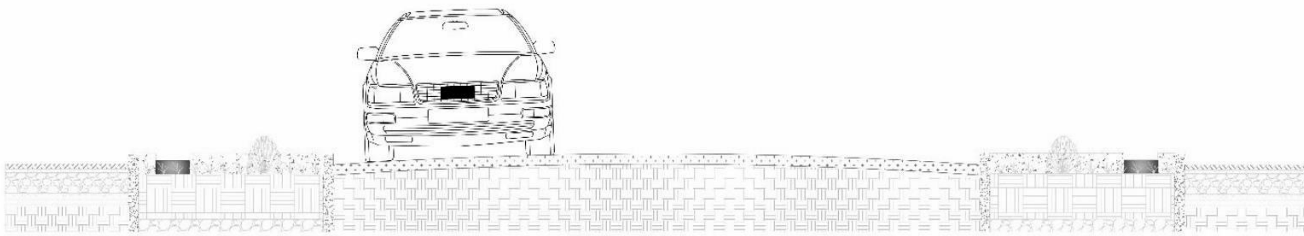


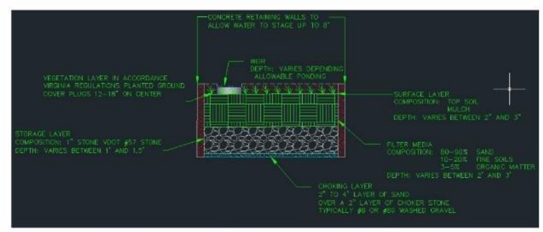


The use of pervious pavers on the street was kept, both as a flood control and signature design feature of the neighborhood, but the cisterns were envisioned as smaller ones than in the original designs, distributed along key roads and intersections in the neighborhood. The pervious paving would be used along the edges of the street, in lower volume areas where cars are parked along the curb. The students researched the maintenance of pervious paving and found that Norfolk already has vacuum trucks needed to keep the infiltration spaces from clogging with dirt and debris, minimizing the maintenance load.

SOLUTION #3

Urban Bio-Retention



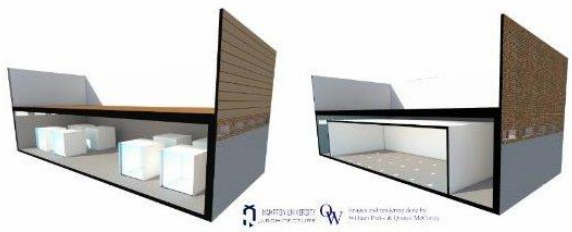


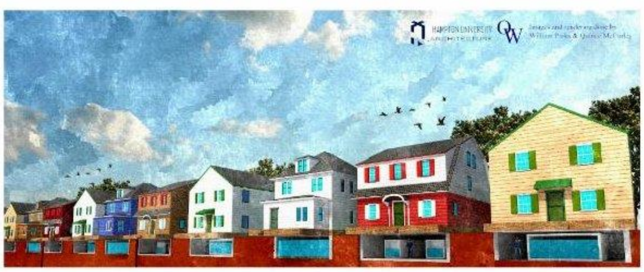
The areas between the street surface and the sidewalks were designated for urban bio retention systems, with media-filled cisterns lining the street to collect and infiltrate rain water. In addition at certain locations where flooding occurs, such as at the end of Marlboro Avenue, a bio retention system using a dry pond was proposed.

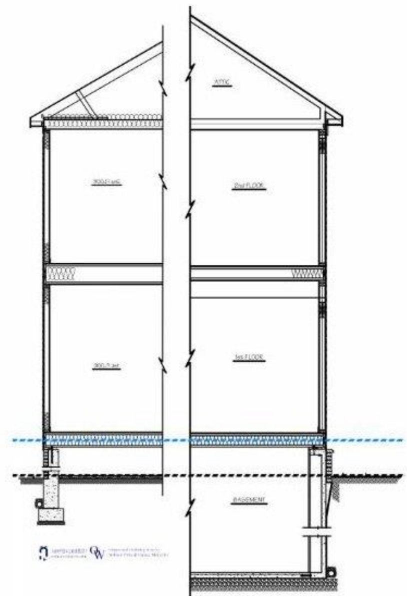
These cistern and bio-retention systems provide both flood control and significant storm water pollution reduction, especially in these areas where cars are parked and leaking motor oil and other automotive chemicals concentrate. By trapping and holding the first flush of rainfall runoff, heavily laden with these pollutants, these approaches provide storm water pollution reductions that can be credited toward the municipality's mandated storm water pollution reduction standards.

SOLUTION #4

Base-tern System







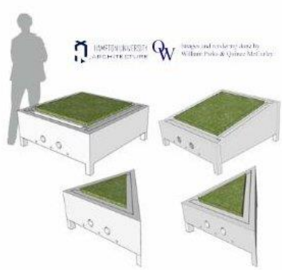
During the community interviews, the students heard residents describe their basements as having brick floors that during flood events would allow water to enter and then, later, drain out. The frequency of the basement flooding seemed to be increasing in recent years so most residents did not keep much in their basements that could be damaged. This started the students looking at basements as water storage cisterns. They calculated that without the basements storing water, the flooding levels in the neighborhood would be higher.

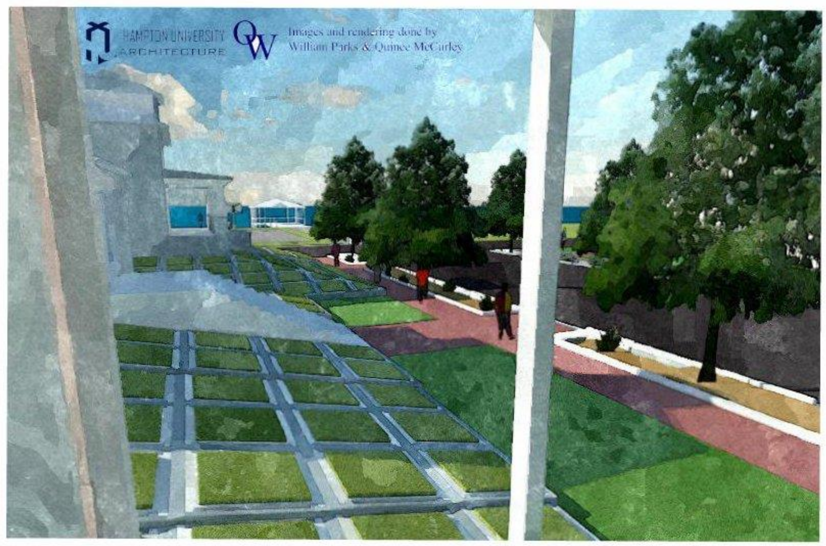
Chesterfield Heights is unique among shoreline neighborhoods with the presence of basements in many older homes. The land in the central part of the community is fairly high and the groundwater is far enough below grade to allow basement construction when the original homes were built. Those homes have basements that are ¾ below grade and ¼ above grade, allowing windows to be installed on the above-grade portion of the basement.

The students researched reports that basements were being used as cisterns to hold water and discovered work in Milwaukee, WI to use basements as storm water holding cisterns (see "Foreclosed Homes, Stormwater Managment's Secret Weapon"). The students worked with structural engineers and historic restoration masons to come up with a concept of basement cisterns (Base-terns) in Chesterfield Heights.

The Base-terns are separate and sealed from the rest of the living space to avoid mold and other problems. Many in the neighborhood observed that the ventilation from opening the above-grade basement windows allowed post-flooding drying out, minimizing the mold risk and other consequences of high humidity. The Base-terms are open on the bottom, allowing water to flow up into them, but sealed to the basement floor. When flood waters recede, the water held in the Base-terns will slowly infiltrate into the ground.

SOLUTION #5
Rooftop Disconnect





The students devised an approach using a system for disconnecting the rooftop down spouts and directing the water into a system of cisterns in front of the house. With the potential for rain/flood water infiltration using the type B soils and depth to groundwater, the water held in these interconnected, modular cisterns would slowly be released to infiltrate back into the ground after the storm event.

These ground cisterns have flow valves for interconnecting and directing water flows and have a top with a medium that allows planting, similar to a green roof. These modular cisterns could be stacked and sloped from the house to change the grade for houses needing to be elevated, softening the lines from street to porch. In this way, it was hoped that the historic status (and tax treatment) of the house would be maintained even in the face of aggressive adaptation measures.

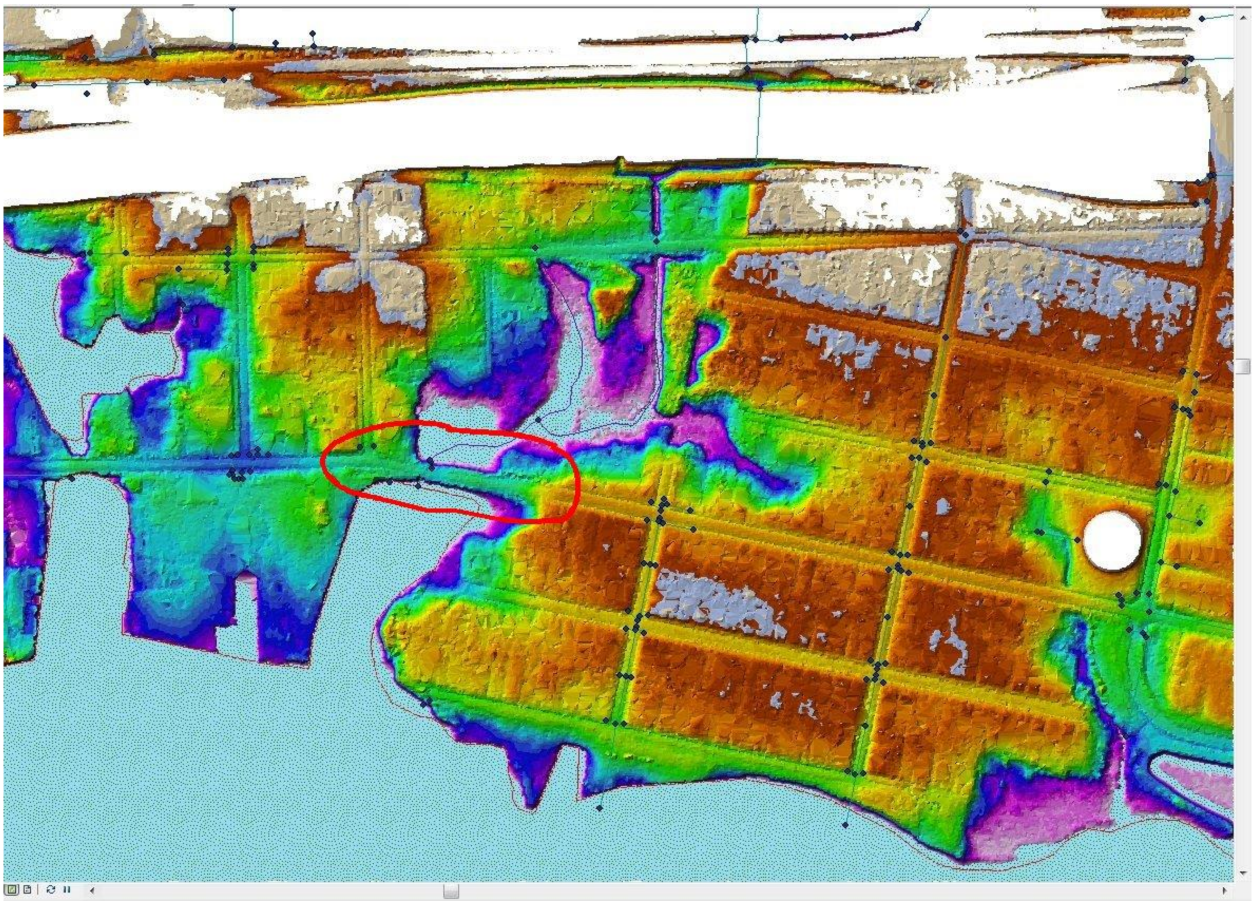
Design/Engineering Outcomes

All of these low impact development storm water solutions removed enough peak storm water flow to allow the community's undersized and compromised storm water system to work during storm events now and into the future. The ODU engineering team ran the SWMM model to validate that. In fact, according to the engineering report done by the ODU students, the addition of these low impact development design features to the flood model reduced flooding volumes during the 2009 nor'easter by over 90%.

In addition, these designs removed significant phosphorous and nitrogen from storm water, contributing to clean water regulatory requirement under federal and state law. The first flush of rainfall brings the highest concentration of pollutants and the low impact development designs capture and hold that first flush, providing significant reductions in storm water pollution. Many of the sources of impairment identified by the Virginia Department of Environmental Quality are addressed by these design/engineering approaches.

The students also did an estimate for the cost of the proposed low impact design adaptation measures and compared them to the estimated cost of replacing existing storm water infrastructure (pipes, etc.). The existing infrastructure, according to an earlier engineering study done for the city of Norfolk, could be replaced for $705,000. The cost of the low impact design adaptation storm water solutions (not including the living shoreline) is estimated to be $900,000. While more expensive, the nutrient pollution reduction credits provided by the adaptation design approaches make that investment more attractive. As well, the adaptation approaches, using signature brick paving providing community identity and bringing other amenities could be justified even at the higher cost.

Kimball Terrace Roadway



One additional flooding adaptation project was the raising of a critical road in the community, a low-lying portion of Kimball Terrace, circled in red above in the lidar image of the community. The estuary at left-center is crossed by a low-lying section of Kimball Terrace, one of only two access roads to the neighborhood. The areas above that crossing (purple/blue) are low-lying tidal wetlands and lower elevation parcels that are prone to flooding from elevated water levels in the Elizabeth River (see earlier image of the 100-year floodplain in the community). There is a failing culvert under that roadway connecting the wetlands to the tidal flows of the Elizabeth River's Eastern Branch.

The engineering students sought to deal with three problems: impaired vehicle access to Kimball Terrace during flooding, storm surge flooding of structures above the road/culvert, and allowing full flushing of the wetland system to allow it to survive. The preferred option developed was to raise Kimball Terrace over much of the low lying crossing of the marsh/estuary to provide storm surge protection for the interior of the neighborhood.

To allow further protection from storm surges, while allowing essential flushing for ecosystem health, the students recommended replacing the failing culvert with a culvert/storm surge gate system. In the picture below, during normal water levels the device remains open allowing flushing of the marsh. With storm surges of a set height, the gate system closes, preventing the storm surge from entering the central part of the neighborhood. When storm waters recede, the gates open again allowing normal water exchange.

Conclusions

The original designs for larger structural adaptation approaches were gradually replaced by low impact development approaches distributed throughout the neighborhood. The use of many smaller approaches to reduce peak flow of storm water became the preferred option with the uncovering of soils and hydrology data for the site. These approaches provided the needed peak flooding reduction while also providing pollution reduction benefits.

The process was as important as the design products. Approaches to adaptation need to be fitted onto the community, in consultation with the residents and mindful of ecosystem and other priority values: there are no "off the shelf," universal adaptation designs. Community-scale adaptation work needs to begin with community engagement, before any work is done. Gaining the trust of the Chesterfield Heights civic league early on was essential to the success of this project.

Locating needed infrastructure, hydrology and soils data, and other basic background information can be difficult in older communities and needs to be undertaken early. This requires the full cooperation of the municipal government staff and consulting design/build firms who know where this old data can be found.

Multiple benefits need to be considered during adaptation design. The flood reduction measures using low impact development approaches provide significant nutrient pollution reduction benefits as well, making them more attractive to municipalities. Other amenities also emerge with this approach, such as the discovery of the community's valuing the brick pavers and using that to expand to brick pervious pavement throughout the neighborhood as an identifying characteristic of Chesterfield Heights.

In the course of this work, we discovered a number of issues for further work. The shoreline segment of this community is owned in common by the original development corporation, which went bankrupt in 1948. The title to the land is held in receivership and no permits can be issued for the living shoreline until this matter is resolved. Wetlands Watch is working with the community and the city of Norfolk to remove this barrier to the installation of the living shoreline.

We found that the flood insurance rates for houses with basements are reduced by the Federal Emergency Management Agency (FEMA) when the basements are filled in and no longer used as "living space." Yet once filled in, the basements no longer provide water storage capability, frustrating efforts to use "Base-terns" and, ironically, increasing the flood risk to the community. We will be working with FEMA to try and resolve this conflict.

We need to explore the adaptation options proposed and how they will affect the availably of historic preservation tax credits. We are also looking into a number of other conflicts between these proposed adaptation designs and existing regulatory programs, potential barriers to financial opportunities, and the like.

This design work also raises issues around the financing of some of these measures, a subject for future inquiry. The use of historic restoration funding and tax credits might be an option, as long as the historic nature of the homes are preserved, especially the porch-to-street relationship. The rooftop disconnect approach and needed cistern systems might be eligible for cost sharing using funding set aside for storm water pollution reduction approaches that might otherwise to go larger, capital projects. It may be that the potential for storm water runoff reduction affords a greater funding stream than flood protection and prevention programs.

Follow On

At the conclusion of this work, the students made public presentations in fulfillment of their course requirements. At one of these presentations in Norfolk, senior city staff were present and were impressed with the design work done by the students.

Student Presentation of Work

The City was organizing a five-day design charrette, “Dutch Dialogues Virginia” around its adaptation and resiliency needs focused on the “Tidewater Drive” district, adjacent to Chesterfield Heights. After seeing the presentation, city staff moved to include the Chesterfield Heights in the design meeting. Students, faculty, and many of the advisory group for the Chesterfield Heights effort were included as participants in the Dutch Dialogue process.

The Dutch Dialogues Virginia resulted in conceptual resiliency designs for three developed watersheds in the Hampton Roads region prone to flooding: Newmarket Creek in Newport News/Hampton, Newtown Creek in Norfolk, and Ohio Creek (Chesterfield Heights) in Norfolk. The designs for Ohio

Creek were almost entirely taken from the student design work in the Tidewater Rising Resiliency Design Challenge.

With the Dutch Dialogues, the region began to assemble a grant proposal under the US Department of Housing and Urban Development (HUD) National Disaster Resilience Competition (NDRC). This was a post-Sandy national program inviting regions affected by past natural disasters to submit plans for dealing with future disasters using resilience design strategies. The focus areas of the Dutch Dialogues Virginia were rolled into Virginia's proposal.

The city of Norfolk recognized the project with its 2015 2015 Environmental Resilience Award of Excellence in 2015.

(Part of Design Team at Norfolk Award Ceremony – September 2016)

In January, 2016, Virginia was awarded $120 million, most of which was to implement the designs on the Ohio Creek Watershed/Chesterfield Heights. This completed an amazing cycle wherein the student designs were developed over the 2014-2015 academic year and funded for implementation one year later.

(NDRC grant award ceremony in Norfolk January 21, 2016.: l-r, Peter Madonia, Chief Operating Officer, Rockefeller Foundation, Hon. Julian Castro, Secretary of Department of Housing and Urban Development, Hon. Paul Fraim, Mayor of Norfolk, Hon. Terry McAuliffe, Governor of Virginia, Rep. Robert Scott (D- VA 2nd District)

Other Design Work

A number of regions have been at this design work in recent years around the country. Other coastal regions that have held/are holding similar design efforts: Rising Tides in San Francisco, Rising Currents in New York City (2010), Designing Recovery (New Orleans, Joplin, NYC), Far Rockaway Competition (NYC), the Dutch Dialogues (New Orleans), Changing Course (Louisiana), Urban Green Council (NY/NJ), Miami Resiliency (Miami), Rebuild by Design (NYC).

Subsequent to this project, the cities of Norfolk and Hampton sponsored a Dutch Dialogue in Hampton Roads

There are a number of design approaches taken in these other efforts:

Competition Guide for Designing Recovery – a post-hazard design effort, but the process has some interesting options for work here.

Rebuild by Design Brief – again, a recovery/post-hazard design process but has some elements that can be borrowed.

Sea Level Rise and Smart Historical Coastal Communities

http://elpnet.org/elp-innovation-grant-sea-level-rise-and-smart-historical-coastal-communities

Florida International University Students and Adaptation Design

http://www.miamiherald.com/news/local/community/miami-dade/coral-gables/article4000484.html