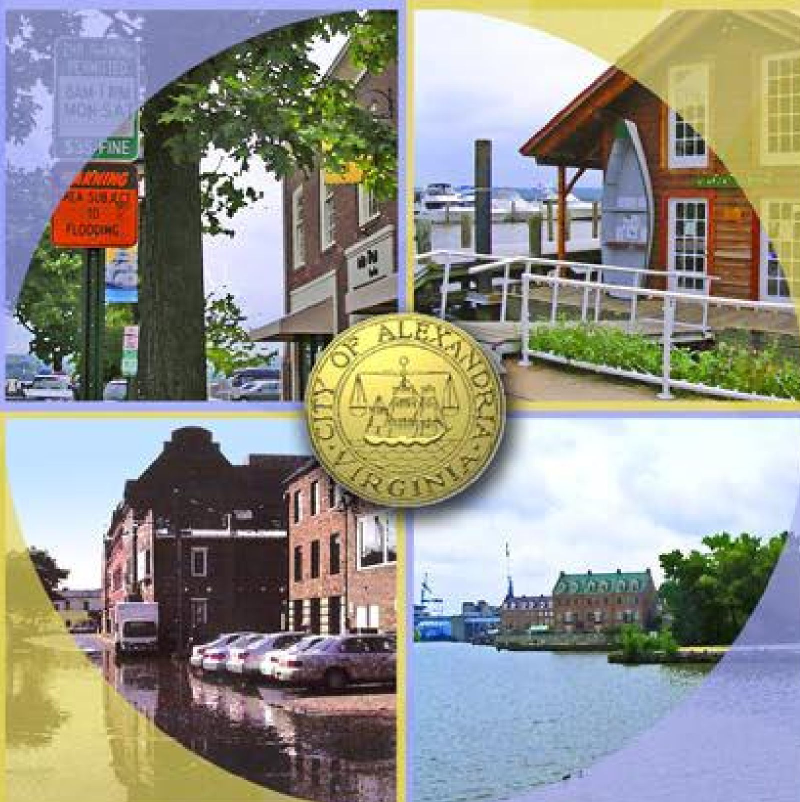
City of Alexandria



Potomac River
Waterfront Flood
Mitigation Study

Evaluation and Recommendation of Mitigation Measures

prepared by
URS Corporation
200 Orchard Ridge Drive
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July 2010

URS

FINAL REPORT

POTOMAC RIVER WATERFRONT FLOOD MITIGATION STUDY

EVALUATION AND RECOMMENDATION OF MITIGATION MEASURES

Prepared for

The City of Alexandria, VA
City Hall
301 King Street
Alexandria, VA 22314

July 2010

URS

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Project Number: 15298592

TABLE OF CONTENTS

TABLES

FIGURES

Appendices

ac	acre
A/E	Architectural/Engineering
ADA	American with Disabilities Act
ASCE	American Society of Civil Engineers
ASCE 24	ASCE Standard 24, "Flood Resistant Design and Construction"
BAR	Board of Architectural Review
BCA	Benefit Cost Analysis
BCR	Benefit Cost Ratio
BFE	Base Flood Elevation
BRV	Building Replacement Value
C	Centigrade
CFM	Certified Floodplain Manager
CFR	Code of Federal Regulations
cfs	cubic feet per second
COA	Certificate of Appropriateness
CRS	Community Rating System
D.C.	District of Columbia
DCR	[Virginia] Department of Conservation and Recreation
DPZ	Department of Planning and Zoning
EAB	Expected Annual Benefit
EAP	Expected Annual Probability
FEMA	Federal Emergency Management Agency
FFE	Finished Floor Elevation
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FMA	Flood Mitigation Assistance
FMV	Fair Market Value
GIS	Geographic Information System

GPS	Global Positioning System
HAZUS	Hazards United States
HMGP	Hazard Mitigation Grant Program
I&I	Inflow and Infiltration
IBC	International Building Code
IP	Individual Permit
IPCC	Intergovernmental Panel on Climate Change
JPA	Joint Permit Application (USACE)
LAG	Lowest Adjacent Grade
LSI	Lower Substantial Improvement Threshold
MD	Maryland
MHW	Mean High Water
NAVD88	North American Vertical Datum of 1988
NC	North Carolina
NEPA	National Environmental Policy Act
NFIP	National Flood Insurance Program
NGS	National Geodetic Survey
NGVD29	National Geodetic Vertical Datum of 1929
NHPA	National Historic Preservation Act
NPS	National Park Service
NPV	Net Present Value
NRHP	National Register of Historic Places
PDM	Pre-Disaster Mitigation
PID HV9658	Permanent Identifier for Benchmark Disk HV9658
RFC	Repetitive Flood Claims
RPA	Resource Protection Area
SFHA	Special Flood Hazard Area
SPGP	State Program General Permit
SRL	Severe Repetitive Loss

TES	Transportation and Environmental Services
TPS	Total Station (Leica high performance total station series instrument)
USACE	United States Army Corps of Engineers
USBC	Uniform Statewide Building Code
USGS	U.S. Geological Survey
VA	Virginia
VCS83	Virginia Coordinate System of 1983
VDEQ	Virginia Department of Environmental Quality
VDHR	Virginia Department of Historic Resources
VDHR DSS	Virginia Department of Historic Resources Data Sharing System
VMRC	Virginia Marine Resources Commission
VSMP	Virginia Stormwater Management Program

The City of Alexandria frequently experiences flooding from the Potomac River. The flooding affects residences, businesses, and infrastructure along the City's waterfront. In 2006 the City commissioned the Potomac River Waterfront Flood Mitigation Study to identify and assess flooding problems and recommend solutions to reduce flood damages. In October 2007 an Initial Flooding Assessment Report was completed that identified specific flooding problems and their causes, and identified and categorized potential flood mitigation solutions. This report evaluates and recommends the most effective solutions.

Twenty-seven mitigation measures were identified and discussed in a series of meetings with the City and the public. The following mitigation measures were selected for detailed evaluation.

- *Structural measures:* provide dry floodproofing; acquire properties; elevate structures; construct engineered structural barriers (i.e., waterfront floodwall and Jones Point Berm) construct an elevated walkway that would also be a floodwall structure; and increase the inlet and road elevation in the vicinity of the Lower King Street area.
- *Nonstructural measures*: relocate internal supplies, products/goods above the flooding depth; improve the City's floodplain and zoning ordinances; and improve the sandbag programs or provide other temporary flood deterrents

Rather than a single flood mitigation solution, a series of measures is recommended to provide protection against flood events on the Potomac River. Three structural measures are recommended: the elevated walkway, floodproofing, and the inlet and roadway improvements.

The elevated walkway would provide flood protection for up to and including the 10-year flood event. It is a cost effective way to minimize the smaller flood events that frequently damage properties adjacent to the river. The low profile also minimizes the impact on the scenic views from the waterfront area.

Dry floodproofing consists of a variety of methods to protect structures from flood waters during small storm events. These methods generally consist of removable barriers that could be installed in front of doors and windows to prevent flood waters from inundating the first floors of structures.

King Street intersections with Strand Street and North Union Street are low points that frequently require road closures due to flooding. Raising the roadway profiles near these intersections will allow stormdrain catch basins and manholes to be elevated and reduce the frequency of road closures.

These structural measures require significant capital expense and cooperation from private property owners. In addition, these projects call for significant effort to comply with applicable regulations.

To further safeguard all properties, numerous nonstructural recommendations are made, which include improvement of the City's floodplain ordinances and the existing sandbag program. Proceeding with implementation of the recommended flood mitigation measures is essential to reduce the frequent and extensive flood damage in the City.

SECTION ONE: INTRODUCTION

1.1 POTOMAC RIVER FLOOD MITIGATION STUDY OVERVIEW

The Potomac River is a major flooding source within the City of Alexandria. Flooding from the Potomac River is a recurring threat that has significantly impacted residential homes, businesses, and infrastructure along the City of Alexandria's waterfront. In response to the flooding issues, the City of Alexandria commissioned the Potomac River Waterfront Flood Mitigation Study in 2006 to identify and assess flooding problems and to develop, evaluate, and recommend solutions to reduce the threat of flood damages in the City along the Potomac River.

The Potomac River Flood Mitigation Study applied a typical problem-solving process:

1. Identify the specific flooding problems
2. Determine the specific cause of the problems
3. Identify solutions
4. Evaluate solutions
5. Recommend the most effective solutions

The Initial Flooding Assessment Report, prepared by URS Corporation and dated October 2007, addressed the first three steps: identify the flooding problems, determine the causes, and identify potential solutions. This report concentrates on the last two steps: evaluating solutions and recommending the most effective solutions. This report summarizes the detailed engineering assessments conducted as part of the feasibility evaluation of potential measures and recommends cost-effective solutions that consider historic/archaeological resources, business/tourism impacts, and environmental impacts.

1.2 BACKGROUND

The City of Alexandria's waterfront lies within the Potomac River watershed and frequently experiences flooding. Flooding severely disrupts businesses in the area and causes extensive damage to property. The City estimates that $32,000 is expended per flooding event for maintenance and public safety personnel and for material costs for sandbags and equipment. This cost does not include lost business revenue and water damage to businesses or residential properties. Flooding along the waterfront has resulted from heavy rains, snow melt, storm surges, strong winds, tropical storms, and hurricanes.

Major floods within the City of Alexandria in recent history were recorded in 1972, 1983, 1996, and 2003. Two floods in 1996 significantly impacted Alexandria's waterfront. The January 1996 flood was due to a heavy snowfall followed by a period of rain and warm temperatures. In September 1996, Hurricane Fran caused flooding along the Potomac River and evacuations of properties in Old Town Alexandria. In February 2003, record levels of snow followed by rain also caused flooding in Alexandria.

The most significant recent flood event was due to tidal flooding occurring during Hurricane Isabel. Hurricane Isabel, which occurred in September 2003, made landfall on the North Carolina coast. Isabel weakened to a tropical storm in Virginia, but the storm's 40- to 60-mile-per-hour sustained winds pushed a bulge of water up the Chesapeake Bay and the Potomac River. In Alexandria, the water level in Old Town reached 8.8 feet North American Vertical Datum of 1988 (NAVD88). Figure 1-1 is a representative photograph taken in the Lower King Street area soon after Hurricane Isabel passed through. Businesses and residential losses were extensive.

Figure 1-1: Lower King Street Area after Hurricane Isabel, 2003

1.3 STUDY AREA

The study area for this project is defined as the area affected by flooding associated with the Potomac River. In general, the southern boundary is the Capital Beltway and the northern boundary is near the railroad tracks near Bashford Lane. For the purposes of this report, the study area was divided into four focus areas, which are shown in Figure 1-2:

Jones Point: This focus area is named for the Jones Point Park that abuts the residential neighborhood. The houses are built of brick and many have basements. All of the houses in the flood prone areas are multi-family residential homes (e.g., townhouses) with the exception of 210 Lee Court and 211 Lee Court, which are single-family structures. The structures are all located in the National Register District. Approximately 17 of the structures in the Jones Point focus area are predicted to experience flooding for the 100-year event.

King Street: This focus area is a mixed-use area (commercial and residential) near the Lower King Street. The boundary begins at the north at Fayette Alley, runs south down South Union Street, cuts through the neighborhood between Prince and Duke Streets and continues up to South Lee Street. Approximately 23 commercial and six residential structures in the King Street focus area are predicted to experience flooding for the 100-year event.

Waterfront Commercial: The Waterfront Commercial focus area includes commercial structures fronting the Potomac River on the eastern boundary of the focus area. The Torpedo

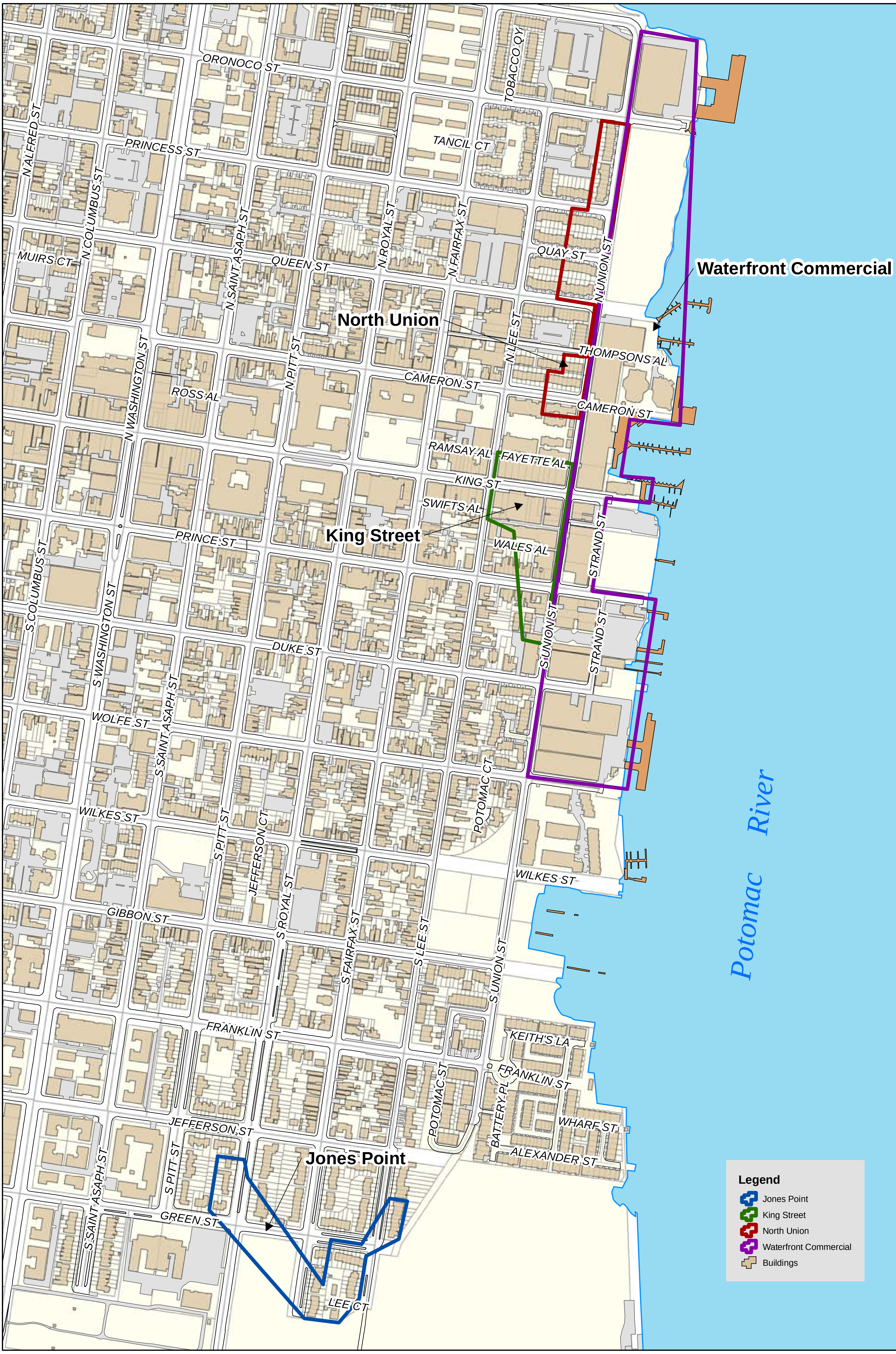
Factory and Strand Street are included in this focus area. South Union Street and North Union Street bound the focus area on the west. It extends to the north where Pendleton Street runs into North Union Street and ends in the south at Wolfe Street. Approximately 22 structures in the Waterfront study area are predicted to flood during the 100-year event.

North Union: This focus area is entirely residential row houses. The focus area is bounded by Oronoco and Cameron Streets and is located just west of the Waterfront Commercial focus area. Approximately 37 structures within the North Union Street Study Area are predicted to flood during the 100-year event.

1.4 REPORT ORGANIZATION

The purpose of this report is to evaluate the solutions identified in the Initial Flooding Assessment Report and recommend the most effective solutions. The remainder of this report is organized as follows:

- Section 2 summarizes the process that was followed to select mitigation options to be evaluated in detail.
- Section 3 describes the mitigation measures identified in Section 2 and the general feasibility of the mitigation measure as a solution to the problems identified in these focus areas.
- Section 4 summarizes the existing data review; the context for the cultural and natural resources analyses; repetitive loss structures within the study area; and the consideration of sea level rise for this study.
- Section 5 describes the methodology used to define and analyze the costs and benefits of mitigation solutions that involve structural design or alteration.
- Section 6 summarizes the conceptual design analyses and results for the structural mitigation measures.
- Section 7 provides overall study recommendations.



CLIENT	City of Alexandria				
PROJ	Potomac River Waterfront Flood Mitigation Study				
REVISION NO	0	DES BY	CJL	09/11/09	
SCALE	1 inch = 400 feet	DR BY	CJL	09/24/09	
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TITLE
Focus Areas

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200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO 15298592

FIGURE 1-2

SECTION TWO: REFINEMENT OF MITIGATION MEASURES

2.1 SUMMARY OF INITIAL FLOODING ASSESSMENT

As part of this project, URS prepared the Initial Flooding Assessment Report, dated October 2007, which summarized flooding problems, identified their causes, and identified and categorized potential flood mitigation solutions. In addition, this report identified three types of flooding events to be considered.

The project considers three discrete flood events: nuisance flooding (elevation 4.0 feet North American Vertical Datum [NAVD]); intermediate flooding (elevation 8.0 feet NAVD); and extreme flooding (elevation 10.2 feet NAVD). The three flood events have return periods associated with them. A return period or recurrence interval is the estimated period of time between occurrences of equal-sized events. For example, the Federal Emergency Management Agency (FEMA) Base Flood has a return period of 100 years; therefore, it is referred to as the 100-year flood or one percent annual flood. Figure 2-1 shows the inundation areas for selected flood-level categories.

For the extreme and intermediate floods, the return period was interpolated from the City of Alexandria and District of Columbia Flood Insurance Studies (FISs), specifically the Potomac River flood profile. The 6-foot flood elevation event was analyzed for a specific flood mitigation alternative that is discussed later in this report. A logarithmic equation was developed using all four flood elevations and known return intervals. For the nuisance flood, the return period was computed through a statistical regression analysis of a U.S. Geological Survey (USGS) tidal stream gage located on the Potomac River at Wisconsin Avenue in Washington, D.C. The return periods for the flood events are listed in Table 2-1.

Table 2-1: Return Periods of Studied Flood Events

Flood Event	Elevation (feet NAVD)	Return Period (years)
Nuisance	4.0	1.5
6-foot Flood (Elevated Walkway)	6.0	10
Intermediate	8.0	30
Extreme	10.2	100

Figure 2-1 shows the areas of inundation for the 4-foot, 8-foot and 10.2 foot flood elevations. Figure 2-2 provides a graphical representation of Table 2-1, with additional reference points including the peak elevation of flooding during Hurricane Isabel, mean high and low water elevations and the relative height for a floodwall that would protect against the 100-year flood level with three feet of freeboard.

CLIENT	City of Alexandria			
PROJ	Potomac Waterfron Flood Mitigation Study			
REVISION NO	0	DES BY	KJM	06/22/07
SCALE	1:12000	DR BY	CJL	10/05/09
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TITLE Inundation Areas for Selected Flood Level Categories

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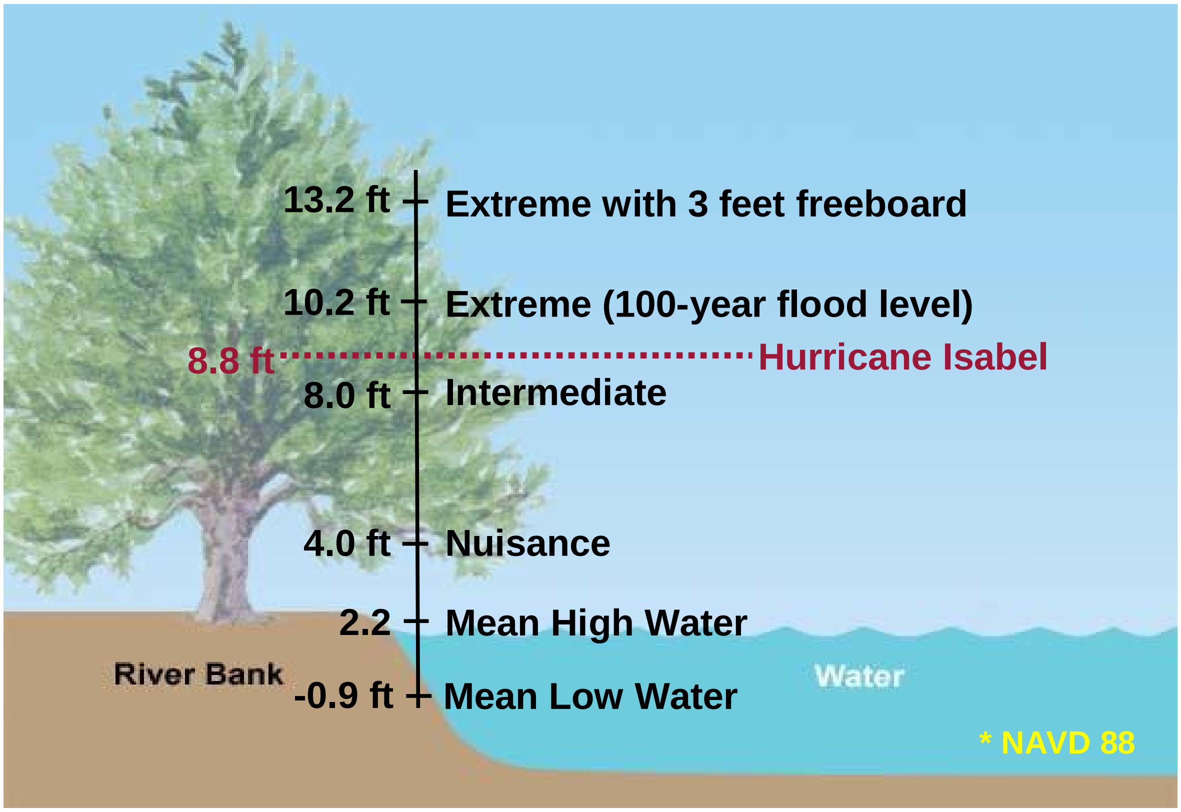
FIGURE 2-1

Figure 2-2: Flood Levels Studied



2.2 LIST OF COMPREHENSIVE FLOOD MITIGATION MEASURES

A comprehensive list of potential flood mitigation measures was developed. This list, which includes 27 potential flood mitigation measures, was developed through a comprehensive brainstorming process in conjunction with the City and from input provided in public meetings that occurred from October 2007 through November 2008. The potential flood mitigation measures were classified by type of mitigation into the following categories:

- Property Protection
- Structural Projects
- Flood Prevention
- Emergency Services
- Public Education and Awareness

A "do-nothing" option was also defined; however, this was used as the baseline alternative and only analyzed during this preliminary solution analysis. Within each type of measure, each alternative was given a general solution title. For example, solutions under property protection that involve preventing damage to contents within a structure are classified as floodproofing solutions. The comprehensive list of potential flood mitigation measures is provided in Table 2-2.

Table 2-2: Summary of All Flood Mitigation Alternatives Considered

Type of Measure	Solution	Description
Property Protection	Floodproofing	**PP1.** Provide wet floodproofing to make uninhabited portions of structures resistant to flood damage.
		PP2. Provide dry floodproofing with impermeable membranes and watertight shields to prevent floodwaters from entering buildings.
		PP3. Relocate internal supplies, products/goods, and utilities above the flooding depth.
		PP4. Relocate external electrical boxes.
	Acquisition	**PP5.** Acquire properties experiencing frequent flooding.
	Elevation of structure	**PP6.** Elevate structures.
Structural Projects	Floodwall	**S1.** Build an engineered structure to act as a barrier between the Potomac River and Alexandria
	Raised boardwalk acting as floodwall	**S2.** Build a pedestrian boardwalk that would also be a floodwall structure.
	Stormdrain improvements	**S3.** Increase the inlet and road elevation to prevent overflow from nuisance flooding events.
		S4. Increase the storm drain pipe size.
		S5. Eliminate Inflow and Infiltration (I&I).

Type of Measure	Solution	Description
		S6. Improve flapgate operation at outflow points.
		S7. Add sump pumps.
	Underground storage	**S8.** Create areas for underground storage.
	Detention structures	**S9.** Provide detention/retention structures.
	Construct an offshore groin	**S10.** Construct an offshore groin.
Prevention	Sewer backflow preventers	**PR1.** Add backflow preventers in homes to prevent stormwater (and sewer) backups.
	Enhancement of floodplain ordinances	**PR2.** Improve the City's floodplain and zoning ordinances.
Emergency Services	Minimizing electrical and gas outages after a flood	**ES1.** Isolate service so that only the buildings affected by flooding would have service turned off.
	ID system	**ES2.** Improve/enhance existing business identification system for returning to impacted area.
	Flood warning system	**ES3.** Implement system to provide text messages, announcements, and/or phone messages regarding the status of the flooding.
	Emergency response	**ES4.** Improve the City's emergency response.
	Temporary structures	**ES5.** Provide sandbags or other flood deterrents for residents and businesses.
	Cleanup program	**ES6.** Provide improved cleanup program.
Public Education and Awareness	Media involvement and outreach	**EA1.** Provide education to area media outlets about what is causing the flooding, how to avoid flooded areas, and what in Alexandria would remain open and accessible.
	Transportation plans	**EA2.** Create maps, provide signs, and help erect barriers (that would be only as large as needed) to show visitors and residents how to navigate the streets and show what businesses and parking areas remain open.
	Insurance outreach	**EA3.** Inform business and residents about reimbursement for damages other than just exterior building damages.

2.3 REFINEMENT OF MITIGATION OPTIONS

As part of this study, the mitigation alternatives in Table 2-2 were ranked using a numerical evaluation criteria to select flood mitigation measures for further consideration. The criteria, along with the respective weighting, are shown in Appendix A. City staff reviewed and approved the scoring matrix criteria. The criteria that were considered in the ranking are listed below, with the heaviest ranked criteria listed first:

- Reduction of Flooding Extent
- Cost to Property Owners

- Loss of Business Revenue
- Aesthetics
- Constructability
- City Liability
- Effect on Potomac River Viewshed
- Private Property Acquisition
- State/Federal Funding
- Repetitive Loss Property Mitigation
- Cost of Flood Insurance
- Property Ownership
- General Environmental Impacts (wetlands, forested areas)
- Loss of Recreational Use
- Historic/Archaeological Resources
- Regulatory Requirements

Each criterion was given a weighting factor, based on the goals of the overall flood mitigation study. A heavier weight was given to options that would prevent more frequent floods. Measures that protect against frequent floods typically provide the greatest cost benefit, because those floods occur more often and result in extensive damages. Second, mitigation measures that provide protection to a large number of structures were also heavily weighted. Since the City's budget is a concern, capital costs were also weighted heavily as directed by City staff. Therefore, project capital cost, the criteria that directly relate to reducing nuisance flooding and the number of structures protected were given the highest weights, a value of 10.

The next level were those criteria that related to extreme or intermediate flood protection, aesthetics, reducing damages, reducing actual flooding extents, loss of business revenue and impacts to the Potomac River viewshed (loss of views along waterfront). These were ranked slightly lower, a weight value of 5, as they are important criteria, but were not considered drivers in this screening process.

A slightly lower weight value of 3 was given to constructability, city liability, maintenance costs, private property acquisition, state and/or federal funding availability, and protection of repetitive loss structures (discussed in Section 4.1.5). Lastly, impacts to flood insurance costs, property ownership, environmental impacts, loss of recreational use, and regulatory requirements were weighted the lowest, at a value of 1.

Each flood mitigation alternative was then given a score for each criterion and the total weighted rankings were summed to provide an overall score. The ranking system was developed so that positive impacts were given a score of 10 and negative or no impacts within that criterion were given a score of 1.

In conjunction with the City, a series of sensitivity analyses were performed with slight variations in the weight factors for certain criteria and for each alternative's ranking within a specific criterion. This was to verify that the final alternatives that would be analyzed in further detail were not being subjectively selected by the process. The final score and overall rank for each flood mitigation alternative are listed in Table 2-3.

Table 2-3: Flood Mitigation Measure Final Rankings

Alternative ID	Total Score	Ranking	Alternative Definition
S1	500	1	Build an engineered structure to act as a barrier between the Potomac River and Alexandria.
S2	499	2	Build a pedestrian boardwalk that would also be a floodwall structure.
PP5	473	3	Acquire properties experiencing frequent flooding.
ES5	466	4	Provide sandbags or other flood deterrents for residents and businesses.
S3	439	5	Increase the inlet and road elevation to prevent overflow from nuisance flooding events.
PP6	435	6	Elevate structures.
PP2	396	7	Provide dry floodproofing with impermeable membranes and watertight shields to prevent floodwaters from entering buildings.
PR2	389	8	Improve the City's floodplain and zoning ordinances.
PP3	379	9	Relocate internal supplies, products/goods, and utilities above the flooding depth.
S6	376	10	Improve flapgate operation at outflow points.
PP1	348	11	Provide wet floodproofing to make uninhabited portions of structures resistant to flood damage.
PR1	339	12	Add backflow preventers in homes to prevent stormwater (and sewer) backups.
ES1	334	13	Isolate service so that only the buildings affected by flooding would have service turned off.
PP4	324	14	Relocate external electrical boxes.
ES4	323	15	Improve the City's emergency response.
EA3	309	16	Inform business and residents about reimbursement for damages other than just exterior building damages.
Do Nothing	309	16	Do nothing.
ES2	303	18	Improve/enhance existing business identification system for returning to impacted area.
ES3	303	18	Implement system to provide text messages, announcements, and/or phone messages regarding the status of the flooding.
ES6	299	20	Provide improved cleanup program.
EA1	294	21	Provide education to area media outlets about what is causing the flooding, how to avoid flooded areas, and what in Alexandria would remain open and accessible.
EA2	279	22	Create maps, provide signs, and help erect barriers (that would be only as large as needed) to show visitors and residents how to navigate the streets and show what businesses and parking areas remain open.
S7	254	23	Add sump pumps.

Alternative ID	Total Score	Ranking	Alternative Definition
S4	252	24	Increase the storm drain pipe size.
S5	244	25	Eliminate Inflow and Infiltration (I&I).
S10	242	26	Maintain an offshore groin.
S8	227	27	Create areas for underground storage.
S9	210	28	Provide detention/retention structures.

The top nine highest-scoring flood mitigation measures were selected for further evaluation. The measures selected are listed below:

Structural Measures

- Provide dry floodproofing by preventing floodwaters from entering the building with impermeable membranes.
- Acquire properties.
- Elevate structures.
- Build an engineered structure to act as a barrier between the Potomac and Alexandria.
- Build an elevated boardwalk that would also be a floodwall structure.
- Increase the inlet and road elevation to prevent overflow from nuisance flooding events.

Nonstructural Measures

- Relocate supplies and products above the flooding depth.
- Recommend improvements to the City's floodplain and zoning ordinances.
- Recommend improvements to the sandbag program or provide other temporary flood deterrents for residents and businesses.

SECTION THREE: OVERVIEW OF FLOOD MITIGATION MEASURES

As described in Section 2, ten flood mitigation techniques were selected for further consideration. They include measures that have structural elements, such as flood barriers, as well as those that do not require structural changes, such as ordinance revisions and modification to the City's sandbag program. It should be noted that the ranking analyses were performed without assessing specific applicability to the City. The flood mitigation measures and their applicability for use within the City of Alexandria are described in this section.

3.1 STRUCTURAL MITIGATION MEASURES

3.1.1 Structural Flood Barriers

Flood barriers are man-made structures that are built to protect low-lying areas from the inundation of floodwaters. These barriers provide either permanent or temporary flood protection. Temporary flood barriers are described in Section 3.2.3.

Permanent flood protection is a passive system, meaning it is always in place and requires no human interaction to activate during flood events. These measures include levees, floodwalls, and berms. Levees and berms are typically earthen structures that require significant land while floodwalls take up less space and are typically constructed of concrete or steel. Permanent flood protection is typically an expensive option, which requires ongoing maintenance for continued flood protection.

Selection of the most appropriate flood barrier needs to take into account the frequency, typical depth, and duration of flooding. Next, the level of protection desired and the size of the area that needs protection need to be considered. Since the areas being protected by the systems are low-lying, all flood protection methods need to be extended to (i.e., tied-in to) high ground. Aesthetics is another important consideration in choosing an appropriate flood barrier. Levees, floodwalls and berms cause visual impacts and can be viewed as unattractive; they may also hinder access to waterways. Access to waterways through a flood barrier can be provided by using a floodgate, which is an opening in the flood barrier that is lowered or closed during flood events. Consideration of all of these factors will determine the best type of flood barrier for the project area.

Once the flood barrier is selected, an important design component is interior drainage. During most rainfall storm events, the discharge from the interior areas can be conveyed by gravity through the existing stormdrain systems. Stormdrain systems are typically designed to convey the 10-year discharge.

However, during periods of high elevation on the Potomac River, high water in the river prevents gravity flow through the stormdrain system, while flapgates prevent back flow. During this worst-case scenario (referred to as "coincident peaks"), the flood barrier system would need to convey the interior drainage for events at least up to the estimated 100-year flood discharge. Therefore, design concepts include pumping stations to pump the discharge into the Potomac River in the event the flapgates are sealed or blocked.

Finally, if the flood protection barrier is to be recognized by FEMA as a flood protection device, the levee must meet the requirements contained in Section 65.10 of the National Flood Insurance

Program (NFIP) regulations. These requirements include at least 3 feet of freeboard above the Base (one-percent annual chance) Flood Elevation (BFE), an operation and maintenance plan. If these criteria are met, the areas on the landward side of the levee may be removed from the floodplain. Only permanent structural flood barriers are permitted to change the floodplain.

Three potential permanent structural flood barrier solutions are evaluated in this report. They are:

- 100-year Floodwall along the Potomac River Waterfront
- Elevated Walkway in the Lower King Street Area
- Jones Point Berm

Conceptual designs were prepared for each of these flood mitigation alternatives to evaluate the technical and cost feasibility. Further analysis is presented in Section 6.

3.1.2 Acquire Properties

In recent decades, FEMA's preferred flood mitigation alternative has increasingly been property acquisition because, in many cases, it is more cost-effective than large engineered solutions. Property acquisitions or flood buyouts are the process of purchasing flood-prone structures and demolishing them to eliminate future flood damage claims from those structures. Often these acquired properties become an amenity for the community through the creation of new open space that can be used to create parks or wildlife areas. It is also a permanent solution for mitigating those flood hazards.

Various factors should be considered to determine whether or not property acquisition is a viable mitigation measure in the City. Because buyouts are a voluntary measure, a critical factor is the willingness of residents to participate in the program.

To determine acquisition costs the following parameters were estimated: fair market value of each property, the number of properties likely to require a special survey, and project work schedule. Average costs were used for property appraisals, real-estate closings, structure demolition, debris disposal, and legal fees. Administrative costs are also expected to be incurred for report preparation, overtime, and incidental expenses.

One disadvantage to the acquisition option is that it precludes the preservation of historic buildings. Potential political or socioeconomic implications involved with such a project need to be considered. Further, potential opposition from property owners reluctant or unwilling to support the acquisition must be considered.

Acquisition within the study area is a technically feasible alternative, but it is not feasible for every property. Therefore, a more detailed assessment of the study areas is required. While acquisition may be technically feasible in some study areas, the cost effectiveness of this alternative is highly variable. The cost variability is dependent on characteristics such as real estate values and flood depths. Therefore, this alternative will be further analyzed in Section 6.

3.1.3 Floodproofing

Floodproofing is the process of modifying a structure or its contents in such a way that the damages from future flood losses will be reduced or eliminated. The two types of floodproofing are wet floodproofing and dry floodproofing.

Wet floodproofing involves modifications to a structure so that the contents of the structure are protected when floodwaters enter it. The primary modifications involve elevation or relocation of appliances, electrical, and utility systems, as well as use of flood-resistant materials inside the structure. This type of floodproofing is most appropriate for structures that have a basement or crawl space and a First Floor Elevation (FFE) above the BFE. It is important to note that flooding will still occur within the structure, so extensive clean up may still be necessary after flooding events, especially if the floodwaters are contaminated. However, these modifications can reduce the total damages to structures and their contents.

Dry floodproofing is the process of making the portion of a structure that is below a certain flood elevation watertight. This prevents floodwater from entering the structure and causing damage. This process involves applying a membrane or coating to the surface of the structure as well as sealing any openings, such as doors and windows, with permanent or removable barriers such as a floodgate (see Figure 3-1).

Figure 3-1: Floodgate

Some risks arise when dry floodproofing structures. One is that dry floodproofing is generally not recommended for structures with basements. This is because these buildings are susceptible to underseepage, which can create a strong buoyancy force that might damage the structure. However, floodproofing structures with basements is considered to some extent for this project due to the limited number of alternative feasible flood mitigation options. Also, dry floodproofing is not recommended for wood frame buildings or other buildings with weaker construction materials, because these structures are more likely to fail from hydrostatic forces that result from deep water. Even structures with stronger construction materials, such as brick or concrete, should not be dry floodproofed above 3 feet (Figure 3-2).

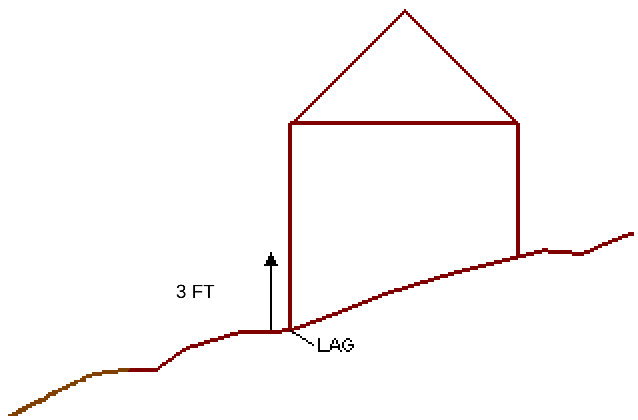


Figure 3-2: Three-Foot Dry Floodproofing Limitation

The lowest adjacent grade (LAG) for a structure is the lowest ground elevation that is touching the building (Figure 3-2). This location is generally the first point of entry for floodwater (Figure 3-3). Placing fill at this location to increase the elevation of the lowest adjacent grade is another dry floodproofing technique that may prevent floodwater from entering the building (Figure 3-4).

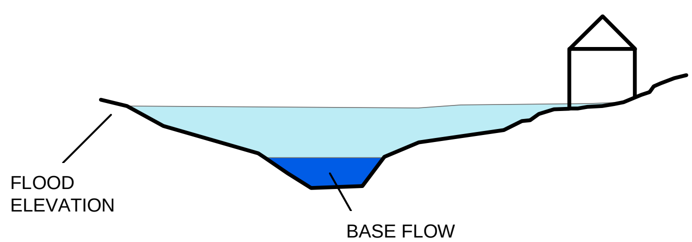


Figure 3-3: Flooded Building

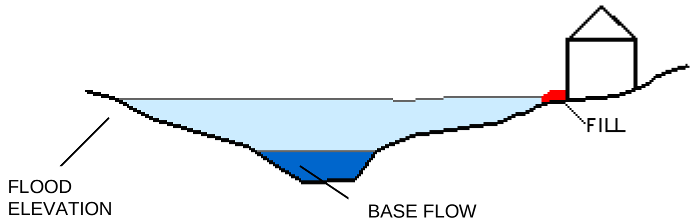


Figure 3-4: LAG Elevated to Protect Building from Flooding

A raised patio is a patio that would be rebuilt at a new, higher elevation to prevent the flow of floodwaters into the structure. Other localized flood barriers can be designed to accomplish the same effect if a patio is not an option, including localized yard berms and small privacy walls that are designed to be floodwalls. The raised patio or other localized flood barrier must be designed by a registered architect, engineer, or other certified professional who is responsible for ensuring that the design prevents flooding.

Two main differences need to be considered when evaluating dry floodproofing for residential structures verses for commercial structures. The first difference is that dry floodproofing a residential structure does not remove it from the FEMA floodplain and, thus, does not alleviate the requirement for flood insurance. However, dry floodproofing can be used to remove commercial structures from the FEMA floodplain. In addition, for a floodproofed structure to be removed from the FEMA floodplain, it is important that any construction that is below the BFE meet the FEMA criteria for flood damage resistance. For more information, refer to FEMA Technical Bulletin 2 (August 2008).

Most wall materials, including brick, will leak unless constructed or modified using special waterproofing techniques. Care should be taken when applying a sealant to the outside of a brick wall. Waterproofing compounds can deteriorate or fail if exposed to floodwater for extended periods of time. In addition, sealants may also be subject to damage, particularly in areas that experience high velocity floodwaters, or waters containing debris or ice.

Floodproof membranes or coatings can also affect the aesthetic quality of a building. Clear coatings, such as epoxies and polyurethanes, are generally not as effective as cement or asphalt based coating. Therefore, the aesthetic appeal of a brick wall is lost with the use of higher quality sealants. One way to solve this problem is to add an additional layer of brick to the structure with the sealant located between it and the original brick surface. However, this is not considered an appropriate technique for historic structures.

Floodproofing the walls of a structure by applying a membrane or coating to the surface could be considered for almost all of the floodprone buildings in the study area. However, without careful care and maintenance, these sealants may still leak. In addition, it is difficult to use this floodproofing method without compromising the building aesthetics. Modifications would require review and approval by the City's Board of Architectural Review, since the focus area is within the designated historic district. Therefore, floodproof membranes or coatings have not been considered as an option for this study.

Structure openings can be floodproofed using permanent or removable shields or valves. Such openings primarily include doors, windows, and air vents. Floodgates are widely available for floodproofing both garage doors and pedestrian doors. However, most of these are active systems; requiring installation after a flood warning has been issued. Special floodproof doors are also available that look and function the same as a regular door (Figure 3-5). Although they are more expensive than a floodgate, these doors have the advantage of being a passive floodproofing measure.

Figure 3-5: Floodproof Door

It is generally less costly to floodproof windows and air vents. One option for windows is to remove them and replace with brick. Another possibility is to seal the window shut with waterproof caulking, which allows the homeowner to retain the aesthetic benefit of the window. A third option is a shield on the outside of the window. These are usually made from Plexiglas, aluminum, or plywood and can be screwed in place or slid into predesigned framed slots. Air vents can only be floodproofed through active systems. Two options include a slide-in-place shield or a watertight adhesive material.

As previously described, dry floodproofing offers many options. The following dry floodproofing options are considered technically feasible in locations within the study area.

- Floodgates
- Floodproof openings
- Raised patios

Internal elevation of contents is another type of dry floodproofing described in Section 3.2.2.

Since floodproofing actions will be driven by individual property owners, it is not likely that this measure will be fully implemented. Therefore, in general, floodproofing is recommended in conjunction with other flood mitigation measures.

3.1.4 Elevate Structures

The goal in elevating structures is to raise the first finished floor above the 100-year flood elevation (extreme flood event). Elevating structures can be accomplished in two ways. A home or business may be elevated by being lifted off its existing foundation, building a new foundation to an appropriate height, and resetting the home on the new foundation. The second way to elevate a structure is to raise the floor inside the house while leaving the outside of the house in its original position. This is only an option for structures with relatively high ceilings or where the elevation required is small. It may also necessitate abandoning a floor that is below the 100 year flood elevation and moving personal property to a higher floor. This is referred to as "internal elevation." Internal elevation is described in Section 3.2.2.

The most suitable structures for elevation are one- or two-story wood frame buildings. Data obtained from the City of Alexandria showed that most structures in the study area are brick or masonry buildings that are attached to other structures. Furthermore, the entire study area is within the Old and Historic Alexandria District. Also, most of the study area is within the National Register District. The nature of this alternative includes an element of risk for historic buildings that may be unacceptable. There is a possibility of excessive cracking taking place when elevating brick and masonry structures. Also, for those structures to be elevated, any attached buildings would need to be elevated at the same time, which could be a very complex process. A further complication to this process is the fact that the entire study area is within the City's Historic District, so any mitigation work would need to comply with historic preservation guidelines. Therefore, due to the difficulty and complexity of elevating row homes and large masonry buildings, elevation is not recommended as a flood mitigation alternative.

3.1.5 Increase Inlet and Road Elevations

During extreme tide events, Strand Street, within the Waterfront Commercial focus area, is subject to frequent flooding. Storm sewers are typically designed to quickly convey stormwater away from roadways. However, in instances where extreme tides back up into the municipal storm sewer, the storm sewers cannot convey the flow from surface runoff. If the storm sewers back up to an elevation equal to the road surface, the water overflows the catchbasin (inlet) and the roadway floods. This causes traffic safety issues, which generally requires the City of Alexandria officials to close the roadway. Closed roadways present further safety issues in limiting access for emergency vehicles. Other access issues include limiting access to residences and businesses. Note that this occurs at elevations lower than the nuisance flooding elevation of 4.0 feet as defined by this study. Areas where the inlet rim elevations (elevation of the inlet at the top, where it intersects the road) were less than 4.0 feet were the focus of this alternative.

Flooding that occurs more often than the nuisance flood can sometimes be remedied by raising the existing road elevation, as well as the associated inlets and manholes along the road. By increasing the road and inlet rim elevation, the water back-flowing in the storm sewer must reach a higher elevation to overtop the catchbasin and flood the road. Design constraints that need to be analyzed are the elevation of the sidewalks and first floors of the buildings along the roads.

The design constraints are derived from the Americans with Disabilities Act requirements and building first floor elevations, as well as the existing storm drainage around the buildings.

Several years ago, the City completed a road elevation project at the intersection of Duke Street and Strand Street. This action was considered moderately effective at reducing nuisance flooding; therefore, this measure was reviewed for feasibility at King and Strand Streets (including King Street West to North Union Street and Strand Street South to Wales Alley). While this measure is not expected to directly reduce property damage, it would reduce the frequency of road flooding and ensure better and safer access to the area. Section 6 summarizes the concept design for this flood mitigation measure.

3.2 NONSTRUCTURAL MITIGATIONS

In addition to the structural mitigation measures discussed above, three nonstructural mitigation measures were selected for further evaluation as described in Section 2. Implementation of these measures typically requires less capital expense. However, benefits of implementing these measures are difficult to quantify because they do not reduce flood risk for specific structures. Therefore, these measures are recommended in tandem with structural flood mitigation measures. A discussion of the nonstructural flood mitigation measures is provided below.

3.2.1 Improve Floodplain Zoning Ordinances

The City of Alexandria has a floodplain ordinance in place under the Zoning Ordinance Article VI Section 6-300. While this ordinance is comprehensive, revisions and additions to the ordinance can further protect homes and businesses in the floodplain and may qualify the City for reduced flood insurance rates through the Community Rating System (CRS).

The CRS is a program administered by FEMA that rewards communities that undertake floodplain activities beyond the requirements of the NFIP. The three goals of the CRS are to: (1) reduce flood losses, (2) facilitate accurate insurance rating, and (3) promote awareness of flood insurance. Communities can undertake four CRS Activities: Public Information, Mapping and Regulations, Flood Damage Reduction, and Flood Preparedness. The City already participates in the CRS program and expressed interest in exploring additional CRS Activity credits for the Mapping and Regulations CRS Activity. The following four activities are recommended for implementation:

- **Cumulative Substantial Improvements** – The NFIP allows improvements or repairs to existing structures valued at up to 50 percent of the building's pre-improvement value to be permitted without meeting the current flood protection requirements. Over the years, a community may issue a succession of permits for improvements to the same structures. This can increase the overall flood damage potential within a community as well as the insurance liability to the Federal Insurance and Mitigation Administration. This element provides credit to a community that tracks the total value of all improvements or repairs permitted over the years to ensure that it does not exceed 50 percent of the original value of the structure. When the total value does exceed 50 percent, the original building must be protected according to the current ordinance requirements for new buildings.

To receive CRS full credit of 45 points, the community must have a system to track improvements for at least 10 years. However, Alexandria could receive 25 CRS points if the records are accessible for at least five years.

This element may require no specific ordinance language, but simply a policy decision to interpret the 50 percent improvement threshold as cumulative. In such cases, as required by the CRS program, documentation must include a legal opinion or directive from the legal counsel stating how the ordinance is to be interpreted. In any event, the City would need to maintain permit records by parcel number or address, so that the history of improvements or repairs to a particular structure is checked before the next permit is issued.

This element requires that more structures be brought into compliance with the NFIP, thereby lowering costs from flood damages and decreasing flood insurance rates. There will be an increased cost for homeowners and business owners who reach the substantial improvement threshold earlier and will be required to bring their structures into compliance with the floodplain regulations. For the City, costs would be associated with changing the zoning ordinances and policies and educating permitting officials on the change.

However, one difficulty expressed by the City's staff is evaluating the value of the improvement in comparison to the value of the structure. The City's current ordinance is written based on NFIP requirements, which calculate the improvement as a percent of "market value of the structure." If the City were to change the definition within the ordinance to reflect different measurement criteria, such as square footage, the change may not meet NFIP requirements. Therefore, it is recommended that the City consult with FEMA regarding the method of measuring cumulative improvement values.

- **Lower Substantial Improvements** – This element has the effect of requiring more structures to come into compliance after a disaster, because damage repair is included in "improvements" under the NFIP rules. The City of Alexandria already includes a 50 percent substantial improvement threshold. To receive CRS credit for the Lower Substantial Improvement Threshold, the City would need to lower the threshold to less than 50 percent. For instance, if the regulatory threshold was lowered to 49 percent, the City would qualify for an additional 10 points. If the threshold was lowered to 39 percent, the City would qualify for an additional 50 points.

  In a manner similar to the cumulative substantial damages element, this element provides more flooding protection by requiring more structures be brought into compliance with the NFIP, thereby lowering costs from damages and decreasing flood insurance rates. However, it results in an increased cost for homeowners and business owners who reach the lower substantial improvements threshold earlier and will be required to bring their structures into compliance with the flood maps. Again, the only costs to the City would be associated with changing the zoning ordinances if necessary and educating permitting officials on the change.

- **Protection of Critical Facilities** – CRS credit is provided only if regulatory language protects critical facilities. FEMA defines types of critical facilities as follows:

  - Structures or facilities that produce, use, or store highly volatile, flammable, explosive, toxic and/or water-reactive materials

- Hospitals, nursing homes, and housing likely to have occupants who may not be sufficiently mobile to avoid injury or death during a flood
- Police stations, fire stations, vehicle and equipment storage facilities, and emergency operations centers that are needed for flood response activities before, during, and after a flood
- Public and private utility facilities that are vital to maintaining or restoring normal services to flooded areas before, during, and after a flood

Requiring protection for critical facilities serves several purposes: it reduces damage to vital public facilities; it reduces pollution of flood waters by hazardous materials; and, most importantly, it ensures that the facilities will be operable during most flood emergencies. To receive full credit for this element, the regulations must be enforced in the 500-year floodplain.

On older Flood Insurance Rate Maps (FIRMs), the 500-year floodplain is shown as the Special Flood Hazard Area (SFHA) plus Zone B. The ordinance can simply specify the types of facilities prohibited from or protected within Zones A and B. On newer FIRMs with Zones AE and X, the 500-year floodplain is shown as the SFHA plus the shaded Zone X. In either case, the 500-year flood elevation becomes the “flood protection elevation” for critical facilities. If the community enforces critical facility protection regulations in only part of its flood hazard area, e.g., in the floodway or Zone V, the impact adjustment is based on the 500-year floodplain rather than an RF, the area of the regulatory floodplain.

Based on our review of available Geographic Information System (GIS) data, there are no critical facilities currently identified in the 500-year floodplain within the study area. To obtain CRS credit, the City can implement a requirement in the regulations to prevent construction of critical facilities in the floodplain. If there are critical facilities or plans to build new ones, this regulation may not be possible. The fact that no critical facilities are currently identified in the regulatory floodplain may indicate a City policy, but adopted regulations are required to gain credit for protection of critical facilities.

- **Staff Training** – A CRS credit is available when inspectors are Certified Floodplain Managers (CFMs). In addition, increased general knowledge of floodplain management better equips staff to make informed decisions. Therefore, it is recommended that staff involved in reviewing plans and issuing permits for floodplain development and conducting field inspections become CFMs.

  Training staff involved in reviewing plans and issuing permits as CFMs would increase enforcement of the approved regulations because the staff will have better knowledge of the regulations they are enforcing. The cost of training and maintaining the CFM certification for relevant staff will have to be included in the City’s budget.

  A maximum of 50 points of CRS credit is provided if all regulatory staff are CFMs. Twenty-five points credit is provided for CFM review of all proposed development in the floodplain and associated certificates of occupancy. If neither of these items is possible, credit is granted for each staff person who is a CFM or a graduate of an NFIP-approved course on floodplain management, up to 25 points total.

In addition to these items directly recommended by the CRS program, it is recommended that the City take several other steps to enhance their existing regulations.

- **Permitting and Inspection –** In addition to reviewing permits, it is recommended that the City increase the frequency of inspecting new construction to ensure that the work is being conducted according to the provisions of the floodplain ordinance. The ordinance can also be amended to give the floodplain administrator the right to issue a stop work order or revoke building permits if the inspections show that a violation has taken place. Sample code from the City of Charlotte in Mecklenburg County, NC is shown in Appendix B, Exhibit 1.

  This activity would ensure that buildings are constructed in compliance with the building permits and prevent unauthorized work, such as converting basements into living spaces, from occurring, thereby reducing flood damages. Costs for the City include additional staffing to support more frequent inspections.

- **Accessory Structures –** It is recommended that additional regulations regarding accessory structures such as sheds and garages be added to strengthen the existing ordinances. For example, regulations could prohibit structures from being constructed within the floodplain. The sample code from Charlotte in Mecklenburg County, NC is shown in Appendix B, Exhibit 1.

  This activity would prevent accessory structures from being constructed in the floodplain, which would lower costs from damages. Costs for the City would be associated with changing the zoning ordinances and educating permitting officials on the change.

- **Variances –** A review of approved City variances indicates that no variances related to floodplain protection were granted within the last 3 years. However, it is recommended that the City consider strengthening the language to ensure that floodplain variances are discouraged. The sample code from Roseville, CA is shown in Appendix B, Exhibit 1.

  Reducing the number of floodplain variances would potentially lower costs from damages by further minimizing construction within the floodplain areas. There may be an increased cost for homeowners and business owners who will not be granted variances. For the City, the only costs would be associated with changing the zoning ordinances and educating permitting officials on the change.

Regulatory Consistency

During this study, a discrepancy between the City of Alexandria's floodplain ordinance and building code was discovered. The specific discrepancy is that under the floodplain ordinance (Section 6-307), the FFE of new or substantially improved structures must be at or above the BFE. However, the City's Building Code (Section 8-1-2) is more restrictive in that there must be a minimum freeboard requirement with regards to the FFE.

The City of Alexandria building code states that the City has adopted the Virginia Uniform Statewide Building Code (USBC). Therefore, the USBC is the guiding, legal document when the City's code does not contain construction specifications. Within the USBC, the flood-resistant construction provisions of the International Building Code (IBC) are specifically adopted. Therefore, the City has effectively adopted the IBC with regards to flood resistant construction.

The IBC (Section 1612.4) states that "…the design and construction of buildings and structures located in flood hazard areas, including flood hazard areas subject to high velocity wave action, shall be in accordance with ASCE 24." This means that all design and construction of structures located in flood hazard areas are governed by the specifications within American Society of Civil Engineers (ASCE) Standard 24. ASCE Standard 24 is titled "Flood Resistant Design and Construction," and is the guiding document for construction within the floodplain. ASCE 24 states that with the exception of Class I structures, which are limited to agricultural, temporary, and minor storage, all new and substantially improved structures must be designed and built with a FFE at the BFE plus 1 foot or more.

Therefore, all construction within the Zone AE floodplain of the City of Alexandria is required to meet the more restrictive ASCE 24 design, rather than the NFIP design. FEMA is aware of this inconsistency; currently a guidance document is being prepared that advises communities on how to deal with this within their floodplain ordinances. However, it is recommended, at a minimum, that the City require conformance to the required building codes, thereby requiring 1 foot of freeboard to the FFE. Therefore, the City, by reference, requires 1 foot of freeboard. It is recommended that the City request that FEMA consider awarding CRS points for this element.

3.2.2 Elevate Internal Supplies and Goods

Elevation of supplies, products, or goods above the flooding depth is a type of wet floodproofing that can be readily implemented and can protect structure contents from flood damage. This measure would require businesses and residents to realign their internal work and storage areas, which may affect the function of the internal spaces. Although this solution is applicable for buildings that are flooded by an extreme flood, this mitigation solution focuses on buildings affected by nuisance flooding because it is believed that business operators and residents that experience frequent flooding would be willing to restructure their internal spaces.

For this mitigation solution, elevating supplies and utilities to a height of approximately 2.5 feet, which is a standard table or desk height, was considered. Supplies could also be stored in shelving units or overhead suspension systems that are above that height. Another important component of this solution is outreach and education to residents and business owners who could benefit by internal elevation.

Approximately 23 structures are located within the area of nuisance flooding. Using either the FFE or the minimum topographic contour, 13 of these structures have an FFE at or above the 4-foot contour and are not expected to experience nuisance flooding. An additional two buildings receive too much flooding for elevation of internal supplies to be feasible. The final eight buildings have flooding depths less than 2.5 feet and would be candidates for this mitigation measure. All of these buildings are commercial properties within the Waterfront Commercial focus area and are listed in Table 3-1.

Table 3-1: Structures Recommended for Elevation of Contents

	Property ID	Address	Description	Min. Contour (NAVD88)	FFE (NAVD88)	Flooded Depth (ft)
1	065.03-07-04	2 Queen St	The Virginia Shop	3.9	-	0.10
2	075.01-05-01	102 S Unions St	Old Dominion Boat Club	2.0	3.75	0.25
3	075.03-03-02	6 Prince St	Garage with offices on top	3.7	-	0.30
4	075.01-05-01	100 S Union St	Commercial	3.2	3.51	0.49
5	075.01-05-01	6 King St	Starbucks Coffee	2.4	3.51	0.49
6	075.01-06-11	103 S Union St	Mai Thai	2.0	3.51	0.49
7	075.01-03-10	105 King St	Chart House Restaurant	2.5	-	1.50
8	075.01-04-05	1 King St	Shops	2.2	-	1.80

In addition to the structures listed above, internal elevation of goods and supplies is also recommended for consideration for large commercial structures near the waterfront. Section 6 identifies applicable structures for this mitigation measure.

It is recommended that the City conduct a site visit to each location to educate the business owners about this mitigation measure and to determine whether tables, shelving, or a more complicated suspension system would be options for their businesses. The costs for the City would include conducting site visits and providing subsequent support by a City employee or contractor. The business owners will be responsible for the cost of the appropriate storage systems.

3.2.3 Sandbagging and Other Temporary Measures

The City currently maintains a sandbag distribution system for affected businesses and residential areas within the Potomac River waterfront area. The City provides a predetermined number of sandbags to the residences and businesses located along Union Street and other flood-prone streets, depending on the expected intensity of flooding. In addition, several tons of loose sand and empty bags are also available to the residents in a designated location.

The sandbags serve as temporary flood barriers for low flooding depths. Other types of temporary measures were researched for applicability. These measures can include inflatable barriers, frame constructed barriers with watertight membranes, and removable steel or Plexiglas panels. Although the capital costs for these systems are typically less than for permanent flood barriers, such as floodwalls, they are active systems that require human interaction. Some of the temporary flood protection systems are complicated, requiring training on proper installation techniques. These systems typically work well for occasional shallow flooding, or for extending a permanent flood barrier to a higher elevation, but are not good options in areas with deep and/or frequent flooding.

Water-inflatable barriers were considered for implementation. These barriers, typically made of vinyl coated polyester, are single-tubed devices with an inner restraint baffle. These barriers are not recommended for use in the City because they are high maintenance, use considerable space, and are difficult to operate. Once inflated, they severely restrict ingress and egress to the protected area. Also, this measure must be installed by trained technicians, and it is critical that the barriers be initially positioned correctly, because once inflated with water, they cannot be transported. Because the urbanized focus areas do not have sufficient space to set up this flood barrier, this measure was not considered feasible for the City.

No other temporary flood barriers were identified as being suitable for implementation. Therefore, it is recommended that the City maintain the sandbag program and consider the following changes to the current sandbag guidelines:

- The current sandbag distribution areas are relatively small compared to the portions of the waterfront area that are within the boundaries for the nuisance, intermediate, and extreme flood events. It is suggested to expand the sandbag service areas to include all flood-prone areas of the Potomac waterfront. Because the current sandbag distribution plan requires so much labor effort, these expanded areas could be serviced on a self-serve basis by adding one additional sand drop off point at 400 North Union Street to the existing drop off point at 500 South Union Street.
- The current sandbag guidelines state that “The Directors of Emergency Management and TES [Transportation and Environmental Services] are responsible for determining on a case by case basis if routine, minor flooding is expected or a large-scale flooding is expected.” These guidelines rely on the institutional knowledge of City workers to initiate sandbag distribution before each event, and could be lost if those workers leave the City. While each flooding event is unique, it is suggested that the City develop specific guidelines that could be used as a framework for determining when to initiate sandbag distribution. These guidelines could include information about the duration and intensity of rainfall, amount of snowmelt, expected gage heights along the Potomac, and information on approaching tropical storms.
- The City provides general information about sandbags on the Flooding Information section of their Web site. It appears that the City puts together a press release giving the relevant information before each potential flooding event. While press releases are a valuable tool, posting general information about the sandbag program on the Web page could reduce the number of inquiries the City receives, as well as informing residents outside of the distribution areas that they may need to make their own provisions for sandbag procurement. In addition to posting sandbag information, a simple fact sheet or a “common questions about the sandbagging program” could be developed. Last, the Flooding Information page cannot be found using the search feature on the City’s Web page. Adding this information to the search tool could make the sandbag information more accessible to Web site users.

3.3 OTHER MEASURES

The section above describes the nonstructural mitigation measures that were selected for detailed evaluation. Additional nonstructural mitigation measures were identified that were not selected for detailed analyses. Although these measures did not rank high enough to be evaluated in detail, many of these measures can be implemented relatively simply, with little or no cost incurred by the City. Recommendations for the following non-prioritized measures are provided in Appendix C:

- Improve flapgate operation at outflow points.

- Add backflow preventers in homes to prevent stormwater and sewer backups.
- Isolate gas and electrical service lines.
- Relocate external electrical boxes.
- Improve the City's emergency response.
- Inform businesses and residents about NFIP contents coverage.
- Improve/enhance existing business identification system.
- Provide updated information to residents.
- Provide education to area media outlets.

SECTION FOUR: TECHNICAL ANALYSES SUPPORT

4.1 EXISTING DATA

Key information used in the evaluation potential of flood mitigation measures included technical reference information listed in Section 8, References, and the City's extensive GIS. The City maintains a robust GIS that includes topographic data, natural features, planimetrics, utilities, and other pertinent mapping data. The datum for the GIS is the North American Vertical Datum of 1988 (NAVD88). The City's GIS data were used for all mapping products created for this study.

The 100-year regulatory floodplain boundary from the City's FIRM is also provided in the City's GIS. The regulatory FIRM boundaries are the actual boundaries as shown on the FIRM, without regard to recent topographic data. Therefore, the regulatory floodplain does not necessarily match the topographic data. A plot of the 100-year floodplain elevation on the City's GIS is a more accurate representation of the flood risk. The vertical datum of the FIRM is National Geodetic Vertical Datum of 1929 (NGVD29). The conversion to the NAVD88 datum for the Alexandria area is -0.8 feet. Thus, the FEMA 100-year flood elevation of 11.0 feet NGVD29 is 10.2 feet NAVD88. Figure 4-1 shows the calculated flood zone compared to FEMA's regulatory floodplain boundary. The City and FEMA are in the process of updating the FIRM to reflect up-to-date topographic data, and these maps were issued in a preliminary state on September 16, 2009.

4.1.1 Building Elevation Data

Knowledge of the building elevation data is a key to determining the flood risk to properties. As described in the Initial Flood Assessment report, building elevation data used in this study was provided by the City from their GIS records. The City's data showed over 300 buildings in the project areas that would be inundated by extreme flood.

To supplement available FFE data, field survey for 35 residential and commercial structures was conducted. Careful consideration was taken in determining the structures for which additional survey would be most useful. Since the Waterfront Commercial focus area is the most flood-prone location in the project area, first-floor elevations were obtained for all structures in the area where data were not already available. Outside of the Waterfront Commercial focus area, most of the buildings without known FFEs are residential row houses. Survey was conducted for these buildings with the assumption that if the FFEs were known for one or two houses in a row, the others could be reasonably estimated. In addition, a few of the available FFEs appeared to be inconsistent with field reconnaissance information, so some of those structures were selected to be surveyed to verify the accuracy of the data.

Elevations were based on NAVD88 and horizontal position was specified in the Virginia Coordinate System of 1983 (VCS83). Control was set using a National Geodetic Survey (NGS) control monument, Global Positioning System (GPS) 52 (PID HV9658), in Founders Park across the street from 101 Queen Street.

CLIENT	City of Alexandria			
PROJ	Potomac Waterfron Flood Mitigation Study			
REVISION NO	0	DES BY	KJM	06/22/07
SCALE	1:12000	DR BY	CJL	10/05/09
W:\City of Alexandria\15298470 - Lower King St\Task 3 \Report\Final\Figures\MXDs\F4-1 Fema_flood.mxd		CHK BY	MER	10/04/09

TITLE Calculated Flood Zone Compared to FEMA Flood Zones

URS
200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO 15298592

FIGURE 4-1

The staff identified the FFE and the lowest point of entry for each structure and also took photographs of the structures. Property owners were notified that the survey was taking place, but the surveyors were not able to gain access to the interior of most of the structures. If they were not able to access a structure, an FFE was estimated.

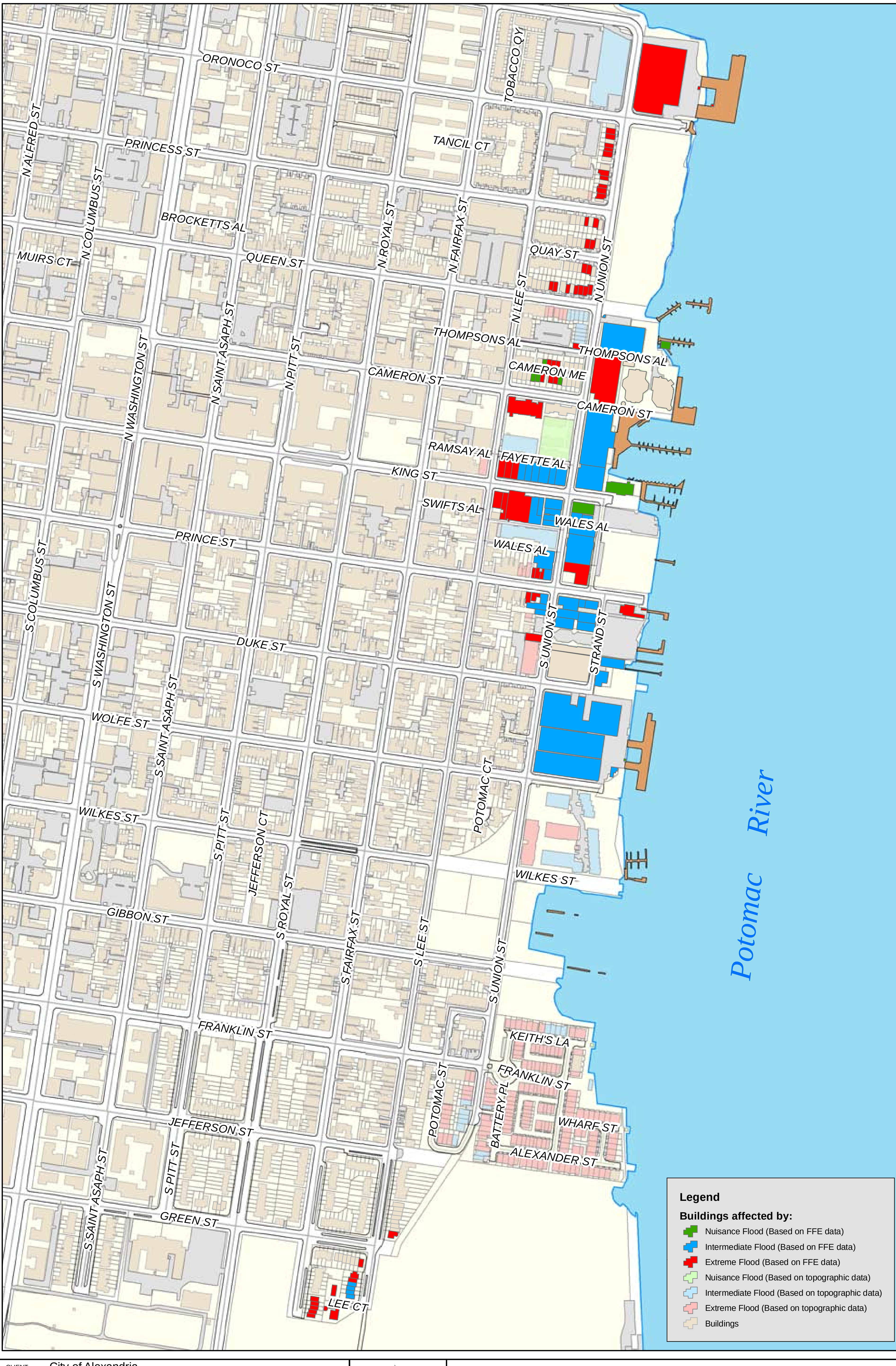
FFE survey data were not obtained for all structures located within floodprone areas. If FFE data were not available for a structure, the FFE was estimated using available topographic data. Figure 4-2 illustrates structures affected by the nuisance, intermediate, and extreme flood events based on FFE information (if available) and topographic information. A summary of the survey data can be found in Appendix D as Exhibit 1.

4.1.2 Field Reconnaissance

Several site visits were conducted throughout the course of this study. Detailed field visits were conducted on July 25, 2006 and July 23, 2009. Field visits were conducted to document the project area through photographs and field notes. First floor elevation data provided by the City were evaluated for reasonableness to help identify areas where additional survey would be beneficial. Assessments were conducted to determine where floodproofing would be appropriate. The field visits are summarized in Appendix D as Exhibit 2.

4.2 OVERVIEW OF CULTURAL RESOURCES CONTEXT

Old Town Alexandria is enriched by a diverse concentration of cultural resources focused around the waterfront setting. The Potomac River serves as the backdrop and focal point of the City, which was originally incorporated in 1749. Alexandria is defined by, and defines itself by, its significant number of historic properties, including buildings and archeological resources. These resources, in conjunction with recreational spaces and waterfront viewsheds, enhance the quality of life for residents, commuters, and tourists, and are a highly-valued point of pride for the City. Accordingly, in reviewing the potential impacts that the flood mitigation measures could have on the City's historic properties, the requirements and potential schedule and cost impacts related to aboveground and belowground cultural resources were considered.



CLIENT	City of Alexandria			TITLE	Structures Predicted to be Flooded for Each Event
PROJ	Potomac River Waterfront Flood Mitigation Study				
REVISION NO	0	DES BY	CJL	09/11/09	PROJ NO 15298592
SCALE	1 inch = 400 feet	DR BY	CJL	09/24/09	FIGURE 4-2
W:\City of Alexandria\15298478 - Lower King St\Task 3 \Report\Final\Figures\MXDs\F4-2 Structure Flooding.mxd		CHK BY	MER	10/04/09	

URS
200 Orchard Ridge Drive
Gaithersburg, MD 20878

4.2.1 Local Protection for Historic Properties

To safeguard its historic assets, the City of Alexandria regulates alterations to designated historic properties through the Department of Planning and Zoning (DPZ). Alexandria has several historic districts that are both nationally and locally designated. All buildings within these historic districts are legally protected on a local level through administrative review procedures. The City of Alexandria Master Plan for Historic Preservation states that any building proposed for construction, reconstruction, alteration, or restoration within the district must be approved by the Board of Architectural Review (BAR). The BAR also has authority over the moving, removing, encapsulation, and demolition of buildings in the district as well as the approval of signs (City of Alexandria, 1992). For new construction or renovations within the districts, compatibility of design is currently required for compliance with the City's permitting process and established design guidelines. Review of alterations within the historic district allows for protection of the historic context of individual buildings, including settings and viewsheds within the districts.

All of the proposed flood mitigation alternatives are located within the Old and Historic Alexandria District. Coordination at the local level will involve, at minimum, the BAR. The BAR regulations state that "a Certificate of Appropriateness (COA) is required for all new construction and exterior alterations that are within an historic district and are visible from a public right of way, including those visible from public streets and alleys, waterways, and parks."

Any proposed project would also likely trigger review and compliance with Section 11-411: Archaeology Protection, part of the Zoning Ordinance of the City of Alexandria, Virginia. Due to the age of the buildings in the project area, some dating to the mid-18th century, and the continuous historic occupation of the area since then, the potential for the proposed flood mitigation alternatives to impact archaeological sites, both documented and undocumented, is high. Any subsurface disturbance within the project area is likely to encounter evidence of past historic and/or potentially prehistoric occupation. Moreover, the waterfront and near-shore areas are of heightened sensitivity given the historic use of the area as a port. The adjacency of the Potomac River to the project area and the nature of the proposed alternatives raise the possibility of nautical as well as terrestrial archaeological investigations.

4.2.2 Federal Protection for Historic Properties

Historic properties are also protected under Section 106 of the federal National Historic Preservation Act (NHPA). Historic properties, as defined in the NHPA, are those buildings, structures, sites, objects, and districts that are listed in or eligible for listing in the National Register of Historic Places (NRHP). The implementing regulations for Section 106 state that prior to approval of any federally-funded or licensed project, also known as an "undertaking," the project's effects, either direct or indirect, on historic properties is to be taken into account. In the case of adverse affects, federal agencies must seek ways to avoid and minimize these adverse effects, and if none are found, mitigate the loss to the public. The process, known as Section 106 Review, is laid out in 36 CFR Part 800, and involves consultation with legitimate stakeholders, including the State Historic Preservation Officer, which in Virginia is the Virginia Department of Historic Resources (VDHR). Direct effects include actions that would physically impact a resource, while indirect effects can include actions, such as changes in noise or changes to physical setting, which would diminish the historical integrity of a resource.

Although the proposed flood mitigation alternatives would be undertaken by the City of Alexandria or private property owners, one or more alternatives or components of these alternatives may use federal funding, such as a grant from FEMA, or may require a federal permit, such as one from the United States Army Corps of Engineers (USACE). In either case, the funding or licensing agency would be required to comply with Section 106 of the NHPA.

In addition to being a locally designated historic district, the Old and Historic Alexandria District is listed in the NRHP, and as such, any undertaking affecting the district, or any contributing resource in the district, would trigger Section 106 of the NHPA. Because Section 106 applies to both NRHP-listed and NRHP-eligible properties, other potential historic properties in the project area would need to be identified by a qualified cultural resource professional, and effects on these properties considered in the process. This applies to both aboveground resources such as buildings and belowground (archaeological) resources. In both cases, the funding or licensing federal agency would be responsible for conducting studies to determine what historic properties are present in the project area.

For aboveground resources such as buildings, pedestrian survey and historical research would be undertaken, and a formal evaluation made as to whether or not the property meets the criteria for listing in the NRHP in consultation with VDHR and other stakeholders. For archaeological investigations in the state of Virginia, identification of historic properties is completed through a systematic investigation in the form of a Phase I Identification and, if warranted, a Phase II Evaluation.

If it is determined that an undertaking will have an adverse effect on a historic property, landscape feature, or archaeological site, then federal agencies are required to consider ways to avoid or minimize those adverse effects. This may include the relocation of the project to avoid archaeological sites, or redesign to reduce the visibility of project components, incorporate buffers, or use more historically sensitive approaches. If the adverse effects cannot be avoided or minimized, then the funding or licensing agency must determine appropriate mitigation measures in consultation with stakeholders and formalize them in a legally-binding Memorandum of Agreement. For aboveground historic properties, mitigation measures could include recordation of a historic property through written and photographic documentation, measured drawings, architectural salvage, or public interpretation through exhibits or Web sites. For archaeological resources, mitigation often takes the form of Phase III Treatment.

4.3 OVERVIEW OF NATURAL RESOURCES CONTEXT

Projects in Alexandria occurring in the Potomac River require authorization by USACE Norfolk District, the Virginia Department of Environmental Quality (VDEQ), Virginia Marine Resources Commission (VMRC) Habitat Management Division, and the City. Any proposed construction on the Virginia shoreline requires both VDEQ and VMRC Water Protection Permits for impacts to state-owned subaqueous bottom and/or tidal wetlands.

The National Park Service (NPS) owns Jones Point Park and the George Washington Memorial Parkway. Any work that affects either property would require a temporary construction permit, or, if impacts are permanent, approval from the NPS. This includes construction work over or under the parkway as well as any traffic control measures that impact the parkway.

The area 100 feet landward of the top of bank on the Potomac River is located within a Resource Protection Area (RPA), which applies to perennial streams in the Chesapeake Bay Watershed. Activities proposed in the RPA are regulated by the City under their Environmental Management Ordinance. In addition, the District of Columbia should be notified of work that may affect the Potomac River's navigable channel.

The proposed construction of flood mitigation measures is anticipated to have limited impacts on upland forest vegetation and forested nontidal wetlands. If the measures are undertaken, they will require a Clean Water Act Section 404 Individual Permit (IP) Water Quality Certification from the USACE and Section 10 (Navigable Waters) Authorization. Compensatory mitigation would be required for unavoidable impacts after implementation of avoidance and minimization measures during the design process. Compensatory mitigation would be required at a 2:1 replacement ratio for forested wetland impacts and should be located within the affected watershed if possible. Identification of appropriate compensation would occur during the permitting process in consultation with the USACE, VDEQ, and other federal and state resource agencies, including on-site opportunities, off-site opportunities, regional mitigation banks, and the Virginia Aquatic Resource Trust Fund.

If federal funds are used for the project, a National Environmental Policy Act (NEPA) environmental review would be required. The appropriate level of environmental analysis (Categorical Exclusion, Environmental Assessment, Finding of No Significant Impact, or Environmental Impact Statement) required would be determined by the project sponsor. NEPA requires the sponsor to consider potential environmental consequences of the project, document the analysis, and make the information available to the public for comment before implementation. NEPA also requires federal agencies to conduct environmental reviews of otherwise non-federal projects if those projects include some federal involvement, such as federal approvals, permitting, or funding.

4.4 REPETITIVE LOSS PROPERTIES

Repetitive loss properties are any insurable building for which two or more flood insurance claims of more than $1,000 were paid by the NFIP within any rolling 10-year period. FEMA uses this definition to delineate frequently flooded properties. Although there may be other structures that experience more frequent flooding, repetitive loss properties are specifically defined by FEMA.

Through the City's participation in the CRS program, mitigating repetitive loss properties is a specific method to improve the City's score and lower flood insurance rates for property owners within the City of Alexandria. In addition, mitigating repetitive loss properties reduces future flood losses and facilitates accurate insurance ratings.

Table 4-1 is a list of the repetitive loss properties within the study area:

Table 4-1: Repetitive Loss Properties within Study Area

Address	Notes	FFE (NAVD88)
110 Cameron St	Condos #110, 102, 103, & 104	4.6
1 King St.	Boat Club	3.75
6 King St	Mai Thai	3.5
101 King St	Same building as 103 King St	5.0
104 S. Union St	--	3.9

It should be noted that the FFE listed in the City's repetitive loss database for 110 Cameron Street appears to be unfinished storage space for all units. Based on our field review, the FFE is above the extreme flood level. However, since this property has been identified as a repetitive loss structure by FEMA, flood mitigation measures were identified for this structure.

Section 6 lists flood protection provided for the repetitive loss properties for each structural mitigation measure. All of these properties have a recommended mitigation alternative. This recommendation may not protect the property from every flood event; however, it will reduce the frequency of flood damages. A reduction in flood damages directly reduces the impact to the property owner, and the amount of time the City spends supporting that property owner. In addition, a reduction in the frequency of flood damage is considered by FEMA to be successful mitigation for a repetitive loss property, thus improving the City's CRS score.

4.5 CONSIDERATION OF SEA LEVEL RISE

Because flood control structures proposed in this study have design lifetimes greater than 10 years, the potential effects of climate change on the Potomac River were considered. Climate change is a subtle, yet progressive change in climatic conditions such as temperature and precipitation over a given period of time. Climate data records illustrate a significant climate shift in the early 1900s, and further studies indicate that climate change is occurring ever more rapidly, although changes differ regionally and seasonally. Climate change occurs from natural climatic variations, teleconnections (correlation between oceanic and atmospheric anomalies), and human activity. Confirmation of a global temperature rise comes from the observed temperature increases in the oceans, observations of sea level rise, and diminished snow cover in the Northern Hemisphere.

A small temperature increase (say 2^o Centigrade [C]), expected by the end of the 21st century, will drastically impact human life and the future global economy and environment. Global warming alters the hydrologic balance, resulting in extreme events such as drought and heat, increase in the power of hurricanes, decreased water flow in rivers, melting of glaciers, and increased variability in precipitation and flood risks.

Flooding Issues

Climate change results in increased precipitation intensity and variability, which change the antecedent conditions of river basins and river flows. Higher intensity precipitation events will significantly increase flood risks. Moreover, rising sea levels will increase flood risks in tidally influenced areas. A recent study of large basins worldwide (referenced in the Intergovernmental Panel on Climate Change (IPCC) 2008 Technical Report on Climate Change and Water) showed that the 100-year flood is projected to occur more frequently.

Flood control structures and remedial actions are often designed in terms of a certain flood frequency. Though the flood frequency is very likely to change under climate change conditions, very few studies have been done on the assessment of change in risk. Additionally, current global climate models do not have the capability to accurately simulate short-duration rainfall, and thus cannot predict flood events with high certainty.

Susceptibility to future flood damages will depend significantly on land use decisions, quality of flood forecasting, and warning and response systems. Uncertainties lie in projecting future flood risks, volumes, and damages because of uncertainties in future land use, future greenhouse gas emissions, and hydrologic and global climate models. Additionally, defining changes in flood-producing rainfall is challenging, because translating large spatial and temporal scale climate change projections into local flood events presents difficulty. Without credible climate scenarios that reflect changes in flood producing rainfall events, one cannot estimate the changes in flood frequency due to climate change and variations. Long-term climate change raises sea levels, which then may affect tidal flooding. If sea levels continue to rise due to global warming, the City of Alexandria may need additional protection from flooding. In the near future, increases in sea-level fluctuations for the City of Alexandria are anticipated to be driven by high tides and storm surges.

Adaptation

Adaptive management includes operational and demand management and changes in infrastructure. Adaptations implemented for flood risk preparedness include alteration of methods and procedures, such as design standards and calculation of climate change allowances. As more data become available, the local sea-level datum will likely be altered. Future designs will be affected by both a sea-level datum correction and altered flood maps. It is important to make sure that local regulations protect residents by identifying the most current standards available.

Mitigation

Climate change impacts can be mitigated by adaptation measures that address impacts of societal, economic, and management change. Communities must mitigate effects of climate change by minimizing the degree of vulnerability to climatic extremes. IPCC's 2008 Technical Report on Climate Change and Water provides mitigation strategies to address flooding due to climate change. Flood damages are projected to increase unless current flood management policies, practices and infrastructure are changed. To adapt and mitigate such impacts, communities must develop adaptation strategies that minimize the risk under changing circumstances.

Reducing vulnerability relative to anthropogenic climate change will correspond directly to strategies for reducing risks associated with natural climate variability. Modification of flood control structures and reservoirs may be necessary to mitigate future flood risks. The longer a structure's design lifetime, the greater will be the need to allow for the possible influence of climate change. The USACE provided a policy circular, titled *Water Resource Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Work Programs*, dated July 1, 2009, that specifically states: "…engineering designs should consider alternatives that are developed and assessed for the entire range of possible future rates of sea-level change."

The USACE policy discusses the methodology to derive the sea-level rise at a specific location, which is based on an updated and modified National Research Council report from 1986. The methodology involves calculating the sea level rise based on location, year project is built, and expected age of project.

The City of Alexandria is a highly urban area, which limits opportunities to provide structural flood mitigation measures. The floodwall proposed in this study provides 3 feet of freeboard above the 100-year flood elevation to meet FEMA's levee certification requirements. Three feet of freeboard will accommodate the anticipated sea level fluctuations. However, if the City prefers to achieve and retain FEMA levee certification, additional freeboard should be considered. Consideration of sea level rise for the Jones Point berm can be accomplished in the same manner as the floodwall.

Another large-scale flood control alternative proposed in this study is the elevated walkway. The elevated walkway height, at an elevation of 6.0 feet NGVD, was selected as the maximum practical height based on topographic information. The intent of the elevated walkway is to mitigate frequent flood events while preserving the look and feel of the waterfront; therefore, increasing the height of the elevated walkway to accommodate the sea level fluctuations will have a direct impact on the intent of the project. The proposed road height was also selected based on topographic constraints; therefore, consideration of sea level rise for this measure is not feasible.

SECTION FIVE: ECONOMIC VALUATION (BENEFIT-COST ANALYSIS)

5.1 DEFINING THE SCOPE OF ANALYSIS

The economic valuation used in this study is a benefit-cost analysis (BCA). BCA is a technique to assess the relative desirability of competing alternatives in terms of economics. BCA is based on the economic notion of efficiency—allocating resources where they have the most added value to society. BCA does not incorporate the notion of equity, which relates to the fairness of allocation.

The BCA determines the cost-effectiveness of flood mitigation alternatives by calculating the Benefit Cost Ratio (BCR). The BCR compares the net benefits of the project to the total project cost. This analysis helps select which flood mitigation measures to implement. To determine whether or not the alternative is cost-effective, benefits should outweigh the costs, resulting in the BCR equating to at least 1.0. A BCR is not a precise calculation; instead, it relies upon skilled conservative estimates of the parameters involved. The final result should be interpreted as having a wide error range. The net benefits are derived from the Net Present Value (NPV) of the project, thereby incorporating the value the project provides over time.

The BCR was calculated for each of the structural mitigation measures. Section 6 summarizes the analyses for each mitigation measure and compares total expected benefits to the total expected costs and provides a resultant BCR for each measure within the appropriate area of study. As the BCR increases, the likelihood that the mitigation measure will be accepted increases.

For this study, the benefits were defined as the flood damages mitigated by a specific structural mitigation alternative. In general, flood damages were divided into direct building damages, contents damages, and indirect losses. Direct building damages include any damage to the physical structure, cost of replacing utilities (e.g., electrical wiring, telephone), and restoring the structure to a pre-flood condition. Methodology for valuing residential properties differs from that of commercial properties. For example, content damages were any damages to personal or commercial property within a structure. For residential properties, contents include furniture, appliances, housewares, etc. For commercial properties, contents include any office equipment, retail stock, etc. Indirect losses were lost income (business losses) or costs incurred by a resident when they are unable to occupy their home (residential displacement).

The project costs were derived from conceptual designs, specific contractor estimates in the case of certain floodproofing alternatives, property fair market values, and various administrative costs. The concept designs were developed using accepted engineering standards and codes, existing data, and engineering judgment. A unit measurement of the total materials and labor costs is calculated. Finally, unit costs values from national construction cost code guides were used to created total project costs. For acquisition, the fair market value was the main project cost. A more detailed discussion regarding the costs for each structural alternative is discussed later in this section.

Results from the BCA are included as Appendix E.

5.2 CALCULATION OF PROJECT BENEFITS

The benefits for each mitigation alternative were analyzed at a planning level, so assumptions were made to simplify the analysis. Instead of analyzing all flood depths at a structure for all flood elevations, each of the analyzed discrete flood event's (extreme, intermediate, and nuisance) benefits were calculated then summed together. If an alternative did not provide any mitigation at a specific flood event, then no benefits were calculated.

The following data were used to develop benefits as well as some cost data:

- Assessed Value of 406 properties (land and building value)
- United States Census Bureau Web site for annual business income
- Surveyed FFEs
- Business questionnaire regarding Hurricane Isabelle

The steps for calculating benefits are outlined below.

1. **Determine the Flood Depth**

   Structure FFEs for all potential flood prone structures were compared to the previously specified flood events (i.e., extreme, intermediate, and nuisance) for the different flood frequencies.

   Example: The home is a 2-story residential building located in the Jones Point study area. The FFE is 8.47 feet (with basement). The flood depth at the extreme flood event (10.2 feet NAVD88) in this case would be 1.73 feet.

   The following assumptions were made because of data limitations:

   - All residential basements were considered finished.
   - All basements were assumed to be the first floor flooded.
   - All commercial buildings were assumed to not have basements.
   - A comparison between the FFE and the LAG was performed, to determine if the FFE was the basement or a higher floor. The LAG was determined by known LAG data (surveyed information) or using the City of Alexandria topography.
   - If the FFE was lower than the LAG, then the basement was determined to be the FFE; otherwise, the FFE was reduced by 8 feet to reflect the basement elevation.

2. **Calculate the Average Depth (only for residential structures)**

   For residential structures, the average depth was used for all structures within a study area. A sensitivity analysis was performed for the Jones Point Area to determine the disparity between the benefit calculated for each house using individual depth data and using average depth data. In the final total benefit, only about a four percent difference occurs. For commercial structures, too many variables occur to make similar assumptions, so the flooding depth at each event was calculated on a structure-by-structure basis.

3. Determine the Structure Value

The assessed value of the property, which was obtained from City of Alexandria real estate data, was used for the structure value instead of a Building Replacement Value (BRV). The individual assessed building price was compared to values obtained from a standard construction cost guide values (RS Means Residential and Commercial Replacement Cost Data, 2009) and the assessed value was comparable to the standard replacement value. In the future, if a detailed, single structure benefit-cost analysis is conducted, the Building Replacement Value should be used.

4. Determine the Content Value of Properties

The content value was calculated using FEMA's standard content values based on historical insurance claims data for all property types being analyzed. The standard content value is a percentage of the building value based on whether the building is commercial or residential. Commercial buildings are further delineated based on the type of commercial entity within the building. For mixed use structures, all were commercial on the first floor, therefore commercial values were used. For residential properties the content damage was selected to be 100 percent of the building value.

5. Determine the Structure and Content Damage

The building and content damage for residential properties was based on depth-damage curves developed by the USACE. For the commercial properties the source of the curve is HAZUS, FEMA Mitigation Planning How-To Guide 32, *Understanding Your Risks: Identifying Hazards and Estimating Losses FEMA 386-2*.

6. Determine the Business Income Loss

A major factor in determining benefits for commercial structures is the loss of business income. The loss of income is the product of the net income for commercial business per day and the number of days of functional downtime.

Days of business lost information was derived from the business questionnaire, specifically the responses to how many days the business was out of service. The approximate flooding depth was developed based on Hurricane Isabelle flood elevation of 8.8 feet and the FFE of the responder’s business. Table 5-1 summarizes the information collected relating the flood depths to out-of-service days. Responses that gave extreme values were concluded to be outliers and, therefore, were excluded from the analysis. Interpolated depths were derived to provide a full range of flood depths.

Table 5-1: Estimated Loss of Business Time

Flood Depth (ft)	Out of Business (Days)
1	7
2	14
3	21
4	28
5	35
6	42
7	49

The daily business loss was calculated from United States Census Bureau data, specifically annual sales data for the City of Alexandria. The data were an average for the City of Alexandria in that the annual data was converted to daily loss data. Different business types had different annual data; therefore, each business type was evaluated individually.

7. Residential Displacement Costs

Residential structures incur displacement costs during the time a resident is unable to occupy the home including any time for repairs. For residential displacement calculations, a generic FEMA value was used which is $1.44 per square foot per day of displacement. The time the resident would be displaced was calculated to be the same time as the business losses.

8. Determine the Total Benefit

The total benefit was based on the sum of building and content damage, business loss or residential displacement (as appropriate) for each flood event and mitigation options, which then was discounted based on the lifetime of the project. The discount rate estimated the present value of benefits over the life of a project. Seven percent was used in this study, which is the standard value set by the United States Office of Management and Budget.

1. Simplified Expected Annual Benefit (EAB) calculated for all of the structures in an area:

   EAB = (All Structure Damage + All Content Damage + Business Loss + Displacement) * Expected Annual Probability

   The Expected Annual Probability (EAP) is the percent chance of that specific flood level from occurring.

   For this study, three flood events were analyzed: nuisance, intermediate, and extreme. The EAP for the extreme and intermediate were derived from the return interval discussed in Section 2 of this report. The EAP is effectively the inverse of the return interval. For example, the extreme flood has a return interval of 100 years. Therefore, the EAP is 1/100 or 0.1. Table 5-2 summarizes the EAPs for all floods of interest in this study:

Table 5-2: Expected Annual Probabilities

Flood Stage	EAP
Nuisance (4.0 feet)	0.667
Intermediate (8.0 feet)	0.04
Extreme (10.2 feet)	0.01
Pedestrian Walkway Analysis (6.0 feet)	0.1

2. The total benefits were then calculated using the EAB and factoring that value by the discount rate and the life of the project. The following equation shows how those components are factored together:

$$Total\ Benefits = B\left[\frac{1-(1+r)^{-T}}{r}\right]$$

B = EAB

T = Estimated amount of time (in years) that the mitigation action will be effective or project lifetime

r = Annual discount rate, 7 percent

5.3 CALCULATION OF PROJECT COSTS

5.3.1 Acquisition

For acquisition, the cost was based upon the fair market value (FMV) of the property to be acquired. To estimate the FMV, the following data from the City of Alexandria's tax assessment Web site were used:

- Assessed Land Value
- Assessed Building Value
- Sale Date
- Sale Price
- Assessed Value at the Time of Sale
- Year Built

Sales market value ratios were developed for residential and commercial properties in the study area. The ratio was developed by comparing average sales prices to the assessed value of both the land and building at the time of the sale. Separate ratios were developed due to the large differences between the sales price of residential and commercial properties. The FMV was then the property's assessed value multiplied by this ratio.

Additional costs in determining the total cost estimate for acquisition include:

- Appraisal, Property Survey, and Closing
- Structure Demolition (hazardous material removal, demolition)
- Legal Fees Related to Contract Review and Settlement
- Administrative Costs

These additional costs were estimated based on technical expertise, phone interviews, and internet research. The costs for property acquisition are summarized in Appendix J.

5.3.2 Floodproofing

Several different options for floodproofing structures were investigated, as discussed in Section 3. In addition, there were several different sources and methods for determining the cost of floodproofing options. The costs for the floodproofing options are summarized in Appendix K.

First, price quotes were obtained from private companies that specialize in floodproofing systems, specifically flood gates, internal elevation, and floodproof doors and windows. The cost of elevating patios for floodproofing was obtained by developing a conceptual design for a standard residential building and then calculating the units of material, equipment, and labor necessary. The unit cost price was obtained from the 2009 RS Means Construction Cost guide. The conceptual design included placing fill and the cost to rebuild the patio.

Cost estimates for each floodproofing option were increased by 50 percent to account for uncertainty in the conceptual design and estimation of units, and to provide a more conservative cost for the BCR. To be conservative, the most expensive feasible floodproofing option for each specific study area was used.

5.3.3 Other Structural Mitigation Measures

Cost estimates for the structural mitigation measures, including the Jones Point berm, floodwalls, elevated pedestrian walkway, and the storm drainage improvements, were based on the conceptual designs. Material costs for these alternatives were determined from the 2009 RS Means Construction Cost guide.

In addition to material cost, several other factors were included in the total cost for these other structural alternatives. Cost estimates for contingency and miscellaneous items were based on 20 percent of the total construction costs. Additionally, design costs (preliminary and final) were based on 20 percent of the total project cost. For each alternative, 5 percent of the construction cost with a minimum of $50,000 was included to account for mobilization and demobilization of construction equipment and staging areas and erosion and sediment control measures.

Permitting costs were also included in the estimate. The permitting costs consider grading plan approval, cultural resources approval (i.e., historic structures and archeology concerns), and natural resources permits. In particular, the permitting costs for cultural resources activities have the potential to vary widely. Our costs include initial archaeological survey, but additional expense may be incurred, depending on the initial investigations.

Altogether, the sum of the above costs represents the total capital expense. Annual maintenance cost was estimated to be 5 percent of the total capital expense, where appropriate.

Table 5-3: Cultural Resource Approval Relative Schedule, Level of Effort, and Cost

	Adverse Effects	Scale of Adverse Effects	Local Review (Months)	Federal Review (Months)	Level of Effort, Local	Level of Effort, Federal	Cost of Compliance
Flood Proofing	Exp.*	Mod.	4-12	12-24	Mod.	Mod.	$20K-$250K
Jones Point Berm	Pos.	Mod.	6-12	9-12	Mod.	Mod.	$40K-$250K
100-Year Flood Wall	Exp.	Sig.	12-24	18-24	Sig.	Sig.	$100K-$2M
Elevated Walkway & 550' Long Flood Wall	Exp.	Sig.	12-24	12-18	Sig.	Sig.	$100K-$1M
Roadway Alterations	Pos.	Mod.	6-12	9-12	Mod.	Mod.	$50K-$1M
Acquisition/ Demolition	Exp.	Sig.	9-12	9-18	Sig.	Mod.	$100K-$2M

* Table Abbreviations: Exp. = Expected, Pos. = Possible, Mod. = Moderate, Sig. = Significant

SECTION SIX: STRUCTURAL MITIGATION MEASURE CONCEPTS

6.1 FLOODWALL

The largest flood mitigation solution proposed is a concrete floodwall located along the Potomac River Waterfront, which would protect three of the four focus areas from the nuisance, intermediate, and extreme flood events. The proposed area being protected includes all repetitive loss structures in the study area.

6.1.1 Description of Alternative

The floodwall is proposed to be a concrete structure constructed to an elevation of 13.2 feet (NAVD88). This elevation provides protection against the FEMA 100-year flood elevation of 10.2 feet plus 3 feet of freeboard. In accordance with FEMA regulations, 3 feet of freeboard is required above the 100-year water surface elevation for floodwall structures to be considered as providing protection against the 100-year flood event. According to FEMA levee requirements, 3.5 feet of freeboard is required at the upstream end of a levee or floodwall. When analyzing this alternative for this study, 3 feet of freeboard was assumed for planning level purposes for the entire floodwall.

Before detailed analyses were conducted on the floodwall, five different floodwall layout options were considered. The options were analyzed based on the amount of protection provided, the feasibility of implementation, and the level of costs. Figures for each option are provided in Appendix F as Exhibits 1-1 through 1-5. Of particular importance in selecting the option was the feasibility of conveying interior drainage through the floodwall.

Option 1 consists of constructing a floodwall along the Potomac River waterfront from Gibbon Street to the south, to Oronoco Street to the north. The floodwall would be approximately 5,900 feet long. The total interior drainage area behind the floodwall is approximately 82 acres.

Floodwall Option 2 would be constructed from Wolfe Street, to the south, to Queen Street, to the north. This option would be approximately 3,900 feet long. The total drainage area behind the floodwall would be approximately 50 acres.

Option 3 was similar to Option 1 and would be constructed from Gibbon Street to Oronoco Street. However, the floodwall would be constructed to the west of Founder’s Park on North Union Street. This floodwall would be approximately 5,800 feet long. The interior drainage area to the floodwall would be around 77 acres.

Floodwall Option 4 was proposed to be constructed from Duke Street to Oronoco Street. The floodwall would be approximately 4,200 feet long. The approximate interior drainage area for this alternative would be 59 acres.

The floodwall for Option 5 would be constructed from Wilkes Street to Oronoco Street. This alternative would be about 5,200 feet long with an approximate interior drainage area of 76 acres.

Table 6-1 summarizes the evaluation of potential floodwall layout options.

Table 6-1: Comparison of Potential Floodwall Layout Options

Floodwall Option	Pros	Cons
1. (Gibbon Street to Oronoco Street)	▪ Offers protection to all flooded structures, except the north Robinson Terminal structure ▪ Provides limited interior drainage storage areas	▪ Most costly option ▪ Requires elevation or permanent closure of Union St at North and South end ▪ Large interior drainage area ▪ Requires handling of potentially contaminated soils at Oronoco Outfall ▪ Alternate flood mitigation measures (i.e., floodproofing) appear to be feasible for the residential structures in the vicinity of the north end of the floodwall, therefore large structural measures are not likely to be cost effective for this area
2. (Wolfe Street to Queen Street)	▪ Shortest floodwall option, therefore costs and visual impact reduced ▪ Avoids potential contamination at Oronoco Outfall ▪ Minimal interior drainage (excludes outfalls at Princess, Queen, Wolfe, between Wolfe and Wilkes) ▪ Does not require road closures	▪ Does not provide protection to row houses off of Quay and Union; however, floodproofing, which is a less expensive option appears to be feasible for this area. First floor elevations are above the extreme flood event for this area. ▪ Does not provide protection to houses off Wilkes and Union; however, floodproofing, which is a less expensive option, appears to be feasible for this area. First-floor elevations are above the extreme flood event for this area. ▪ Requires elevation of Queen St to tie out with North Lee St intersection ▪ Potential access problems for structure at N Union and Queen

Floodwall Option	Pros	Cons
3. (Gibbon Street to Oronoco Street, west of Founders Park)	▪ Reduces option 1 floodwall by approximately 200 feet ▪ Avoids disturbance to Founder's Park ▪ Provides protection to all flooded structures, except north Robinson Terminal	▪ Requires major reconstruction or permanent closure to N Union Street ▪ Potential access problems for building at N Union and Queen ▪ Requires handling of potentially contaminated soils at Oronoco Outfall ▪ Large interior drainage area
4. (Duke Street to Oronoco Street)	▪ One of the shorter length floodwall options ▪ Provides protection for all of focus areas (aside from Jones Point and Robinson Terminal buildings) ▪ Relatively small interior drainage (excludes outfall at Duke St.)	▪ Requires major reconstruction or permanent closure to N Union Street ▪ Requires handling of potentially contaminated soils at Oronoco Outfall ▪ Does not offer protection to houses off Wilkes and Union. However, floodproofing, which is a less expensive option, appears to be feasible for this area. First floor elevations are above extreme flood even in this area.
5. (Wilkes Street to Oronoco Street)	▪ Provides protection to all flooded structures, aside from north Robinson Terminal ▪ About 700 feet less floodwall length would need to be constructed	▪ One of the more costly options based on the length of the wall and the interior drainage. ▪ Requires handling of potentially contaminated soils at Oronoco Outfall ▪ Second largest interior drainage area ▪ Could possibly affect pedestrian tunnel at Wilkes St ▪ Requires elevation of N Union and S Union to reach tie in

After examining each floodwall option, Option 2 was selected as the best layout for consideration. The proposed floodwall option provides protection for the area from Queen Street to the north and Wolfe Street to the south (Figure 6-1). The proposed floodwall is 3,900 feet long and constructed to an elevation of 13.2 feet NAVD88. The floodwall would be a reinforced concrete wall (Appendix F, Exhibit 2-1).

CLIENT	City of Alexandria			TITLE	Proposed Floodwall Layout	
PROJ	Potomac River Waterfront Flood Mitigation Study					
REVISION NO	0	DES BY	CJL	09/11/09	URS 200 Orchard Ridge Drive Gaithersburg, MD 20878	PROJ NO 15298592
SCALE	1 inch = 200 feet	DR BY	CJL	09/24/09		FIGURE 6-1
W:\City of Alexandria\15298470 - Lower King St\Task 3 \Report\Final\Figures\MXDs\F6-1 Floodwall Overall Layout.mxd		CHK BY	MER	10/04/09		

Due to space constraints, in the waterfront area between Thompson's Alley and King Street, reinforced concrete plates would be bolted into the bulkhead to offer protection for the Old Dominion Boat Club, the Torpedo Factory, and the Chart House (Appendix F, Exhibit 2-2). The floodwall provides protection for 50 commercial structures and 44 residential buildings.

To prevent flooding behind the proposed floodwall, interior drainage needs to be managed. Approximately 50 acres drain to the proposed floodwall (Figure 6-2). During the 100-year flood event, the total volume of runoff is predicted to be approximately 26 acre-feet. Because no storage areas are available to temporarily store the stormwater runoff, the interior drainage system needs to convey the entire 100-year flood discharge. A summary of flood discharges and volumes is provided in Table 6-2. Additional information on discharge estimates is provided in Appendix F as Exhibits 3 and 4.

Table 6-2: Floodwall Discharges and Volumes

	Area 1 (11 acres)	**Area 2 (39 acres)**
Recurrence interval	Q (cfs)	Q (cfs)
2 year	40.1	127.4
10 year	56.4	180.8
100 year	81.2	263.3

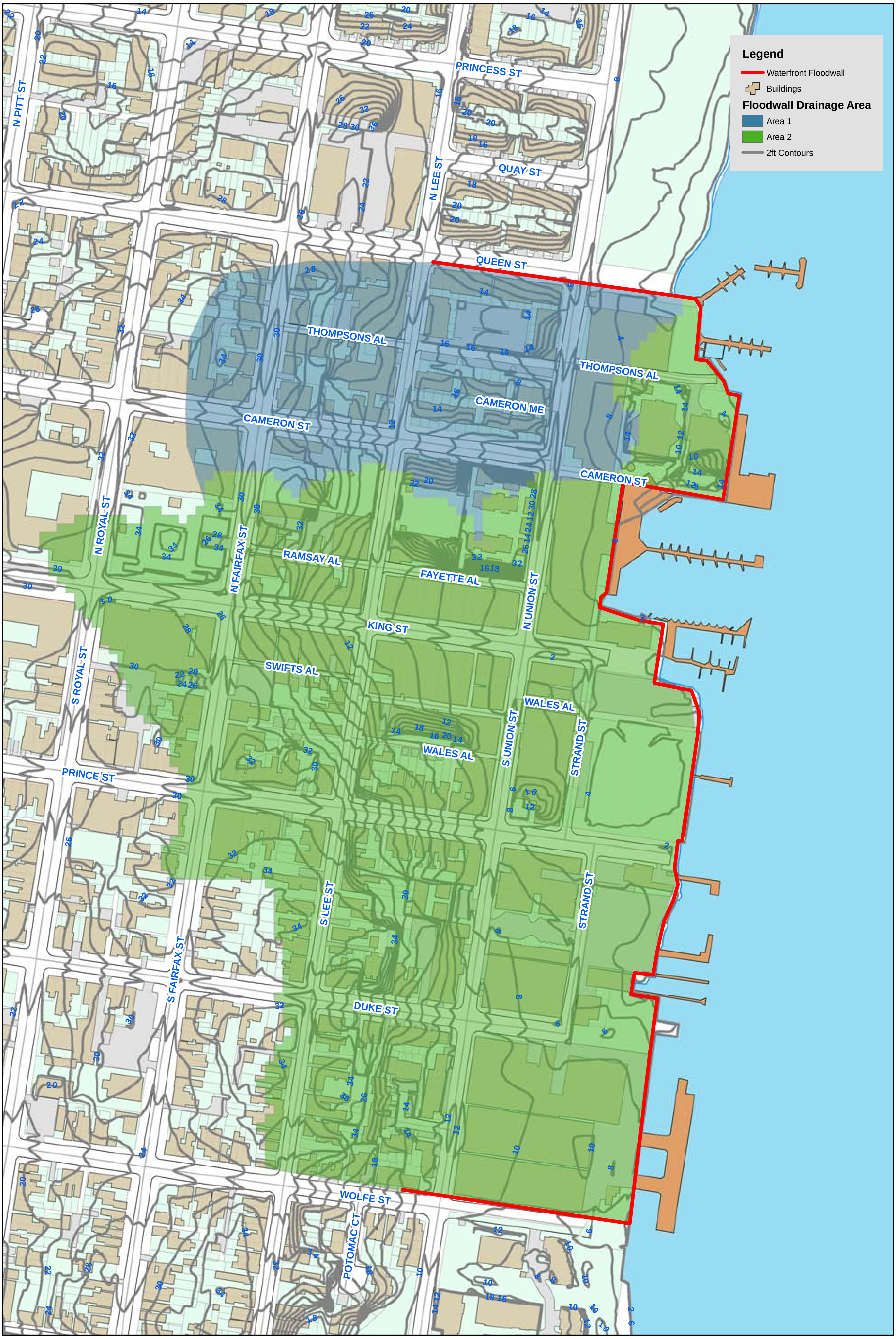
cfs = cubic foot/feet per second

To adequately protect structures behind the floodwall, three pumping stations are required to pump the runoff from the 100-year flood event. Conceptually, these stations would be installed close to the floodwall at Thompson Alley, King Street, and Duke Street.

Based on a review of the existing storm drainage system, it does not appear to be feasible to implement a gravity-based stormdrain diversion to reduce the size or number of pumping stations.

6.1.2 Assumptions

Several assumptions were made for the conceptual design of a waterfront floodwall. The floodwall was assumed to be a reinforced concrete wall. Engineering judgment indicates that a properly sized reinforced concrete wall could withstand the hydrostatic force experienced during an extreme flood event from the Potomac River. An average height of 8 feet above ground was assumed for the reinforced concrete wall. This height was based on the existing ground profile and the height needed to reach an elevation of 13.2 feet NAVD88. Based on this height, dimensions for a reinforced concrete wall were chosen.



CLIENT	City of Alexandria			TITLE	Interior Drainage Area of Proposed Floodwall
PROJ	Potomac River Waterfront Flood Mitigation Study				
REVISION NO	0	DES BY	CJL	09/11/09	PROJ NO 15298592
SCALE	1 inch = 200 feet	DR BY	CJL	09/24/09	
W:\City of Alexandria\15298470 - Lower King St\Task 3 \Report\Final\Figures\MXDs\F6-2 Floodwall Drainage Area.mxd		CHK BY	MER	10/04/09	FIGURE 6-2

URS
200 Orchard Ridge Drive
Gaithersburg, MD 20878

6.1.3 Potential Impacts

The visual and physical obstruction to the view of the Potomac River is the most significant impact to such a historic city. Based on the average height, the floodwall could completely block the view of the Potomac River in some places. Any of several options, if implemented in conjunction with the floodwall, could minimize the aesthetic disruption to the waterfront. These options include installation of “viewing windows” in the floodwall or building an “invisible floodwall.” The viewing windows would require installation of aquarium glass strong enough to handle the hydrostatic pressure the wall would experience during the extreme flood event while still offering viewports of the Potomac River. The invisible floodwall involves the construction of a concrete base with slots where aluminum planks would be actively placed during the anticipation of a large flood event. This solution could be used when constructing the floodwall in the areas where it would cross Union Street.

When a flood event is anticipated, the active portion of the floodwall would need to be installed, and access to Union Street at these areas would be closed. By using this flood protection method, there would be limited access problems encountered along Union Street with the construction of a floodwall. This solution would add additional costs, which have been accounted for in the cost estimate.

Another potential impact of constructing a floodwall is access to the waterfront from the Potomac River. Conceptually, the floodwall was planned as a solid wall with no access points to or from the water. This was to provide complete protection from the Potomac River during the extreme flood event. This would disrupt current boat docking/loading access. One potential solution is to add access points through an active floodwall system. These access points could be implemented in a similar way as proposed at Union Street. Sections of the wall could be left open to maintain boat access. Slots for the aluminum planks for the active floodwall system would need to be constructed. Whenever a flood event is imminent, the planks could be placed in the wall. This solution would allow limited interference with boating access and protect the waterfront area during a flood event.

Commercial access will be impacted during construction of a floodwall. Coordination is required with property and business owners to allow enough room to construct the floodwall without disrupting access to these buildings. Assumed disruptions will be minimized through the use of barges to bring in equipment and materials and to perform construction in areas with limited access. Eight properties are fronted by the proposed floodwall. An estimate for acquiring permanent easements is included in the cost estimate. However, pedestrian and consumer access to the waterfront area should be minimally affected during construction of the floodwall.

Precautions need to be taken when constructing within contaminated land. The only noted contamination at this time was at the eastern end of Oronoco Street. Contaminated waste from a manufactured gas plant that was in existence for 95 years is discharged through a pipe near Founder’s Park. The conceptual design of the floodwall separates Founder’s Park from the Potomac River.

6.1.4 Permitting/Approval Requirements

The proposed floodwall requires significant excavation throughout an historic district. Therefore, environmental, historic, and archaeological permits would be required for construction. The permitting requirements are anticipated to take a significant level of review effort. The local review schedule may take anywhere between 12 and 24 months and any federal review is anticipated to take between 18 and 24 months.

Site Plan Approval

Grading associated with the floodwall will require approvals from the City of Alexandria and the state of Virginia as described below. The following is a summary of the regulatory programs and permits anticipated for the project:

- Grading plan approval from TES
- City of Alexandria Erosion and Sediment Control Ordinance
- Virginia Stormwater Management Program (VSMP)
- Department of Conservation and Recreation (DCR) Construction General Permit
- National Park Service Temporary Construction Permit for any work affecting Jones Point Park or George Washington Memorial Parkway.

Natural Resources

Preliminary estimates of the proposed construction footprint and access area (approximately 3.6 acres) indicate that the project may require a Section 404 IP from the USACE as well as a Section 10 Permit. The construction within the Potomac River channel would involve more than 1 acre (approximately 1.8 acres) of subaqueous bottom impacts within the Potomac River below the Mean High Water (MHW). The discharge of dredge and fill material required for construction of the floodwall occurring channel-ward of the MHW would require authorization by the USACE Norfolk District, the VDEQ, The VMRC, and the City of Alexandria. The area landward of the Potomac River, including the proposed project area, is also located within an RPA, and requires authorization from the City under their Environmental Management Ordinance. A NEPA environmental review may be required if federal funds are used or if the project includes some federal involvement.

The following list summarizes the water quality permits that may be required for the proposed project:

Federal

- USACE Clean Water Act IP
- Section 10 of the Rivers and Harbors Act Permit

State

- VMRC Habitat Management Division – Subaqueous bottom and/or tidal wetland impact authorization

- VDEQ Section 401 Certification
- VDEQ Water Protection Permit
- Virginia Coastal Zone Consistency Determination (VA Coastal Zone Management Program)

Local

- Chesapeake Bay Preservation Act Authorization (City of Alexandria Environmental Management Ordinance)
- The District of Columbia should also be made aware of any work that might affect the navigable channel for the Potomac River.

If a NEPA decision document is required before construction begins, the process could require 3 to 12 months to complete. The length of time required to develop a NEPA decision document is tied to the level of environmental documentation determined to be appropriate, and to the respective agency and public involvement processes. After the conclusion of the NEPA process, both the state permit application and local permit acquisition processes are expected to require approximately 6 to 12 months.

Resource Protection Area (RPA)

The entire floodwall is located within the RPA. Therefore, implementation of this project would require authorization under the *City of Alexandria's Environmental Ordinance* (Article XIII). Flood control projects are permittable under this ordinance if approved by the Director of TES. Implementation of water quality features such as Low Impact Development measures may be required.

Cultural Resources

Aboveground Resources

This floodwall will be considered to have an indirect adverse effect on the physical setting of the historic district or other individual historic properties, which may diminish the integrity of the resources within the viewshed. The scenic viewsheds of the waterfront are a contributing landscape feature to the Old and Historic Alexandria District. The floodwall will reduce or eliminate the scenic viewshed and will have an adverse effect on the historic district.

Archaeological Resources

A Phase I Archaeological Survey (background research and close interval shovel testing at 10 meters) would likely be triggered. Moreover, if floodwall construction would impact the existing bulkheads requiring marine construction, assessment of underwater archaeological resources will be triggered. Because Alexandria is a port city of great historic significance, resources at the waters edge or near shore would also be subject to NHPA Section 106 review, as it is likely that they would be negatively affected by additional bulkheading, dredging, or marine construction activities related to flood barrier construction.

A Phase I Identification study involving background research and shovel testing within the area of direct effect will be required. This could involve a detailed historical study of the Alexandria waterfront to determine areas of previous use and the potential for water-related infrastructure such as wharfs, cribbing, landings, and docks. Other survey methods may also be necessary, such as a side-scan sonar survey of the near shore areas or underwater documentation and/or excavation of sites that would be disturbed or destroyed by this undertaking. Installation of floodwater-handing systems such as pumps would also likely trigger Phase I testing before installation and Archaeological Monitoring during construction.

If archaeological features are identified, a Phase II (Evaluation) follows and if the archaeological features would be adversely affected by the floodwall construction then Phase III (Treatment) would be required and would likely involve recordation and data recovery excavations.

6.1.5 BCA and Results

The cost of the floodwall is based on construction (materials, labor, and equipment), final design, permitting, acquisition of private property or easements, and administrative costs. The total upfront capital expense of this project is approximately $15,463,000. An annual maintenance fee of 2.5 percent of the total cost of the floodwall was added to the cost of the project. The present cost for the annual maintenance of the floodwall is about $3,400,000. The total cost of the project used in the benefit-cost analysis (BCA) would be about $18,863,000. A more detailed cost estimate is provided in Exhibit 3 of Appendix F.

The total benefits provided by the floodwall, as shown in Table 6-3, will be $12,196,000. This value was derived from the study areas protected by the floodwall, which include all of the Commercial Waterfront with the exception of the northern Robinson Terminal, all of the King Street study area, and the Cameron Mews sections of the North Union Street focus area. The project lifetime is 50 years based on standard USACE and FEMA structural mitigation design lifetimes.

The BCR for the elevated walkway is 0.65, which indicates that this is not a cost-beneficial mitigation project.

Table 6-3: Floodwall Benefit-Cost Ratio

Total Cost of Floodwall including construction, design, and permitting	$18,863,273
Total Benefit for Floodwall	$12,196,000
Benefit-Cost Ratio (BCR) for Structures protected by the Floodwall	**0.65**

6.2 ELEVATED WALKWAY

One structural option being analyzed for flood protection in the City of Alexandria is an elevated walkway along the waterfront of the Potomac River. The principal element of the elevated walkway is a low profile floodwall at elevation 6 feet (NAVD88), which would protect the area from nuisance flooding but not the intermediate or the extreme flood events. The area being protected includes several repetitive loss structures in the study area.

6.2.1 Description of Alternative

The proposed elevated walkway would be constructed to an elevation of 6 feet (NAVD88) and a length of 1,280 feet. The length of the elevated walkway provides protection for the lower King Street and Strand Street area (Figure 6-4). The elevated walkway plan is similar to the floodwall in terms of design and construction materials. Figure 6-3 provides an example of an elevated walkway cross-section. The proposed 5-foot-wide pedestrian path would be constructed on the backfill of the floodwall. The pedestrian path is not critical for flood protection, but it would help maintain pedestrian access to the water's edge and the viewshed.

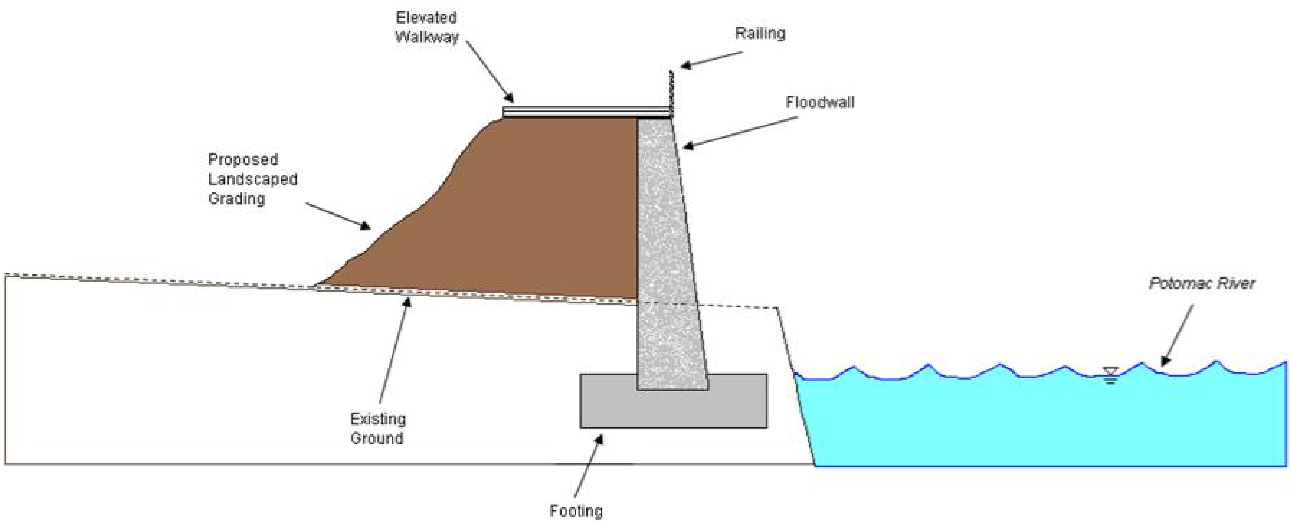


Figure 6-3: Proposed Elevated Walkway Example Cross-Section

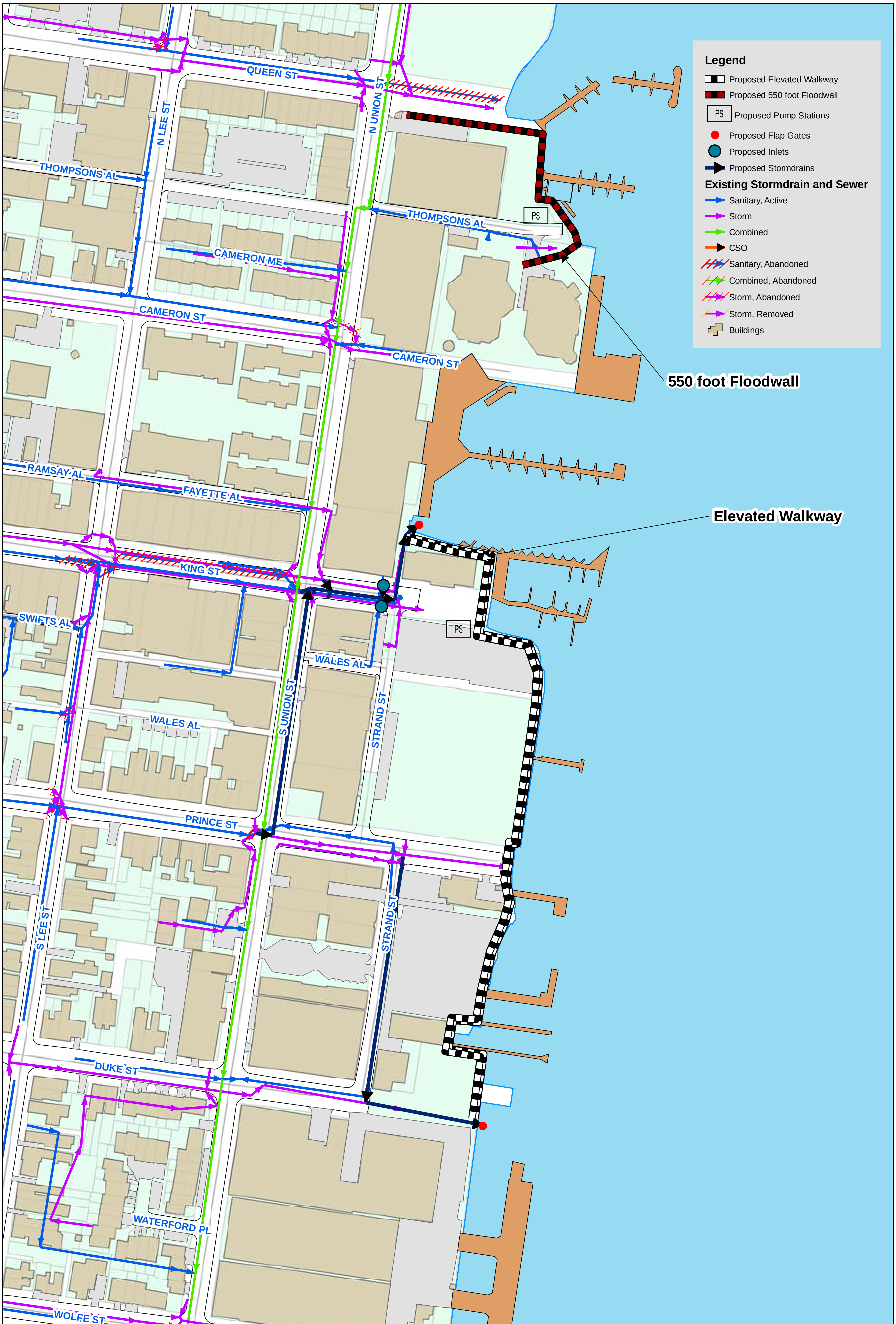
This alternative provides protection from frequent flooding while maintaining a scenic walkway along the Potomac River. The elevated walkway is proposed to have the following dimensions:

- An average height of 4 feet (to reach an elevation of 6 feet NAVD88)
- A base of 5.5 feet
- A varying thickness averaging 1.5 feet

For planning purposes, the walkway was designed to be composed of asphalt and have a width of 5 feet, to accommodate two-way pedestrian traffic. Other materials, such as composite materials, to replicate a boardwalk could be substituted, but they were not included in this estimate.

To prevent flooding behind the proposed floodwall, interior drainage needs to be managed. The runoff volume generated by the approximately 28-acre drainage area for a 100-year storm (Figure 6-5) is approximately 14.9 acre-feet. Therefore, the design concept includes pumping stations that would pump the 100-year event into the Potomac River in the event the flapgates are sealed or blocked.

To reduce the pumping required for this alternative, a proposed stormwater diversion is proposed for the elevated walkway drainage area. The proposed concept diverts runoff from Prince Street, Duke Street, South Union Street, and King Street around the elevated walkway and discharge into the Potomac River. About 1,470 feet of 42-inch concrete pipes is required to tie into the existing stormwater system. Two inlets would also be installed near the corner of King Street and The Strand to capture runoff from King Street. This stormwater diversion reduces the drainage area behind the elevated walkway that would need to be pumped out and is shown on Figure 6-4.



CLIENT	City of Alexandria			
PROJ	Potomac River Waterfront Flood Mitigation Study			
REVISION NO	0	DES BY	CJL	09/11/09
SCALE	1 inch = 150 feet	DR BY	CJL	09/24/09
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TITLE

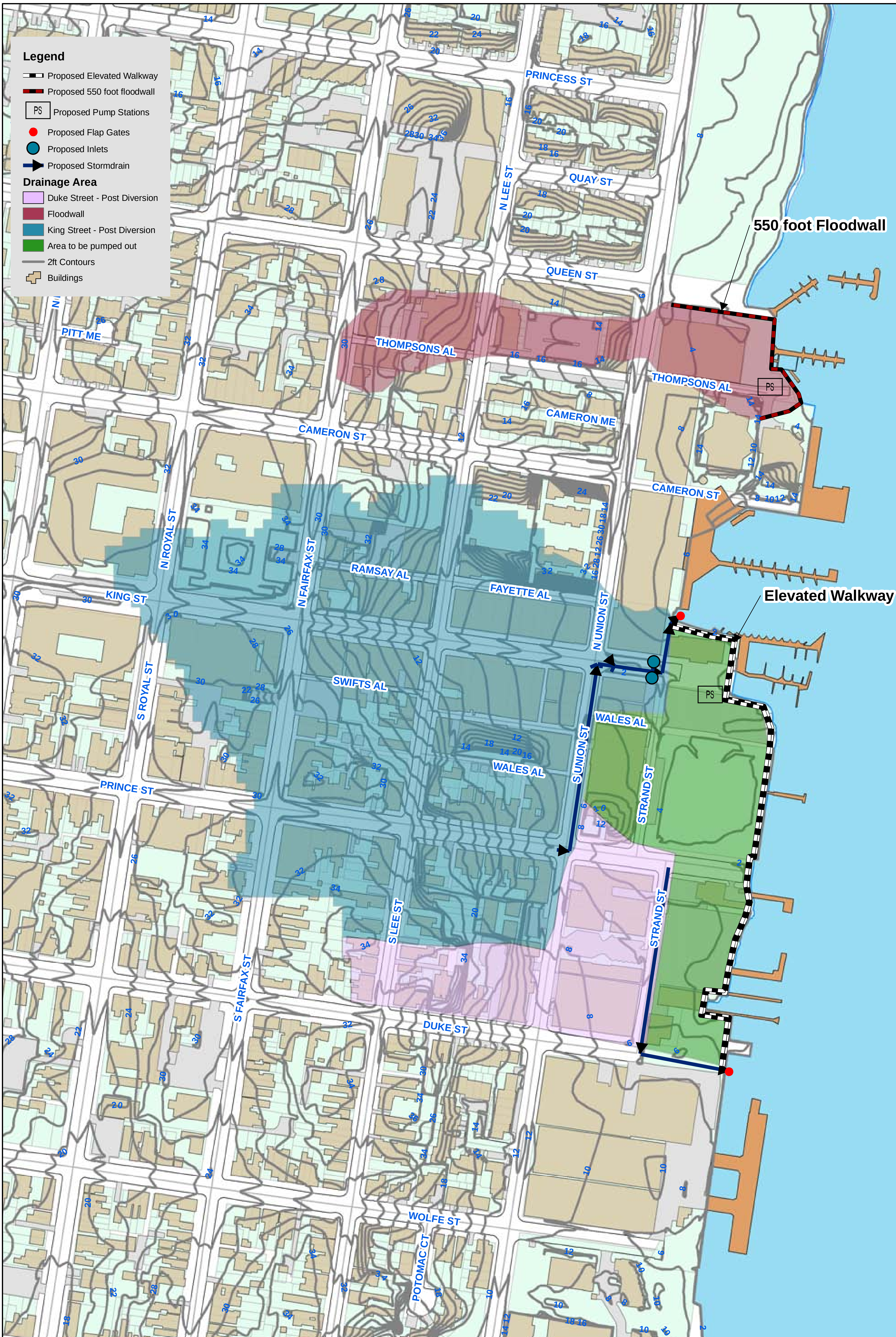
Proposed Elevated Walkway Layout

URS

200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO 15298592

FIGURE 6-4



CLIENT	City of Alexandria			
PROJ	Potomac River Waterfront Flood Mitigation Study			
REVISION NO	0	DES BY	CJL	09/11/09
SCALE	1 inch = 200 feet	DR BY	CJL	09/25/09
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N

0 50 100 200 Feet

TITLE
Interior Drainage Area for Elevated Walkway

URS
200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO 15298592

FIGURE 6-5

The pumping stations would be installed at the roads that run perpendicular to the floodwall. The pumping stations would need to be capable of pumping out the runoff from the extreme flood event. Because no storage areas are available to temporarily store the stormwater runoff, the interior drainage system needs to convey the entire 100-year flood discharge. A summary of flood discharges and volumes is provided in Table 6-4. Additional information on discharge estimates is provided in Exhibit 3 of Appendix G. The pump stations would be located next to the intersection of King Street and Strand Street, and along Duke Street just east of Strand Street.

Table 6-4: Elevated Walkway Discharges and Volumes

	King Street, Area (19.1 ac)	**Duke Street Area (4.0 ac)**	**Remainder Area (4.8 ac)**	**Additional Floodwall Area (3.5 ac)**
Recurrence interval	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
2 year	56.3	11.9	14.1	10.1
10 year	103.5	22.7	26.8	19.2
100 year	148.6	32.3	38.1	27.3

ac = acre
cfs = cubic foot/feet per second

An additional section of floodwall is required to provide protection for this area. On the south side of the Torpedo Factory the existing drainage system is lower than the 6-foot design elevation for the pedestrian walkway. In this area, flooding begins to occur at an elevation of 3.2 feet at Queen Street and Thompsons Alley (Figure 6-4). Without this additional floodwall, the benefits for the elevated walkway would be greatly reduced, as the flooding would back up and flood the area protected by the pedestrian walkway. The proposed floodwall would have dimensions similar to the elevated walkway. However, the additional floodwall would be approximately 550 feet and would not include a pedestrian walkway. The 550-foot floodwall with sloped backfill would have the following dimensions:

- An average height of 3 feet above ground (to reach an elevation of 6 feet NAVD88)
- A base of 3.3 feet
- A varying thickness averaging 1.5 feet

Additional internal drainage measure would need to be addressed for the additional floodwall. Approximately 3.5 acres that drain to this section of floodwall would result in a runoff volume of 0.94 acre-feet during the 10-year storm event (Figure 6-5). During periods of low elevation in the Potomac River, the existing stormdrain would flow by gravity through a proposed flapgate. During periods of high elevation on the Potomac River, a pumping system capable of pumping the peak discharge from the 10-year storm is proposed at this location. Appendix G contains additional information for the elevated walkway concept, including representative sections of the walls.

6.2.2 Assumptions

Several assumptions were made when conceptually designing the elevated walkway and 550-foot floodwall. Both the elevated walkway and the 550-foot floodwall were assumed to be reinforced concrete retaining wall. The elevated walkway was assumed to have a level backfill, due to the need for enough room on top of the retaining wall to place a pedestrian walkway. The 550-foot floodwall was assumed to be sloped backfill to minimize impacts on the structures it would be protecting. An average height of 4 feet and 3 feet was assumed for the elevated walkway and the 550-foot floodwall, respectively. The height was determined from the existing land profile on which the elevated walkway and 550-foot floodwall would be constructed.

The walkway itself was assumed to have a width of 5 feet. This assumption was made based on Federal Highway Administration regulations of sidewalks being, at minimum, 5 feet wide to accommodate two-way pedestrian traffic.

Also, there was assumed to be no potential storage areas for the stormwater runoff behind the elevated walkway and the 550-foot floodwall. Available contour information indicates very limited storage space is available for stormwater runoff below the height of the lowest FFE in the area (e.g., Mai Thai Restaurant and Starbucks FFE are at an elevation of 3.51 feet NAVD88).

6.2.3 Potential Impacts

A potential impact as a result of the elevated walkway and 550-foot floodwall is aesthetics. The conceptual design indicates that the waterfront view of the Potomac River could be obstructed in certain places. However, because there will be pedestrian access, the waterfront view will still be available.

Boating access to the waterfront could potentially be impacted by the elevated walkway and the 550-foot floodwall. To account for access along the waterfront, ramps from the walkway to the piers and docks would need to be included. These items were not accounted for in the conceptual design and would add cost to the overall project.

Furthermore, several commercial buildings could be affected during construction of the elevated walkway and the 550-foot floodwall. There would need to be coordination between the Alexandria Yacht Warehouse, Potomac Arms, the Old Dominion Boat Club, and the Chart House. These businesses would be impacted by having either the elevated walkway or the 550-foot floodwall between them and the Potomac River.

The floodwall may block the existing pedestrian walkway in the vicinity of Thompson Alley. Access issues will need to be addressed in this area and may require a removable system be installed. This system would need to be installed within 24 hours of known tidal or flood events.

For the Old Dominion Boat Club, ramps from the walkway to their piers and docks would need to be provided. Other possibilities would be to align the walkway to the south and west of the building and connect to the eastern side of the Torpedo Factory. Neither of these options was included in the proposed design; therefore, the costs may be higher with either option.

6.2.4 Permitting/Approval Requirements

The proposed elevated walkway and 550-foot floodwall requires excavation; therefore, environmental, historic, and archaeological reviews would be required for construction. The permitting requirements are anticipated to take a significant level of review effort. The local review schedule may take anywhere between 12 and 24 months, and any federal review is anticipated to take between 12 and 18 months.

Site Plan Approval

Grading associated with the elevated walkway will require approvals from the City of Alexandria and the state of Virginia as described below. The following is a summary of the regulatory programs and permits anticipated for the project:

- Grading plan approval from TES
- City of Alexandria Erosion and Sediment Control Ordinance
- VSMP
- DCR Construction General Permit

Natural Resources

Preliminary estimates of the proposed construction footprint and access requirements show that impacts would occur both within and adjacent to the Potomac River channel and would likely require more than 1 acre of subaqueous bottom impacts within the Potomac River below MHW. The discharge of dredge and fill material required for construction of the floodwall occurring channel-ward of MHW would require authorization by the USACE Norfolk District, VDEQ, and VMRC Habitat Management Division. The area landward of the Potomac River, including the proposed project area, is located within an RPA and requires authorization from the City under their Environmental Management Ordinance. A NEPA environmental review may be required if federal funds are used, or if the project includes some federal involvement. The District of Columbia should be notified of work that may affect the Potomac River's navigable channel.

The following list summarizes the water quality permits that may be required for the proposed project:

Federal

- USACE Clean Water Act IP
- Section 10 of the Rivers and Harbors Act Permit

State

- VMRC Habitat Management Division – Subaqueous bottom and/or tidal wetland impact authorization
- VDEQ Section 401 Certification
- VDEQ Water Protection Permit
- Virginia Coastal Zone Consistency Determination (VA Coastal Zone Management Program)

Local

- Chesapeake Bay Preservation Act Authorization (City of Alexandria Environmental Management Ordinance)

Should a NEPA decision document be required before construction begins, the process may require 3 to 12 months to complete. The length of time required to develop a NEPA decision document would be tied to the level of environmental documentation determined to be appropriate, and the respective agency and public involvement processes.

Resource Protection Area (RPA)

The entire elevated walkway is located within the RPA. Therefore, implementation of this project would require authorization under the *City of Alexandria's Environmental Ordinance* (Article XIII). Flood control projects are permittable under this ordinance if approved by the Director of TES. Implementation of water quality features such as Low Impact Development measures may be required.

Cultural Resources

Aboveground Resources

The elevated walkway will be considered to have an indirect adverse effect on the physical setting of the historic district or other individual historic properties, which may diminish the integrity of the resources within the viewshed. The scenic viewsheds of the waterfront are a contributing landscape feature to the Old and Historic Alexandria District. The floodwall will reduce or eliminate the scenic viewshed and will have an adverse effect on the historic district.

Archaeological Resources

A Phase I Archaeological Survey (background research and close interval shovel testing at 10 meters/10 yards) would likely be triggered. Moreover, if floodwall construction would impact the existing bulkheads requiring marine construction, assessment of underwater archaeological resources will be triggered. Because Alexandria is a port city of great historic significance, resources at the water's edge or near shore would also be subject to NHPA Section 106 review, as it is likely that they would be negatively affected by additional bulk-heading, dredging, or marine construction activities related to flood barrier construction.

A Phase I Identification study involving background research and shovel testing within the area of direct effect will be required. This could involve a detailed historical study of the Alexandria waterfront to determine areas of previous use and the potential for water-related infrastructure such as wharfs, cribbing, landings, and docks. Other survey methods may also be necessary such as a side-scan sonar survey of the near-shore areas or underwater documentation and/or excavation of sites that would be disturbed or destroyed by this undertaking. Installation of floodwater handing systems such as pumps would also likely trigger Phase I testing before installation and Archaeological Monitoring during construction.

If archaeological features are identified, a Phase II (Evaluation) follows and if the archaeological features would be adversely affected by the floodwall construction then Phase III (Treatment) would be required and would likely involve recordation and data recovery excavations.

6.2.5 BCA and Results

This option provides protection for approximately 43 commercial structures and 23 residential structures from the nuisance flooding event. Because the design flood elevation for the walkway is 6.0 feet, the return interval and EAP were calculated for this specific case. The return interval is 10 years and EAP of 0.1. The life of the elevated walkway and additional floodwall was assumed to be approximately 50 years. The elevated walkway would protect approximately 66 structures within three focus areas from the nuisance flood and for up to the 10-year storm. The elevated walkway would not protect any structures from the intermediate or extreme flood events. In addition, although it is not included in this planning-level BCA, the elevated walkway would significantly decrease the number of road closures due to flooding. Based on the design elevation and other data, the total benefit of the walkway for the structures is $14,745,000.

An annual maintenance fee of 2.5 percent of the total cost of the elevated walkway and floodwall was added to the cost of the project. The total capital expense of the project would be $5,030,000. The cost for annual maintenance of the elevated walkway would be $1,042,000. The total cost of the project used for the BCA, as shown in Table 6-5, is $6,072,000. A more detailed cost estimate is provided in Appendix G, Exhibit 3.

The BCR for the elevated walkway is 2.43, which indicates that this is a cost-beneficial mitigation project.

Table 6-5: Elevated Walkway Benefit-Cost Ratio

Total Cost of Elevated Walkway	$6,072,000
Total Benefit for Walkway	$12,14,745
Benefit-Cost Ratio (BCR) for Structures protected by the Floodwall	**2.43**

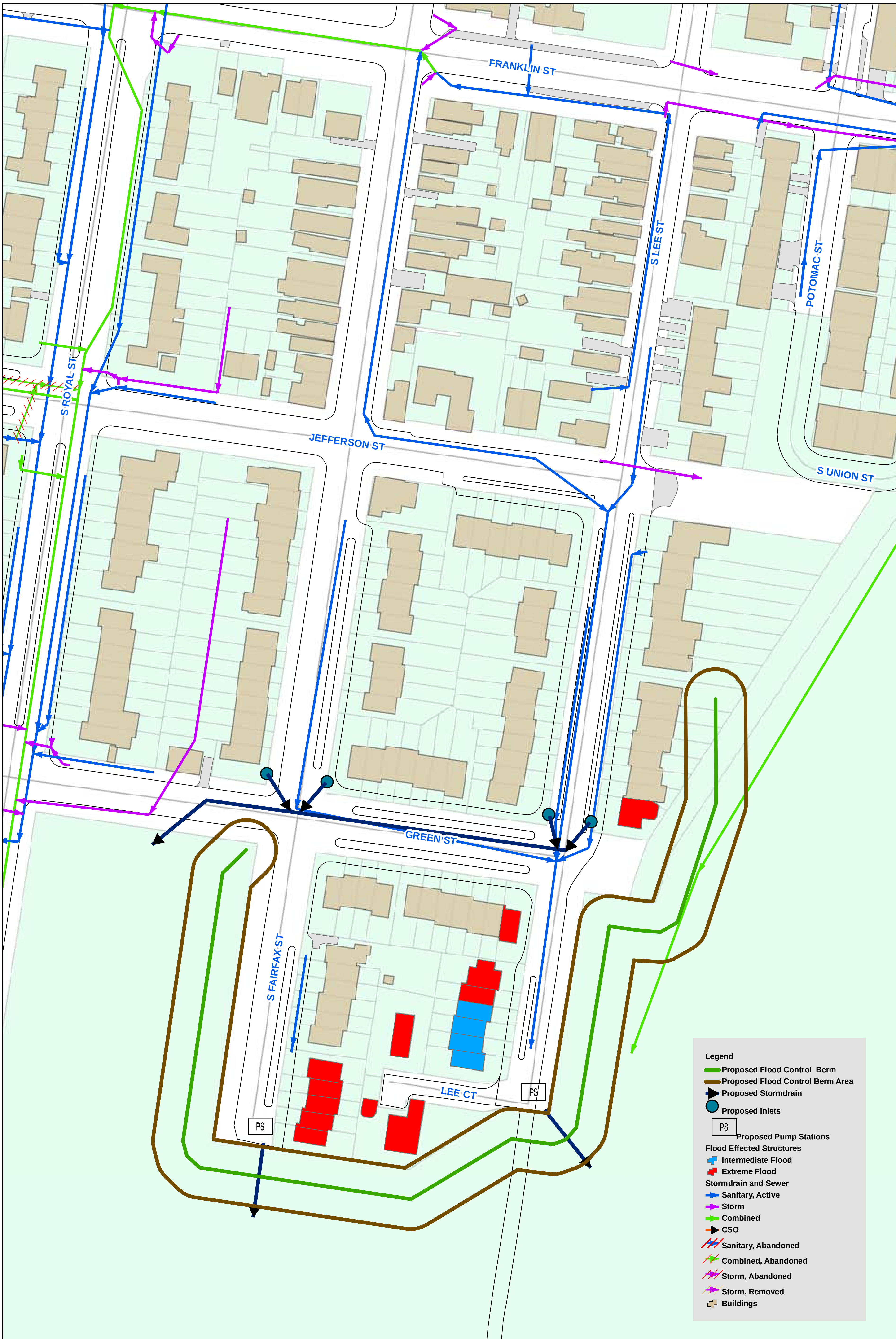
6.3 JONES POINT BERM

During the extreme flood event (100-year recurrence interval storm), 17 of the structures in the Jones Point focus area are predicted to experience flooding of up to 3.35 feet. All of the structures in this area are elevated above the nuisance and intermediate floods; therefore, they only need protection from the extreme flood event.

6.3.1 Description of Alternative

One of the alternatives considered for the Jones Point area is construction of an earthen berm in the low area surrounding the affected structures. The berm would be constructed of earth with a clay fill core. Most of the interior drainage would be conveyed via new stormdrain pipes.

The conceptual design is to construct a 1,370-linear-foot earthen berm to an elevation of 13.2 feet (NAVD88). The elevation provides for 3 feet of freeboard from the predicted 100-year elevation of 10.2 (NAVD88). The berm protects the majority of the homes (15 of the 17 affected by the extreme flood event) in this area and ties into existing high ground (Figure 6-6).



CLIENT	City of Alexandria			
PROJ	Potomac River Waterfront Flood Mitigation Study			
REVISION NO	0	DES BY	CJL	09/11/09
SCALE	1 inch = 100 feet	DR BY	CJL	09/24/09
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N

0 25 50 100 Feet

TITLE

Proposed Jones Point Berm Layout

URS

200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO 15298592

FIGURE 6-6

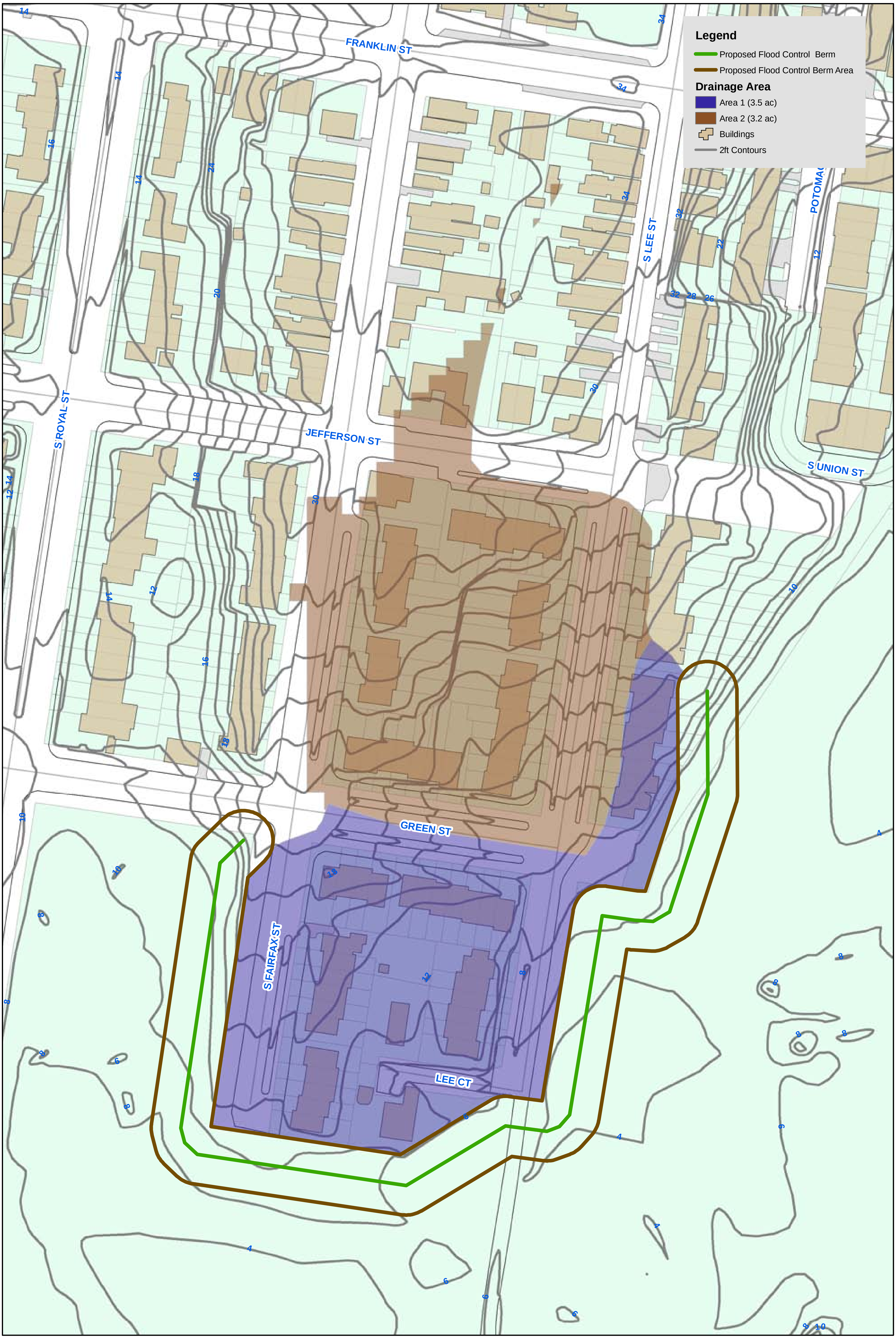
A key consideration in the design of the berm is conveyance of the interior drainage (i.e., runoff that drains to the berm). The area between South Fairfax Street and South Lee Street and north to the area between Franklin Street and Jefferson Street drain to the proposed berm (Figure 6-7). Approximately 6.7 acres drain to the area of the proposed berm via two existing stormdrain systems. During a storm event, storm water runoff from this drainage area would pond behind the berm if adequate storm water diversions were not in place.

Conveyance of the interior drainage is proposed in two parts. First, the existing stormdrain system will be diverted around the berm via construction of new inlets at the corners of South Fairfax Street and Green Street and South Lee Street and Green Street. These inlets would be used to capture overland runoff from the approximately a 3.5-acre drainage area north of Green Street and divert it away from the berm (Area 1). Stormdrain pipes would be constructed to capture runoff from the new inlets and the existing stormdrain pipes. The pipes would be sized to convey the 100-year storm event (31.2 cfs). The concept is for one 36-inch concrete pipe to convey storm water from each inlet to a 48-inch concrete pipe under Green Street outfalling to the west of the berm.

The second part of the interior drainage system is to convey the overland runoff that accumulates within the proposed berm area (e.g., downstream from the proposed stormdrain described above). Approximately 3.2 acres drain directly to the berm. This runoff will be conveyed via two 36-inch concrete culverts through the berm where South Fairfax Street and South Lee Street end at Jones Point Park (Area 2, Figure 6-7). Flapgates would be installed on these culverts to prevent backflow into the area during large storm events. In the event that water levels are elevated on the downstream side of the berm due to flooding on the Potomac River, a combination of storage and backup pumps will be used to convey the interior drainage in this area.

As part of this project, the existing sanitary sewer systems may need to be relocated. The relocation of the utilities has not been incorporated into the cost estimate, as the project is not currently cost effective, and relocation would only increase the costs.

Surveyed first floor elevation data show that approximately 1.35 acre-feet of storage can be provided in low areas along the proposed berm without entering the first floor of any structures. Storage for this area was determined using the existing elevation data. During the extreme flood event on the Potomac River, water would need to be pumped out of this area during a large storm event. For the purposes of this project, because available storage is limited to 1.35 acre-feet, it was assumed that pumps would be needed to convey the 100-year discharge. A table showing stage-storage data is provided in Appendix H.



CLIENT	City of Alexandria			
PROJ	Potomac River Waterfront Flood Mitigation Study			
REVISION NO	0	DES BY	CJL	09/11/09
SCALE	1 inch = 100 feet	DR BY	CJL	09/24/09
W:\City of Alexandria\15298470 - Lower King St\Task 3\Report \Final\Figures\MXDs\F6-7 Berm Interior Drainage Area.mxd		CHK BY	MER	10/04/09

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0 25 50 100 Feet

TITLE

Interior Drainage Area for Jones Point Berm

URS

200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO 15298592

FIGURE 6-7

6.3.2 Assumptions

For the purposes of estimating costs, the geometry of the berm is assumed to be as follows:

- Average berm height of 9 feet
- Trapezoidal shape with side slopes of 3:1
- A bottom width of 64 feet
- A top width of 10 feet
- A rectangular clay fill core with a height of 5 feet and a width of 10 feet

6.3.3 Potential Impacts

The visual and physical obstruction to the view of Jones Point Park was considered during the conceptual design of the berm. The visual obstruction would be significant, with an average berm height of 9 feet. Because this is an earthen barrier, however, landscaping would be used to improve the aesthetics of the berm and reduce the visual impact. The physical obstruction is minimized by the 3:1 slope, specifically where a hiker/biker trail crosses just south of Lee Street. The slope change would also allow maintenance vehicle access from Lee Street if needed.

6.3.4 Permitting/Approval Requirements

The proposed berm requires excavation; and therefore, environmental, historic, and archaeological permits would be required to construct the berm. The permitting requirements are anticipated to cause a significant level of review effort. The local review schedule may take between 6 and 12 months. Any federal review is anticipated to take between 9 and 12 months.

Site Plan Approval

Grading associated with the Jones Point berm will require approvals from the City of Alexandria and the state of Virginia as described below. The following is a summary of the regulatory programs and permits that are anticipated for the project:

- Grading plan approval from Transportation and Environmental Services
- City of Alexandria Erosion and Sediment Control Ordinance
- Virginia Stormwater Management Program (VSMP)
- DCR Construction General Permit
- National Park Service Temporary Construction Permit

Natural Resources

The proposed berm would require the removal of upland forest vegetation and forested nontidal wetlands associated with Jones Point Park. Based on preliminary estimates of the proposed construction footprint and access requirements, the project may qualify for the USACE's State Program General Permit (SPGP-01). In order to qualify, the project may not cause the loss of more than 1 acre of nontidal wetlands or 2,000 linear feet of streams. Activities causing the loss of more than the aforementioned thresholds will require a Norfolk District USACE IP. Compensatory mitigation would be required for unavoidable impacts after implementation of avoidance and minimization measures during the design process. The District of Columbia should be notified of work that may affect the Potomac River's navigable channel.

A summary of the water quality permits that may be required for the proposed project is as follows:

Federal

- USACE SPGP-01

State

- Virginia Water Protection Permit
- Coastal Zone Consistency Determination (MD Coastal Zone Management Program)

Local

- Chesapeake Bay Preservation Act Authorization (City of Alexandria Environmental Management Ordinance)

Both the SPGP-01 joint permit application and local permit acquisition processes, including identifying suitable compensatory mitigation, are expected to take 4 to 6 months to complete.

Resource Protection Area (RPA)

It appears that the berm is outside of the RPA buffer, as it is located over 100 feet away from the Potomac River shoreline. Therefore, authorization under the *City of Alexandria's Environmental Ordinance* (Article XIII) is not anticipated to be required.

Cultural Resources

Aboveground Resources

This alternative may have an indirect adverse effect on the physical setting of the historic district or other individual historic properties which may diminish the integrity of the resources within the viewshed. Any new element introduced into the district that will reduce or eliminate any or all of the scenic viewshed will have an adverse effect on the historic district.

Archaeological Resources

A Phase I Identification study involving background research and shovel testing within the area of direct effect will be required. Installation of floodwater handing systems such as pumps would also likely trigger Phase I testing before installation and Archaeological Monitoring during construction.

If archaeological features are identified, a Phase II (Evaluation) follows and if the archaeological features would be adversely affected by the floodwall construction then Phase III (Treatment) would be required and would likely involve recordation and data recovery excavations.

Additionally, a documented archaeological site (44AX0078) lies directly east of the Jones Point berm area. Previously, as part of the Woodrow Wilson Bridge Replacement Project, this site was been found individually ineligible for listing in the National Register, but was acknowledged to be a contributing element within the Alexandria National Register Historic District by the Keeper of the National Register. However, the Virginia Department of Historic Resources Data Sharing System (VDHR DSS) maps the site as covering the entire Jones Point Park area. Therefore, any subsurface disturbance in this area would constitute a direct effect to this site. This would likely trigger Archaeological Monitoring during construction and Phase III (Treatment) of features within the area directly affected.

6.3.5 BCA and Results

The cost of the berm is based on construction (materials, labor, and equipment), final design, permitting, easements, and administrative costs. The total upfront capital expense of this project is approximately $4,083,000. An annual maintenance fee of 5 percent of the total cost of the berm was added to the cost of the project for the BCA. The present cost for the annual maintenance over the life of the berm is about $1,408,000. The total cost of the project used in the BCA would be about $5,492,000, as shown in Table 6-6. A more detailed cost estimate is provided in Appendix H, Exhibit 1. The total benefits provided by the berm will be $236,400. The project lifetime is 50 years based on standard USACE and FEMA structural mitigation design lifetimes.

The BCR for the berm is 0.04, which indicates that this is not a cost-beneficial mitigation project.

Table 6-6: Berm Benefit-Cost Ratio

Total Cost of Berm including construction, design, and permitting	$5,491,000
Total Benefit for the Berm	$236,410
Benefit-Cost Ratio (BCR) for Structures protected by the Berm	**0.04**

6.4 IMPROVE ROADWAY DRAINAGE

During nuisance flood events, the City of Alexandria encounters flooding between the intersections of King Street and Strand Street, and King Street and North Union Street due stormdrain catch basin elevations being low, as discussed in Section 3. A proposed solution to this problem involves raising the intersection of King Street and Strand Street as well as raising stormdrain manholes and catch basins.

6.4.1 Description of Alternative

Improving the storm drainage in the area requires several steps. First, the roadway in the vicinity of the intersections of King Street and South Union Street, and King Street and Strand Street would be elevated (Figure 6-8). A section of Strand Street would be re-graded to elevation of approximately 4 feet. Because the building elevation on the corner of King Street and Strand

Street (i.e., Mai Thai Restaurant) has an FFE of below 4 feet (i.e., 3.51 feet), additional drainage measures would need to be implemented. A trench drain would be installed between Strand Street and the commercial buildings between King Street and Wales Alley, as well as between King Street and the Old Dominion Boat Club. These drains would account for stormwater runoff from the elevated portion of Strand Street.

As part of elevating the road, the elevation of the inlets would increase. Manhole and inlet inserts would be installed at eight inlets in the area of the proposed storm drainage improvements. The minimum rim inlet would be at an elevation of 3.25 feet as compared to 2.0 feet.

6.4.2 Assumptions

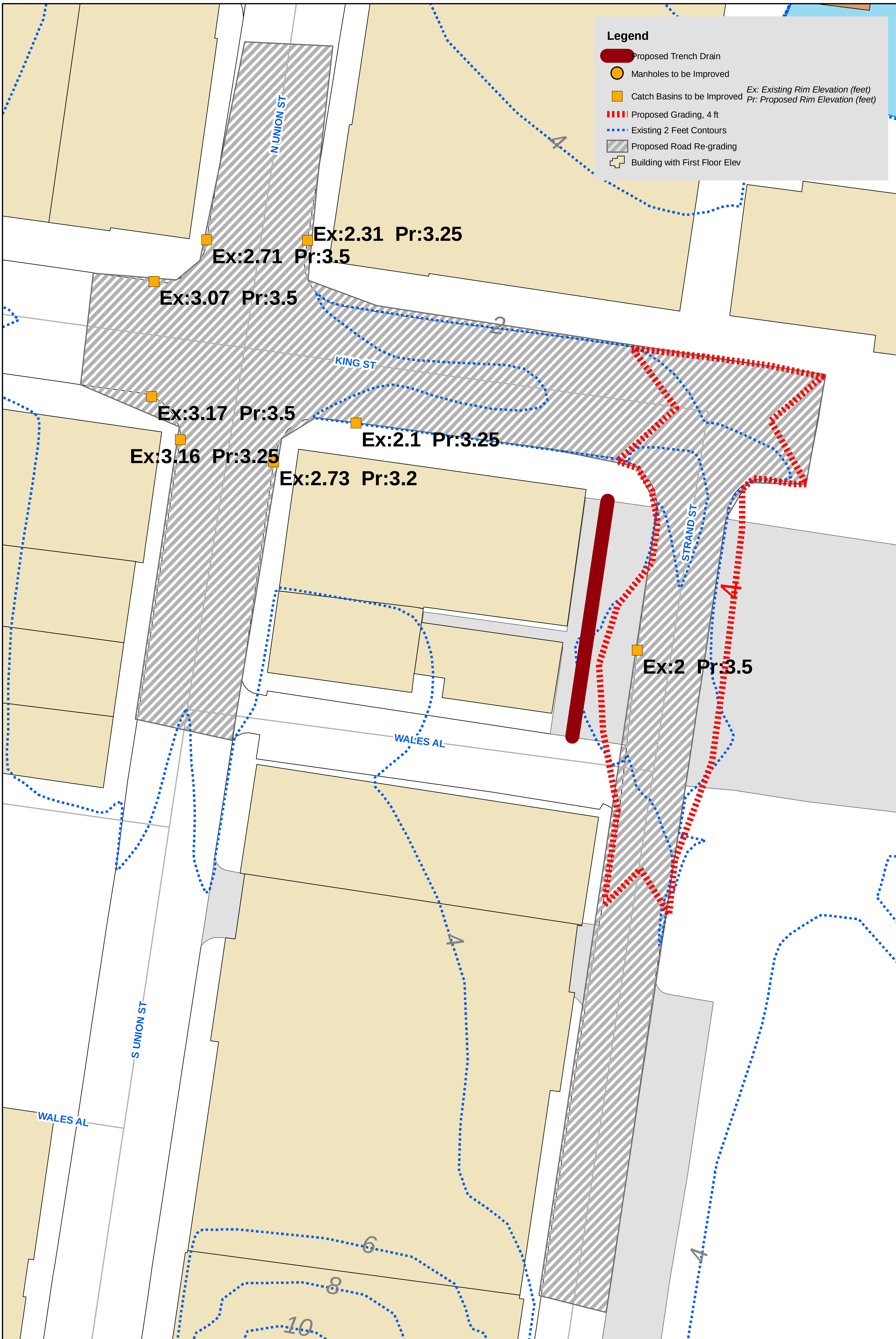
Several factors limit how much the road and inlets can be elevated. Three commercial buildings adjacent to the proposed road and inlet improvements have FFEs below an elevation of 4 feet. The grading for this alternative considered the assumed curb height of 6 inches (although from site visits and photographs, the existing curb was observed to be less than 6 inches), and used the maximum sidewalk slope from the Americans with Disabilities Act (ADA) of 2 percent. Considering these items, the highest proposed inlet elevation would be approximately 3.2 feet. The inlets that would have the greatest increase in elevation are located on the southwest corner of King Street and South Union Street with the rim being elevated to 3.5 feet from 2.0 feet.

This alternative specifically addressed the road and inlet elevation actions. However, this alternative could be enhanced by internally elevating the first floor of the businesses with first floor elevations below 4 feet in the area. Providing slight internal elevation of the structures (i.e., 0.5 foot) would allow the modified storm drain inlet rim elevations to be closer to 4 feet, which would provide greater flood mitigation for the nuisance flooding event. Internal elevation of structures were not included in the cost of this alternative, as this measure would be implemented independently by private property owners.

6.4.3 Potential Impacts

During construction, temporary impacts to the roads and utilities will occur in the project area. Construction impacts include temporary road and sidewalk closures. In addition to the stormdrain and road elevation work, curbs and gutters along King Street, South Union Street and The Strand will be reconstructed, including any curb cuts. Furthermore, the brick sidewalks in this area will be reset after the re-grading of the roadway and curbs and gutters.

Once construction is completed, permanent potential impacts as a result of implementation of this alternative are minor.



CLIENT	City of Alexandria				TITLE	Proposed Roadway Drainage Improvements Layout
PROJ	Potomac River Waterfront Flood Mitigation Study					
REVISION NO	0	DES BY	CJL	09/11/09	PROJ NO	15298592
SCALE	1 inch = 30 feet	DR BY	CJL	09/25/09	FIGURE	6-8
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URS
200 Orchard Ridge Drive
Gaithersburg, MD 20878

6.4.4 Permitting/Approval Requirements

Implementation of this project would require grading and environmental permits due to ground disturbance. The permitting requirements are anticipated to cause a moderate level of review effort. The local review schedule may take between 6 and 12 months, and any federal review is anticipated to take between 9 and 12 months.

Site Plan Approval

Grading associated with the roadway improvements will require approvals from the City of Alexandria and the state of Virginia as described below. The following is a summary of the regulatory programs and permits anticipated for the project:

- Grading plan approval from TES
- City of Alexandria Erosion and Sediment Control Ordinance
- VSMP
- DCR Construction General Permit

Natural Resources

Grading associated with road improvements and sidewalk alterations, which are proposed to involve approximately 40,000 square feet, will require approvals from the City of Alexandria and potentially the State programs summarized below. The need for approvals will depend upon the scope of the ultimate design, project location, and area of disturbance. The following is a summary of the regulatory programs and permits that are currently anticipated for the project:

- Chesapeake Bay Preservation Act
- City of Alexandria Environmental Management Ordinance
- City of Alexandria Erosion and Sediment Control Ordinance
- Virginia Stormwater Management Program
- Department of Conservation and Recreation Construction General Permit

Resource Protection Area (RPA)

The roadway improvement project appears to be outside of the RPA buffer, as it is located over 100 feet away from the Potomac River shoreline. Therefore, authorization under the *City of Alexandria's Environmental Ordinance* (Article XIII) is not anticipated to be required.

Cultural Resources

Aboveground Resources

The roadways and associated features in the Old and Historic Alexandria Historic District are historically significant elements within the district. Features of the roadways or associated with roadways that may, depending upon their period of origin and current condition, contribute to this historical significance include: their alignment (grid pattern); width; paving materials (cobblestone, brick, asphalt, concrete); embedded streetcar/railroad tracks; curbing (granite, brick, brick asphalt, concrete, iron, steel); sidewalks (flagstone, brick, asphalt, concrete); bridges; railings; culverts and other drainage infrastructure; signage; traffic and street lighting; other character-defining hardscape features; landscape features (trees). If any of these historically significant features are altered in the elevation of the roadway, then this could adversely affect the features, and the historic district in general. Additionally, depending upon the nature of the work, adjacent historic properties, such as buildings (residences and business) and structures (retaining walls), objects (fences, bollards), and sites (archaeological, discussed below, landscape elements) may be adversely affected.

The exact scope of work and project location would need to be reviewed for a final determination. In some cases, the work may be undertaken in such a manner as to avoid or minimize adverse effects. For example, if historic materials are removed and replaced in their original location and configuration, only elevated by a few inches – such as brick paving on a sidewalk – this may avoid adverse effects. If historic features are left in place but obscured by new infrastructure such as paving or sidewalks laid on top of the historic features, this may be an adverse effect. Similarly, if elevation of sidewalks occurs directly abutting historic buildings or structures, this may damage or obscure character-defining features of the historic properties such as decorative features, doorways and thresholds, basement windows.

Archaeological Resources

If this alternative requires no subsurface disturbance (i.e., blacktop applied directly to existing surfaces), no archaeological testing would be required and no adverse effects to archaeological resources would be anticipated. Archaeological survey would likely be triggered by alterations to streets within the historic district if subsurface disturbance is involved, as these actions may result in adverse effects to archaeological resources. Construction preparation activities such as road milling may expose historic brick or "cobblestone" streets that are common in port settings such as Alexandria. Moreover, older roadbeds and previous street alignments may also be encountered and/or disturbed by road elevation. This alternative would likely trigger a Phase I Identification study involving background research and shovel testing within the area of direct effect and Archaeological Monitoring during construction.

6.4.5 BCA and Results

A BCA was not performed for this mitigation alternative due to the benefits being difficult to quantify. The primary impact of these less than nuisance floods are road closures and reduced access to the business in the affected area. The proposed project would reduce the frequency of these events, and therefore reduce road closures along eastern King Street and The Strand, and allow greater access to the adjacent business. The reduction in flooding frequency was estimated based on the USGS gage for the Potomac River at Cameron Street. Tidal elevations were reviewed over a 1-year period from September 2008 to September 2009. A graph of this data is shown in Appendix I. The water level elevation of 2 feet was exceeded 186 times. During the same period, the water level elevation of 3.2 feet was exceeded 10 times. Increasing the minimum inlet rim elevation from 2.0 feet to 3.2 feet would considerably reduce the flooding frequency.

The overall project cost would be $565,700, based on the construction, design, permitting, and administrative costs (e.g., road detours during construction). No additional maintenance other than what the City currently provides would be required as a result of the implementation of this project. A more detailed cost estimate for this project is provided in Appendix I.

6.5 ACQUIRE PROPERTIES

Acquisition is the only mitigation measure that truly eliminates risk, because a property is physically removed from the floodplain. This section presents the methodology for the acquisition assessment including the assumptions, the potential impacts of this alternative, and the associated permit requirements. The BCA for each individual focus area is in Section 6.5.4. The methodology for calculating total benefit values and the total costs are presented in Section 5.

6.5.1 Assumptions

Based on the following assumptions, row houses were considered for acquisition if the entire row of houses was affected by flooding:

- Within a series of row houses, one unit (property) cannot be structurally separated without causing significant structural changes to the adjacent units,
- Property owners not affected by flooding are extremely resistant to relocating, and
- The City does not wish to pursue acquisition through eminent domain; only willing residents will participate.

6.5.2 Potential Impacts

Property acquisition will impact the community in numerous ways. One impact of property acquisition is the effect it has on property values and taxes. Community acquisition of privately owned properties reduces the tax base, which can affect the community's ability to maintain existing services. In addition, demolishing residential properties reduces the housing inventory and demolishing commercial properties reduces the commercial services provided in an area.

In the case of this study area, valuable historic buildings would be lost and the character of Old Towne would be changed by removing historic structures. All of these impacts must be considered to ensure that the community can protect itself from flood hazards, while concurrently maintaining its financial stability, ability to provide services, and preserving historic sites.

6.5.3 Permitting/Approval Requirements

Dependent upon the historic value of the building selected for acquisition/demolition, the permitting requirements are anticipated to cause a significant level of review effort. The local review schedule may take 9 to 12 months, and any federal review is anticipated to take between 9 and 18 months.

Site Plan Approval

For projects less than 2,500 square feet, grading plan approval is not required. It is anticipated that for single structure acquisition projects, grading plan approval would not be required. However for large structures, such as a row of townhouses, it is likely that a grading plan showing the demolition details would be required to be submitted to the City's TES group. Other site plan permits/approvals are not anticipated for acquisition activities.

Natural Resources

This alternative creates no anticipated natural resource impacts. However, if soil disturbance is required or a structure to be demolished is within a RPA or a wetland, a permit review should be performed.

Cultural Resources

Aboveground Resources

The demolition of a structure may have direct or indirect effects if the undertaking is to occur to an historic structure or within or next to an historic district. However, each building will have to be reviewed independently. This alternative could result in a cumulative adverse effect on the physical setting and character of the historic district as a whole. With each building that is removed or demolished, the overall integrity of the historic district is further diminished to the point where the area may no longer meet the criteria to be eligible as an historic district.

Archaeological Resources

A Phase I Archaeological Survey (background research and close interval shovel testing at 10-meter/10-yard intervals) would likely be triggered by building demolition, as this would involve subsurface disturbance.

6.5.4 Applicability of Acquisition/Benefit-Cost Analysis

This section defines the applicability of acquisition, describes structures included in the BCA for acquisition in each of the four focus areas (Jones Point, King Street, Waterfront Commercial, and North Union), and presents the benefits, costs, and resultant BCR. Appendix J contains support data for these analyses.

Jones Point

For the Jones Point focus area, all of the houses in the flood prone areas are residential row houses with the exception of two free-standing residential properties on South Lee Street. Only the extreme flood event causes flood damages to the properties. Based on the assumptions listed in Section 6.5.1, 13 properties are feasible for acquisition. The estimated financial benefit for acquisition of these 13 properties is $198,000.

The total estimated cost FMV of land and buildings in the Jones Point Focus Area is $10,951,000. The BCA for the Jones Point focus area is presented in Table 6-7, resulting in a BCR of 0.02. This BCA indicates that property acquisition in Jones Point would not be cost-effective because the costs substantially outweigh the benefits.

Table 6-7: Acquisition for Jones Point Benefit-Cost Results

Total Cost (FMV) of Land + Building	$10,951,000
Other Costs	$329,000
Total Costs	$11,280,000
Total Benefit for Acquisition	$198,000
Benefit-Cost Ratio (BCR)	**0.02**

King Street

The King Street focus area is a commercial area predominantly composed of shops, restaurants, and boutiques with some row houses. In the King Street focus area, 23 commercial and five residential structures are prone to flooding. One residential unit was excluded from this analysis; the unit excluded is attached to a separate row of houses that is not susceptible to flooding. The estimated financial benefit for acquisition of these 28 properties is $4,230,000.

The total estimated cost FMV of land and buildings in the King Street focus area is $85,320,000. The total other costs for residential and commercial properties were an estimated $5,507,000.

The BCA for the King Street focus area is presented in Table 6-8, resulting in a BCR of 0.05. This BCA indicates that property acquisition in King Street would not be cost effective, because the costs outweigh the benefits.

Table 6-8: Acquisition for King Street Benefit-Cost Results

Total Cost (FMV) of Land + Building	$85,320,000
Other Costs	$5,507,000
Total Costs	$90,872,000
Total Benefit for Acquisition	$4,230,000
Benefit-Cost Ratio (BCR)	**0.05**

Waterfront Commercial

The Waterfront Commercial focus area is composed of various commercial buildings including warehouses, parking garages, shops, an office complex, and a gallery**.** Based on the assumptions outlined in Section 6.5.1, our benefit calculations consider only four properties during the intermediate flood event and 28 properties during the extreme event. The estimated financial benefit for acquisition of these properties is $7,336,000.

The total estimated cost FMV of land and buildings in the Waterfront Commercial focus area is $99,000,000. Because of the variance in average building square footage price, the FMV was determined for each of the 22 commercial properties. The total other costs were an estimated $5,375,000

The BCA for the Waterfront Commercial focus area is presented in Table 6-9, resulting in a BCR of 0.07. This BCA indicates that property acquisition in Waterfront Commercial would not be cost-effective because the costs substantially outweigh the benefits.

Table 6-9: Acquisition for Waterfront Commercial Benefit-Cost Results

Total Cost (FMV) of Land + Building	$99,000,000
Other Costs	$5,375,000
Total Costs	$104,375,000
Total Benefit for Acquisition	$7,336,000
Benefit-Cost Ratio (BCR)	**0.07**

North Union

The North Union focus area is a residential community containing only residential row houses. Thirty-four residential properties were considered feasible for acquisition. The estimated financial benefit for acquisition of these 34 properties is $610,000.

The total estimated cost FMV of land and buildings in the North Union focus area is $18,500,000. The total other costs were an estimated $1,360,000.

The BCA for the North Union focus area is presented in Table 6-10, resulting in a BCR of 0.03. This BCA indicates that property acquisition in North Union would not be cost-effective because the costs substantially outweigh the benefits.

Table 6-10: Acquisition for North Union Benefit-Cost Results

Total Cost (FMV) of Land + Building	$18,500,000
Other Costs for North Union	$1,360,000
Total Costs	$19,860,000
Total Benefit for Acquisition	$610,000
Benefit-Cost Ratio (BCR)	**0.03**

6.6 FLOODPROOFING

Floodproofing provides a variety of methods to protect structures from flood waters. As described in Section 3.1.3, dry floodproofing was selected as the mitigation measure to be assessed further. This section presents the analysis of the dry floodproofing assessment including the assumptions, the potential impacts imposed by this alternative, and the associated permit requirements.

6.6.1 Assumptions

The following assumptions were used to assess floodproofing as a mitigation measure for the four focus areas.

- Only dry floodproofing measures were considered.
- Floodproof membranes and window shields were not included due to the historic nature of the area.

- Not all structures were evaluated for construction elements, such as height of windows, size of doorways, materials used, or the presence of basements.

6.6.2 Potential Impacts

Floodproofing has several potential impacts. Positive impacts include protection of structures and contents from flood damages and improving the communities standing in FEMA's CRS. As discussed in Section 3, the historic structures in Alexandria present significant limitations to the selection of some floodproofing options. Elements such as floodproof doors and windows use materials that are not historically accurate. More discussion related to the historic effects is contained in the permit review below.

6.6.3 Permitting/Approval Requirements

Dependent upon the floodproofing alternatives selected by the property owner, the permitting requirements for floodproofing are only anticipated to cause a moderate level of review effort. Given the historic sensitivity, the local review schedule could take between 4 and 12 months, and any federal review is anticipated to take 12 to 24 months.

Site Plan Approval

Site plan preparation and grading plan approval not is likely to be required for any floodproofing project. However, for patio improvements, if the area of disturbance is greater than 2,500 square feet, a grading plan will be required to be submitted to the City's TES group. Other site plan permits/approvals are not anticipated for floodproofing activities.

Natural Resources

This alternative creates no anticipated natural resource impacts. However, if soil disturbance is required, a permit review should be performed.

Cultural Resources

Aboveground Resources

Each building requires independent review with an exact scope of work to assess the impacts of the specific floodproofing measures proposed for that building. Typically, exterior alterations that replace original fabric and design may adversely affect the look of the building. This can be interpreted to result in a cumulative adverse effect on the physical setting and character of the historic district as a whole. As the historic fabric and integrity of multiple buildings are altered and replaced with historically uncharacteristic materials, the overall integrity of the historic district is diminished.

Archaeological Resources

An archaeological survey would likely not be triggered by this alternative. However, if the process requires access to the area around the foundations or basements of historic structures, this could trigger a Phase I Identification focus (background research and shovel testing of the area of direct effect). If archaeological features were identified as a result of this focus, then a

Phase II (National Register Evaluation) focus would follow. If the archaeological features were found eligible for listing in the National Register and would be adversely affected by floodproofing, then Phase III (Treatment) would be required and would likely involve recordation and data recovery excavations. Since membranes and window shields are not proposed, this review process is unlikely to be required for any of the floodproofing recommendations

6.6.4 Floodproofing Applicability/Benefit-Cost Analysis

This section defines the solutions included in the BCA for floodproofing in each of the four focus areas (Jones Point, King Street, Waterfront Commercial, and North Union) and presents the benefits, costs, and resultant BCR. Note that the King Street Focus Area discussion was separated into commercial and residential areas. For purposes of the BCA, it was assumed that any structure susceptible to the nuisance, intermediate or extreme flood event would need a floodproof option. Secondary glazing of windows and window shields are less expensive than replacement windows, and flood gates are less expensive than custom doors. However, given the historic nature of the study area and the variety of construction styles, cost estimates were inflated to allow for the cost variations seen in custom construction. The costs used to determine BCR for each focus area are shown in Table 6-11. The method for computing the cost for each floodproofing method is described in Appendix K.

Table 6-11: Estimated Costs for Various Floodproofing Methods

Method	Cost/Structure
Flood Gate	$900
Custom Floodproof Door	$10,000
Custom Floodproof Window (residential)	$3,000
Custom Floodproof Window (commercial)	$6,000
Raise Patio/Fill	$8,000
Internal Elevation	Based on Average Square Footage Per Focus Area

Where floodproof doors are practical, they are considered. Flood gates are indicated where a door is not practical. Flood gates could be used in place of floodproof doors throughout, but they are an active system and not as aesthetically appealing. The cost estimate for windows assumes replacement windows with suitable historic features. A less expensive flood barrier could be used for the window, but that would require placement of a product before the flood event occurs, and is not as aesthetically acceptable.

Jones Point

Approximately 17 structures in the Jones Point focus area are at risk of flooding from the extreme flood event. All of these buildings are residential. In some cases, field reconnaissance provided limited access because residents were not home.

Table 6-12 shows the different dry floodproofing options and the approximate number of structures within the Jones Point focus area that might benefit from each. Approximately 15 structures could potentially benefit from a floodproof gate or door. Eight structures have windows that require protection. In addition, eight structures may benefit from raising the ground elevation at the point of floodwater entry. The recommended floodproofing measure for each structure in the Jones Point focus area, as well as the level of protection it would provide, is shown on Figure 6-9.

Table 6-12: Floodproofing Options for Jones Point: 17 Residential Structures

Method	Cost / Structure	Number of Structures
Flood Gate	$900	15
Floodproof Openings		
Door	$10,000	14
Window	$3,000	8
Raise Patio/Fill	$8,000	8

For purposes of determining the benefit cost ratio, the most expensive dry floodproofing plan for Jones Point was considered. The most expensive floodproofing option considered is replacing all doors and windows that are below the flood elevation with floodproof doors and windows.

As shown in Table 6-13, the floodproofing BCA results in a BCR of 1.0. Because the most expensive floodproofing scenario is cost effective, any combination of dry floodproofing techniques used in the Jones Point focus area will also be cost effective.

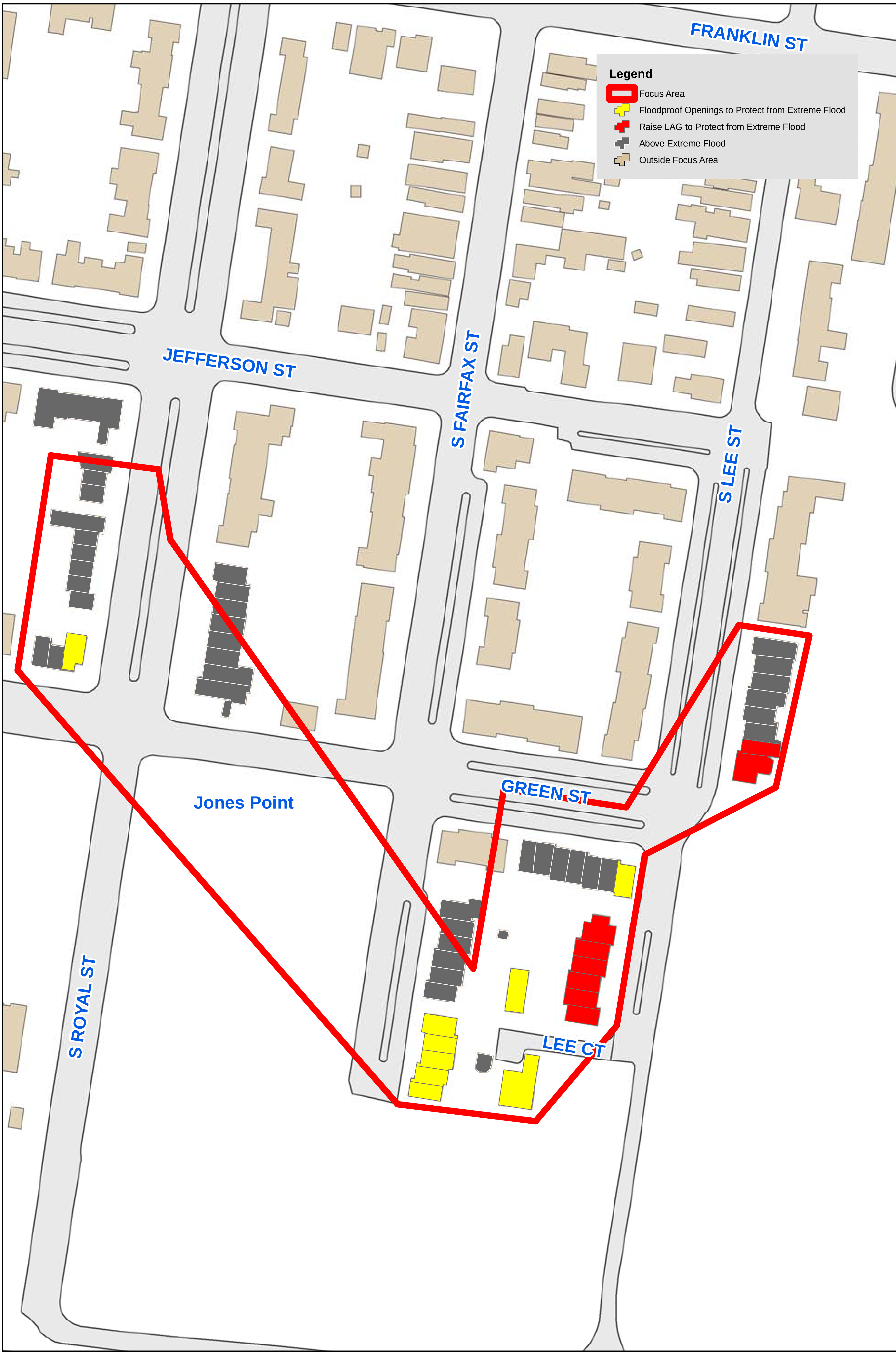
Table 6-13: Cost Ratio for Jones Point: 17 Residential Structures

Method	Cost/Structure	# Structures	Units/Structure	Total Cost
Flood Gate	$900	3	1.5	$4,000
Floodproof Openings				
Door	$10,000	14	1.5	$210,000
Window	$3,000	8	1	$24,000
			Total Cost =	**$238,000**
			Total Benefit =	**$231,000**
			BCR =	**1.0**

King Street Commercial

Approximately 29 structures within the King Street focus area are predicted to flood from the extreme flood event. Of these 29 structures, 23 are commercial structures. About 13 of these structures experience extreme flood depths greater than 3 feet. Therefore, dry floodproofing will not protect these structures from the extreme flood event. However, the depth of flooding from the intermediate flood event is less than 3 feet for all 23 commercial structures.

Table 6-14 shows the different dry floodproofing options and the approximate number of commercial structures within the King Street focus area that might benefit from each. It is estimated that all 23 structures could benefit from floodproof doors and windows. Most of the structures could make use of a flood gate, but floodproof doors are recommended instead of floodgates for commercial properties because they are a passive system of flood protections.



CLIENT	City of Alexandria				
PROJ	Potomac River Waterfront Flood Mitigation Study				
REVISION NO	0	DES BY	JEA	09/22/09	
SCALE	1 inch = 100 feet	DR BY	JEA	09/24/09	
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0 25 50 100 Feet

TITLE

Jones Point Focus Area Floodproofing Options

URS

200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO 15298592

FIGURE 6-9

There are approximately eight commercial structures within this focus area where internal elevation appears to be feasible. These include the following: 100 King Street, Windsor Studio, Ben & Jerry's, Firehook Bakery, Art Craft, Old Town Trading Post, The Small Mall, and Christmas Attic.

For those structures where internal elevation is not feasible, floodproofing of the doors and windows is recommended. The commercial structures in the King Street focus area typically have two doors and two or three windows that need flood protection.

Table 6-14: Floodproofing Options for King Street: 23 Commercial Structures

Method	Cost/Structure	Structures for Benefits
Flood Gate	$900	23
Floodproof Openings		
Door	$10,000	23
Window	$6,000	23
Internal Elevation	$105,000	8

Internal elevation is recommended for eight properties. The remaining 15 properties are estimated with floodproof doors and windows. Although dry floodproofing is generally recommended for up to a depth of 3 feet of flooding, it is usually not possible to internally elevate a structure 3 feet. The height of the ceiling will limit how far the floor can be raised. Therefore, the recommendation assumes that internal elevation can raise the first floor elevation by 1 foot. The recommended floodproofing measure for each structure in the King Street focus area, as well as the level of protection it would provide, is shown on Figure 6-10. It is important to note that floodproofing of the doors and windows can be used instead of internal elevation and could provide up to 2 more feet of protection in conjunction with internal elevation. However, internal elevation is more reliable because it does not require maintenance.

As shown in Table 6-15, the floodproofing BCA results in a BCR of 4.7. Because the most expensive floodproofing scenario is cost effective, any combination of dry floodproofing techniques used in the commercial structures in the King Street focus area will also be cost effective.

Table 6-15: Benefit Cost Ratio for King Street: 23 Commercial Structures

Method	Cost/Structure	# Structures	Units/Structure	Total Cost
Floodproof Openings				
Door	$10,000	15	2	$300,000
Window	$6,000	15	2.5	$225,000
Internal Elevation	$105,000	8	1	$837,000
			Total Cost =	**$1,362,000**
			Total Benefit =	**$6,337,000**
			BCR =	**4.7**

King Street Residential

Of the 29 structures within the King Street focus area described above, six are residential. These are along Prince Street, near the intersection with South Union Street. Only one of these, 100 Prince Street, has an extreme flood depth greater than 3 feet. Therefore, all the rest can be floodproofed to protect from the extreme storm.

Table 6-16 below shows the different dry floodproofing options and the approximate number of residential structures within the King Street focus area that might benefit from each. For example, approximately two structures could benefit from raising the lowest adjacent grade, which is estimated to cost about $8,000 per building. Our topography indicates that these structures may be at risk of flooding from the back of the buildings. However, our field reconnaissance team did not have access to the back of these buildings to determine if there are any points of entry there. It is assumed that placing fill to raise a back patio may be an option for some of the structures.

Two of these structures had low front windows that would need floodproofing. The other four structures would only need the doors floodproofed. Also, it was assumed that some of the structures have back doors and windows that are low points of entry. The recommended floodproofing measure for each structure in the King Street focus area, as well as the level of protection it would provide, is shown on Figure 6-10.

Table 6-16: Floodproofing Options for King Street: 6 Residential Structures

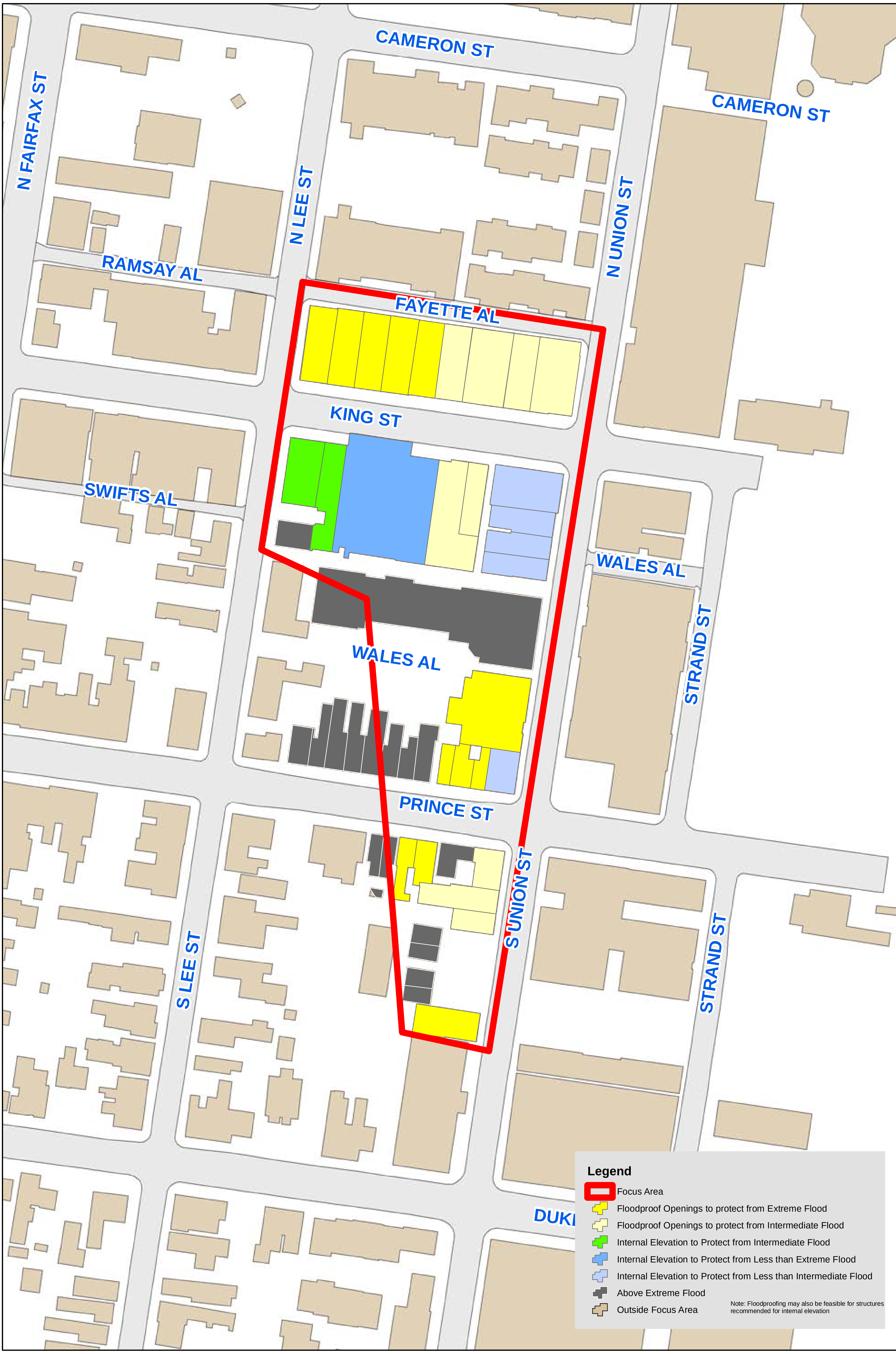
Method	Cost/Structure	Structures That Could Benefit
Flood Gate	$900	6
Floodproof Openings		
Door	$10,000	6
Window	$3,000	2
Raise Patio/Fill	$8,000	2

Because the most expensive floodproofing scenario is to floodproof the doors and windows, it was assumed that this technique would be used whenever feasible.

As shown in Table 6-17, the floodproofing BCA results in a BCR of 11.6. Because the most expensive floodproofing scenario is cost effective, any combination of dry floodproofing techniques used for residential structures in the King Street focus area will also be cost effective.

Table 6-17: Benefit Cost Ratio King Street: 6 Residential Structures

Method	Cost/Structure	# Structures	Units/Structure	Total Cost
Floodproof Openings				
Door	$10,000	6	1.33	$80,000
Window	$3,000	2	3.00	$18,000
			Total Cost =	**$98,000**
			Total Benefit =	**$1,134,000**
			BCR =	**11.6**



CLIENT	City of Alexandria			
PROJ	Potomac River Waterfront Flood Mitigation Study			
REVISION NO	0	DES BY	JEA	09/22/09
SCALE	1 inch = 100 feet	DR BY	xxx	00/00/00
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0 25 50 100 Feet

TITLE King Street Focus Area Floodproofing Options

URS
200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO 15298592

FIGURE 6-10

Waterfront Commercial

Approximately 22 structures in the Waterfront Commercial focus area would flood during the extreme storm. About 16 of these have an extreme flood depth greater than 3 feet and thus can not be floodproofed from the extreme flood. However, approximately 14 of the 18 structures that are susceptible to the intermediate flood can be floodproofed from this flood event. Only two structures in this focus area are impacted by nuisance flooding, and both can be floodproofed. None of these structures have basements, and it is assumed that they do not have openings below the first floor elevation.

Table 6-18 shows the different dry floodproofing options and the approximate number of structures within the Waterfront Commercial focus area that might benefit from each measure. Approximately 22 structures could benefit from floodproofing the doors and windows. Most of the structures could use a flood gate, but floodproof doors are recommended instead of floodgates for commercial properties because they are a passive system of flood protection.

Eight buildings in the Waterfront Commercial focus area that are at risk of flooding appear to be candidates for internal elevation. These include Alexandria Marine, Art League, Robinson South Terminal, the street level shops on Union Street, and Chadwicks. In addition, the shops on Strand Street (Potomac Riverboat/chiropractor/Idea Sciences) appear to have suspended ceilings. They may be candidates for internal elevation if the suspended ceiling height can be raised.

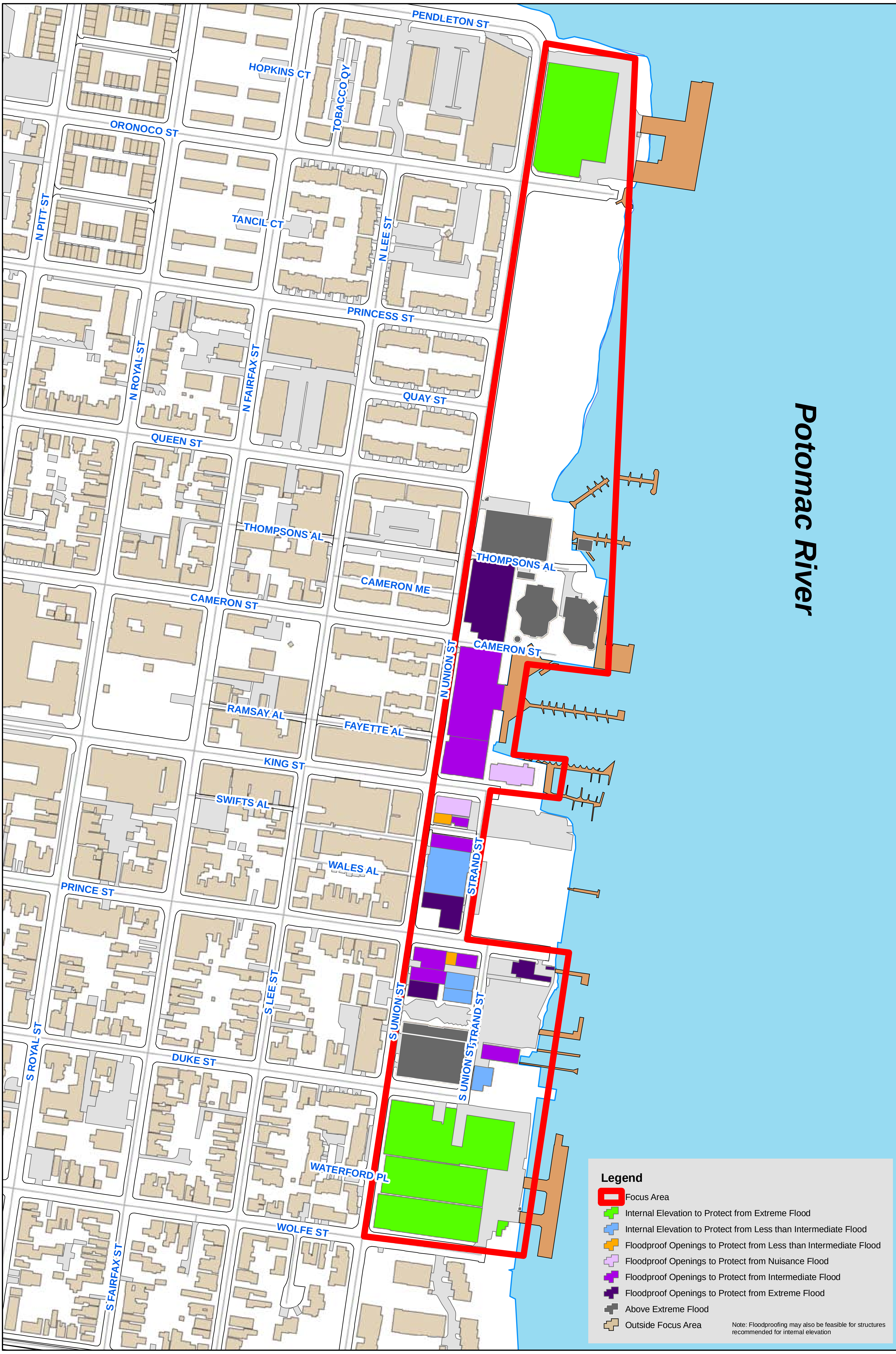
Raising the lowest adjacent grade is not feasible in this focus area, because most of these structures would be inundated by floodwater on all sides. The remaining structures tend to have two doors and several windows close to the FFE; therefore, those openings are recommended for floodproofing. The recommended floodproofing measure for each structure in the Waterfront Commercial focus area, as well as the level of protection it would provide, is shown on Figure 6-11.

Table 6-18: Floodproofing Options for Waterfront Commercial: 22 Commercial Structures

Method	Cost/Structure	Structures That Could Benefit
Flood Gate	$900	22
Floodproof Openings		
Door	$10,000	22
Window	$6,000	22
Internal Elevation	$646,000	6

Because the most expensive floodproofing scenario is internal elevation, it was assumed that this technique would be used whenever feasible.

As shown in Table 6-19, the floodproofing BCA results in a BCR of 2.41. Because the most expensive floodproofing scenario is cost effective, any combination of dry floodproofing techniques used for the Waterfront Commercial focus area will also be cost effective.



CLIENT	City of Alexandria				
PROJ	Potomac River Waterfront Flood Mitigation Study				
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TITLE

Waterfront Focus Area Floodproofing Options

URS

200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO 15298592

FIGURE 6-11

Table 6-19: Benefit Cost Ratio for Waterfront Commercial: 22 Commercial Structures

Method	Cost/Structure	# Structures	Units/Structure	Total Cost
Floodproof Openings				
Door	$10,000	16	2	$160,000
Window	$6,000	16	3	$96,000
Internal Elevation	$646,000	6	1	$3,874,000
			Total Cost =	**$2,790,000**
			Total Benefit =	**$6,728,000**
			BCR =	**2.41**

North Union Street

Approximately 37 structures (including 9 apartments) within the North Union Street focus area would flood during the extreme storm. Many of these have basements; however, as noted previously, floodproofing for structures with basements is recommended on a case-by-case basis. Most of these buildings have extreme flood depths less than 3 feet and can be protected from the extreme flood by dry floodproofing. The only exceptions are the Torpedo Factory Apartments. The apartments themselves are above the extreme flood elevation. However, there is storage space at ground level that is susceptible to the intermediate and extreme floods.

Based on the available topographic data, it appears that the structures in this focus area would flood from water coming off the street. Therefore, it is not necessary to consider floodproofing the back of the structures. A potential exceptions to this are the houses along Cameron Mews, because these structures are vulnerable to flooding from Cameron Street and Thompsons Alley. Many of the structures in the North Union Street focus area have garages that would flood. Floodgates are likely the only available option for floodproofing garage doors.

Table 6-20 provides the different dry floodproofing options and the approximate number of structures within the North Union Street focus area that might benefit from each. Most of the structures could make use of a flood gate for the garage. All of these buildings are row houses. Therefore, all units that are at risk of flooding within the row need to be floodproofed. The only unit in its row to be at risk of flooding is 107 Cameron Mews. Therefore, both floodproofing the points of entry or raising the lowest adjacent grade are reasonable options for this unit. The recommended floodproofing measure for each structure in the North Union Street focus area, as well as the level of protection it would provide, is shown on Figure 6-12.

Table 6-20: Dry Floodproofing Options for North Union: 37 Residential Structures

Method	Cost/Structure	Structures That Could Benefit
Flood Gate	$900	37
Floodproof Openings		
Door	$10,000	37
Raise Patio/Fill	$8,000	1

CLIENT City of Alexandria				TITLE North Union Focus Area Floodproofing Options
PROJ Potomac River Waterfront Flood Mitigation Study				
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W:\City of Alexandria\15298470 - Lower King St\Task 3\Report \Final\Figures\MXDs\F6-12 North_Union_Area.mxd	CHK BY	xxx	00/00/00	FIGURE 6-12

Because the most expensive floodproofing scenario is to install floodproofed doors and windows, it was assumed that this technique would be used whenever feasible.

As shown in Table 6-21, the floodproofing BCA results in a BCR of 1.29. Because the most expensive floodproofing scenario is cost effective, any combination of dry floodproofing techniques used for the North Union focus area will also be cost effective.

Table 6-21: Benefit Cost Ratio for North Union: 37 Residential Structures

Method	Cost/Structure	# Structures	Units/Structure	Total Cost
Flood Gate	$900	25	2	$34,000
Floodproof Openings				
Door	$10,000	40	1.33	$532,000
			Total Cost =	$568,000
			Total Benefit =	**$734,000**
			BCR =	**1.29**

6.6.5 Floodproofing Applicability for Repetitive Loss Properties

Specific information for application of floodproofing for repetitive loss properties is summarized in Table 6-22 below.

Table 6-22: Summary of Floodproofing Applicability for Repetitive Loss Properties

Repetitive Loss Property	First floor Elevation (NAVD88)	Internal Elevation	Raise the LAG	Floodproof Openings
1 King Street (Boat Club)	3.75 feet	Not applicable due to ceiling height	Not applicable as the structure is susceptible to flooding on all sides	Potential option
6 King Street (Mai Thai / Starbucks)	3.51 feet	Not applicable due to ceiling height	Not applicable as the structure is susceptible to flooding on all sides	Potential option
101 King Street (Conrad's Furniture)	5.01 feet	Not applicable due to ceiling height	Not applicable because FFE is above sidewalk	Potential option
104 South Union	4.50 feet	Not applicable due to ceiling height	Not applicable as the structure is susceptible to flooding on all sides	Potential option
120 Cameron Street	4.6 feet	Not applicable as the lowest finished floor is above the extreme flood elevation	Not applicable as the lowest finished floor is above the extreme flood elevation	Potential option

SECTION SEVEN: RECOMMENDATIONS

7.1 OVERVIEW OF RECOMMENDATIONS

Ten flood mitigation measures were analyzed in detail. Because no clear single measure provides flood protection for the entire project area and is technically feasible without extensive resulting impacts, this section recommends a series of options for each of the focus areas. Table 7-1 provides descriptions of the ten flood mitigation measures for which a detailed evaluation was conducted. The measures are not applicable for all structures or focus areas, and the measures have limitations on their use as described in the previous sections. Table 7-1 summarizes the limitations for each mitigation measure and lists the focus areas that benefit from each measure.

Table 7-1: Applicability of Flood Mitigation Measures

Description	Limitations	Recommended Focus Area
Floodproofing	Applicable for flood depths of less than 3 feet for structures with no basements	All
Acquire properties	Applicable for stand alone structures or where all attached units in the structure are affected by flooding	Not recommended
Elevate structures	Applicable for wood structures, single-story structures. Not recommended for historic structures	Not recommended
Floodwall	High project costs and significant aesthetic and humanistic impacts	Waterfront Commercial, King Street
Jones Point berm	High project costs	Not recommended
Elevated walkway	Maximum height of pedestrian floodwall is 6.0 feet NAVD, which does not protect against large storms	Waterfront Commercial King Street
Inlet and road elevation improvements	Adjacent curbs and building entrances limit level of protection	King Street
Relocate internal supplies	Most applicable in commercial establishments	Waterfront Commercial King Street
Floodplain and zoning ordinance recommendations	No limitations	All
Sandbag program improvements	No limitations	All

The remainder of this section presents the recommendations in the following order: focus areas, floodwall, and nonstructural options. The floodwall and nonstructural measures are discussed after the focus area discussion because they protect multiple focus areas.

7.2 KING STREET

Elevated Walkway

The elevated walkway is recommended as the primary flood mitigation measure for this focus area. This flood control project protects up to the 10-year flood event, and the reduced height and design of the walkway are more aesthetically pleasing than the floodwall. The elevated walkway does not significantly impact the Potomac River viewshed. Figures 7-1, 7-2, and 7-3 show visualizations of the proposed walkway. These visualizations are examples of a potential configuration for the walkway. The low profile floodwall at elevation 6 feet (NAVD 88) is the critical flood control element for the elevated walkway. This option allows for a new pedestrian pathway that can be implemented in conjunction with the Waterfront Plan improvements. It would significantly reduce the frequency of sandbagging efforts and road closures in the downtown area.

Figure 7-1: Elevated Walkway at Waterfront Park (View 1)

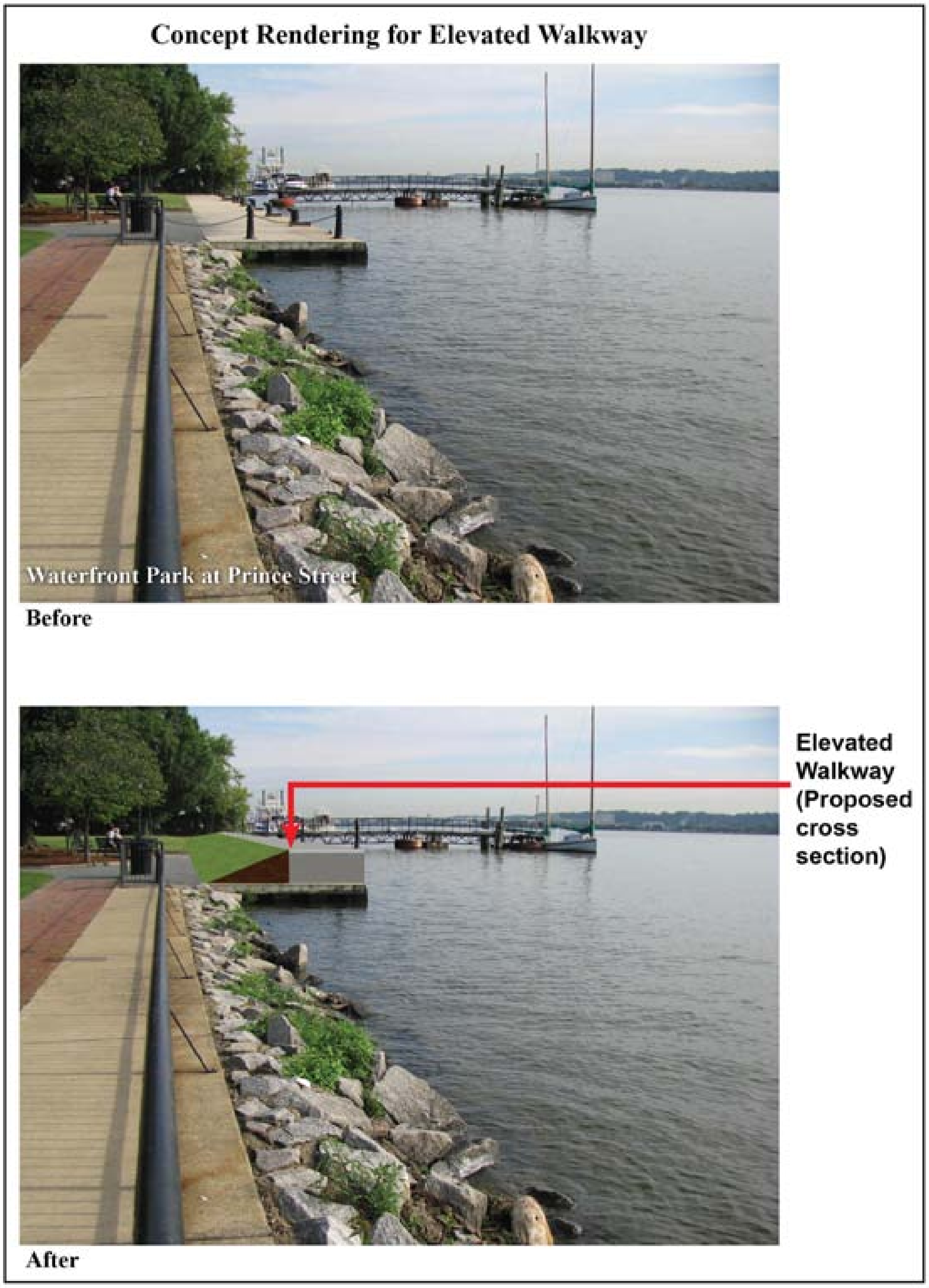


Figure 7-2: Elevated Walkway at Waterfront Park (View 2)

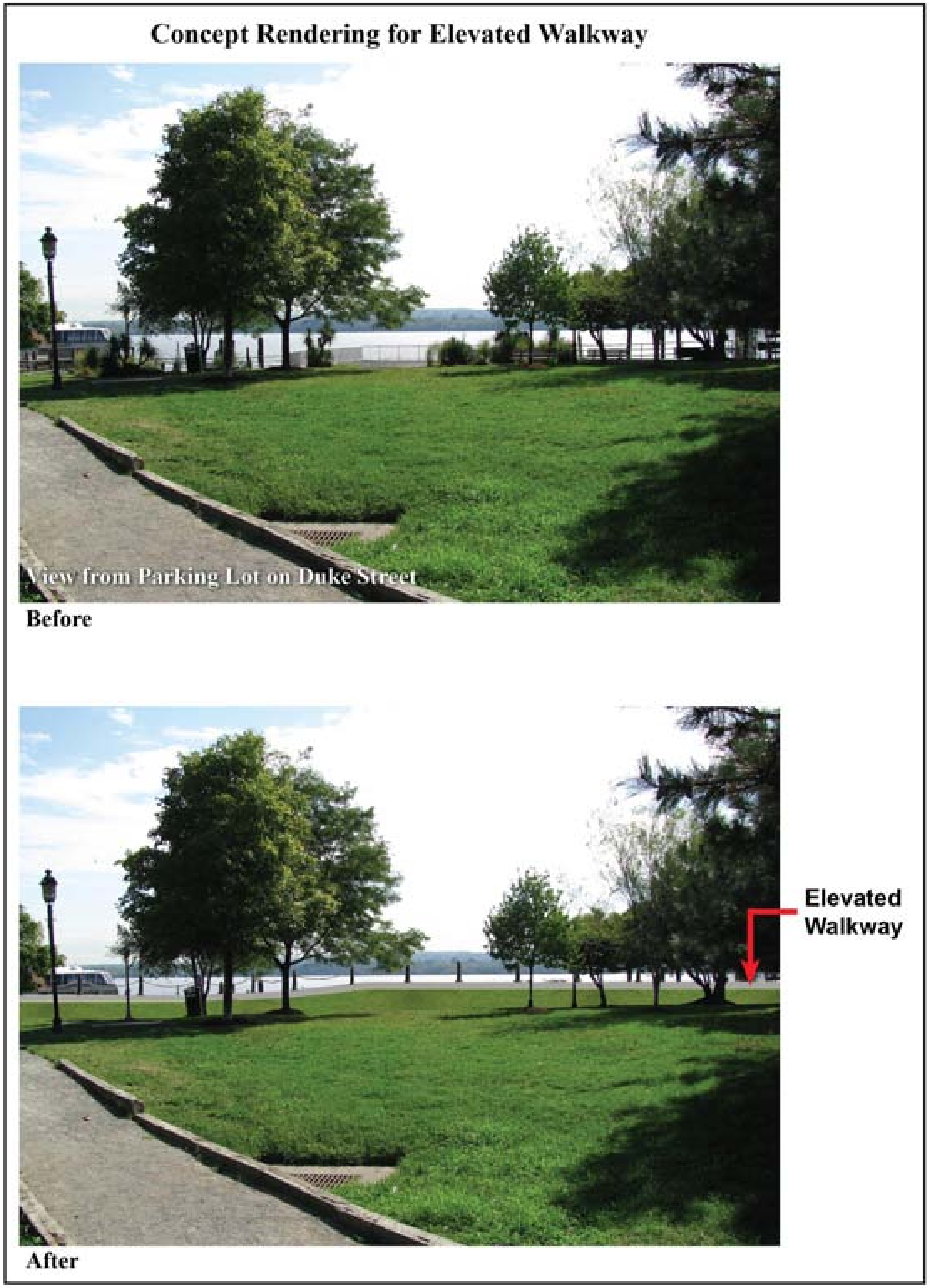


Figure 7-3: Elevated Walkway at Park South of Parking Lot on Strand Street

The elevated walkway is limited in that it only provides protection for up to the 10-year flood event (elevation 6.0 feet NAVD). Figure 7-4 shows a rendering of the before and after inundation at The Strand during the 10-year flood event.

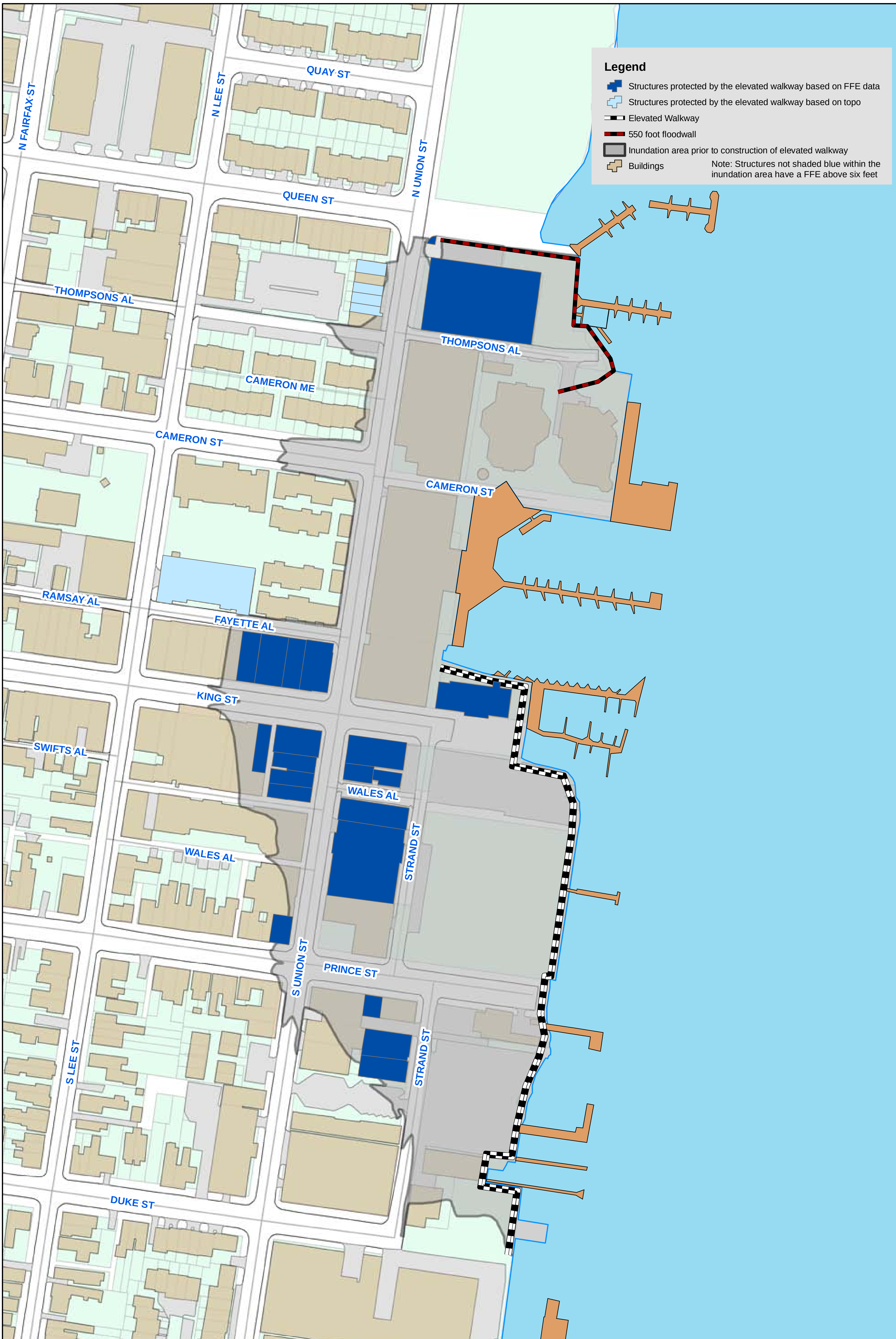
Figure 7-4: 10-Year Flood Inundation Before and After Elevated Pedestrian Walkway

Figure 7-5 shows the structures that are predicted to be protected by the elevated walkway. The proposed elevated walkway protects approximately one-third of the structures in the King Street focus area. In addition, this measure significantly reduces the frequency of road flooding in the vicinity of Strand Street.

Floodproofing

Floodproofing is recommended to provide protection for all the commercial structures. As discussed throughout the report, the historic nature of the area poses challenges to floodproofing. However, it is an effective option for property owners to protect building contents. The recommendation consists of a combination of internal elevation of commercial buildings and floodproofing openings, with gates and custom floodproof doors and windows. There are approximately eight commercial structures within this focus area where internal elevation would be feasible, including 100 King Street, Windsor Studio, Ben & Jerry’s, Firehook Bakery, Art Craft, Old Town Trading Post, The Small Mall, and Christmas Attic.

For historic brick structures, waterproof membranes to cover the outside of the structures are not recommended. Residential structures in the focus area that have basements will need to be considered separately to determine the applicability of floodproofing measures for those structures.



CLIENT	City of Alexandria				
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REVISION NO	0	DES BY	CJL	09/11/09	
SCALE	1 inch = 150 feet	DR BY	CJL	09/24/09	
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TITLE
Structures Predicted to be Protected by the Proposed Elevated Walkway

URS
200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO 15298592

FIGURE 7-5

King/Strand Street Intersection Roadway Improvements

It may be many years before construction of the elevated walkway is complete. Through that timeframe, the King/Strand Street area roadways will continue to be closed for storm events that are less than the nuisance event. The roadway improvement project is relatively simple and has a low cost compared to the other alternatives. As a result, it is recommended that the City consider implementing this alternative as described in the conceptual design presented in Section 6.7 as an interim flood mitigation measure.

7.3 WATERFRONT COMMERCIAL

Elevated Walkway

As mentioned above, the elevated walkway is recommended as the primary flood mitigation measure for this study area. The elevated walkway provides protection for up to the 10-year (elevation 6.0 feet NAVD88) flood event for seven buildings in this study area with FFEs below 6.0 feet. Because most of the flood damages occur at the more frequent events, the elevated walkway provides substantial benefits as compared to the cost of the project, as seen by the BCR. Additionally, some of the aesthetic and viewshed issues with the larger floodwall (discussed below) are not present.

Floodproofing

While the proposed elevated walkway does not protect all structures in the Commercial Waterfront focus area, the floodproofing option could protect commercial structures up to the intermediate storm event, with the exception of the Mai Thai Restaurant, Starbucks, and Old Dominion Boat Club. As discussed throughout the report, the historic nature of the area poses challenges to floodproofing. However, it is an effective option for property owners to protect building contents. The recommendation for the entire area is floodproofing openings with gates and custom floodproof doors and windows. During field visits, the low floor to ceiling heights within the buildings eliminated internal elevation from consideration.

For historic brick structures, waterproof membranes to cover the outside of the structures are not recommended. Floodproofing through internal elevation and covering openings is also an option, although the flooding depths are greater in this area, so the method is not applicable for as many structures as in the King Street focus area. Residential structures that have basements will need to be considered separately to determine the applicability of floodproofing measures for those structures.

Acquisition

Acquisition is not generally recommended in this study because it is not a cost-effective alternative. However, the City recently purchased waterfront properties as part of the waterfront redevelopment initiative. The City may decide to acquire additional waterfront properties as part of the waterfront initiative. The purpose of the acquisition in this case is economic development rather than flood mitigation.

7.4 NORTH UNION

Floodproofing is recommended for this study area, primarily through covering openings. This is a cost-effective and low-impact solution of flood protection for this study area. As discussed throughout the report, the historic nature of the area poses challenges to floodproofing. However, it appears to be an effective option for property owners to protect building contents. Residential structures that have basements will need to be considered separately to determine the applicability of floodproofing measures for those structures.

7.5 JONES POINT

Floodproofing is recommended for this study area, primarily through covering openings. The floodproofing option could protect all the residential structures that are impacted by flooding of up to the extreme flood event. As discussed throughout the report, the historic nature of the area poses challenges to floodproofing. However, it is an effective option for property owners to protect building contents. The recommendation consists of a combination of localized flood barriers (e.g. raised patios) and floodproofing openings, with gates and custom floodproof doors and windows.

For historic brick structures, waterproof membranes to cover the outside of the structures are not recommended. Residential structures in the focus area that have basements will need to be considered separately to determine the applicability of floodproofing measures for those structures.

7.6 FLOODWALL

Our preliminary investigations show that the floodwall is a technically feasible solution that provides protection for all of the structures in the King Street focus area, all but one structure in the Waterfront Commercial focus area, and the Cameron Mews portion of the North Union focus area from the nuisance, intermediate, and extreme flood events. The floodwall would remove the repetitive loss properties from the floodplain. While the floodwall is not as cost effective as the other alternatives analyzed, it is technically feasible. Additionally, it is the only option for the King Street focus area that effectively provides protection against the 100-year flood event.

However, the floodwall may not be a palatable option for area businesses, residents, and tourists. Its substantial viewshed and aesthetic impacts may prevent this measure from gaining public support. Because residential and commercial access to the river is an essential part of the Alexandria economy, those are also important considerations. An additional factor is the potential for increased City liability, specifically if redundant systems fail and residential structures flood. Figures 7-5 and 7-6 illustrate the visual impact of the proposed floodwall concept.

Another important aspect for consideration of the floodwall is that the BCR is low due to the high cost of the project. In comparison, the elevated walkway cost-effectively provides protection against the frequent storm events and has a high BCR. It is recommended that the floodwall be implemented *only* if the City's sole priority is to reduce all flooding to the maximum extent technically feasible. Otherwise, the floodwall is not recommended over other flood mitigation measures described in this section.

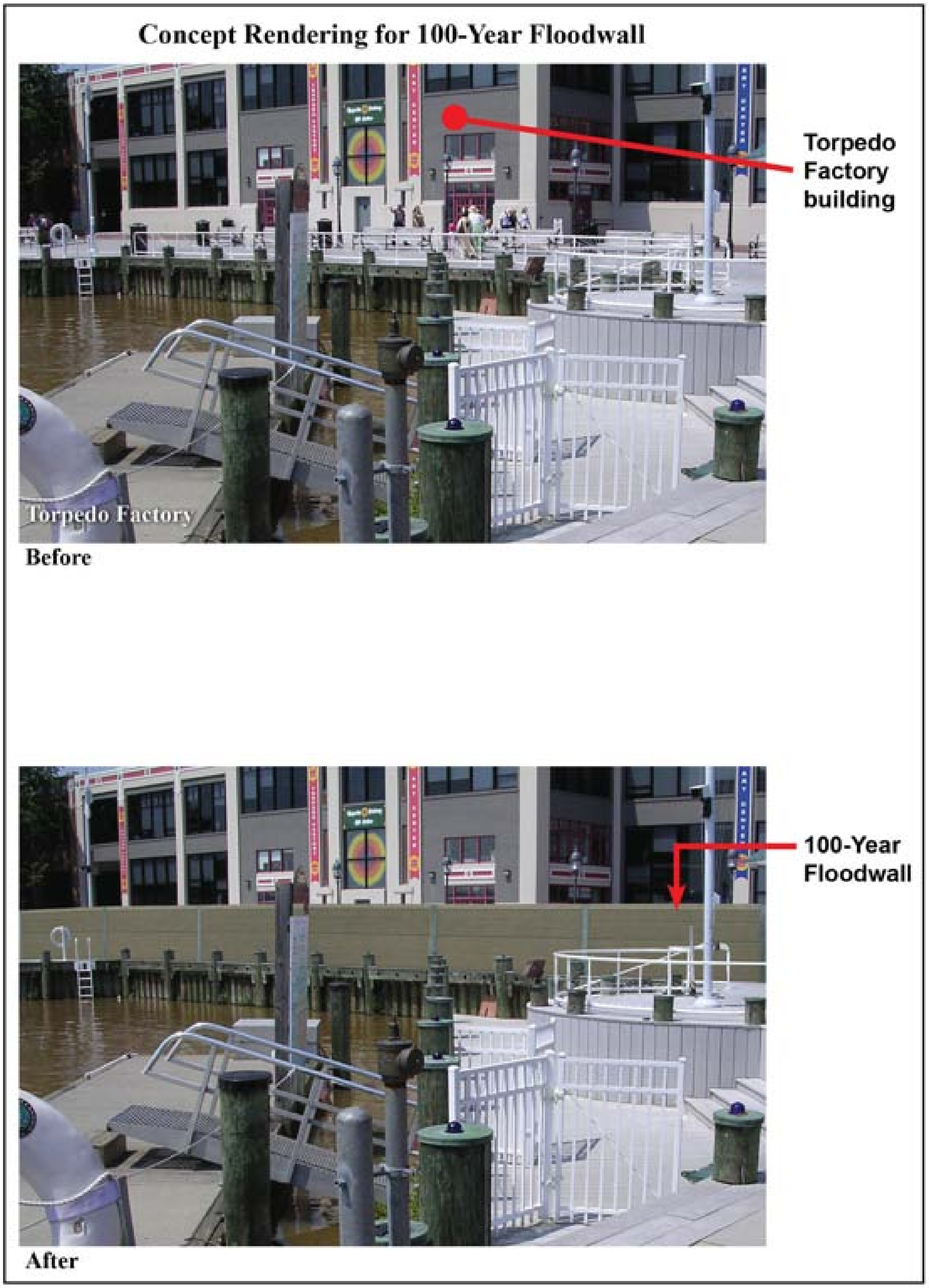

Figure 7-6: Floodwall behind Torpedo Factory

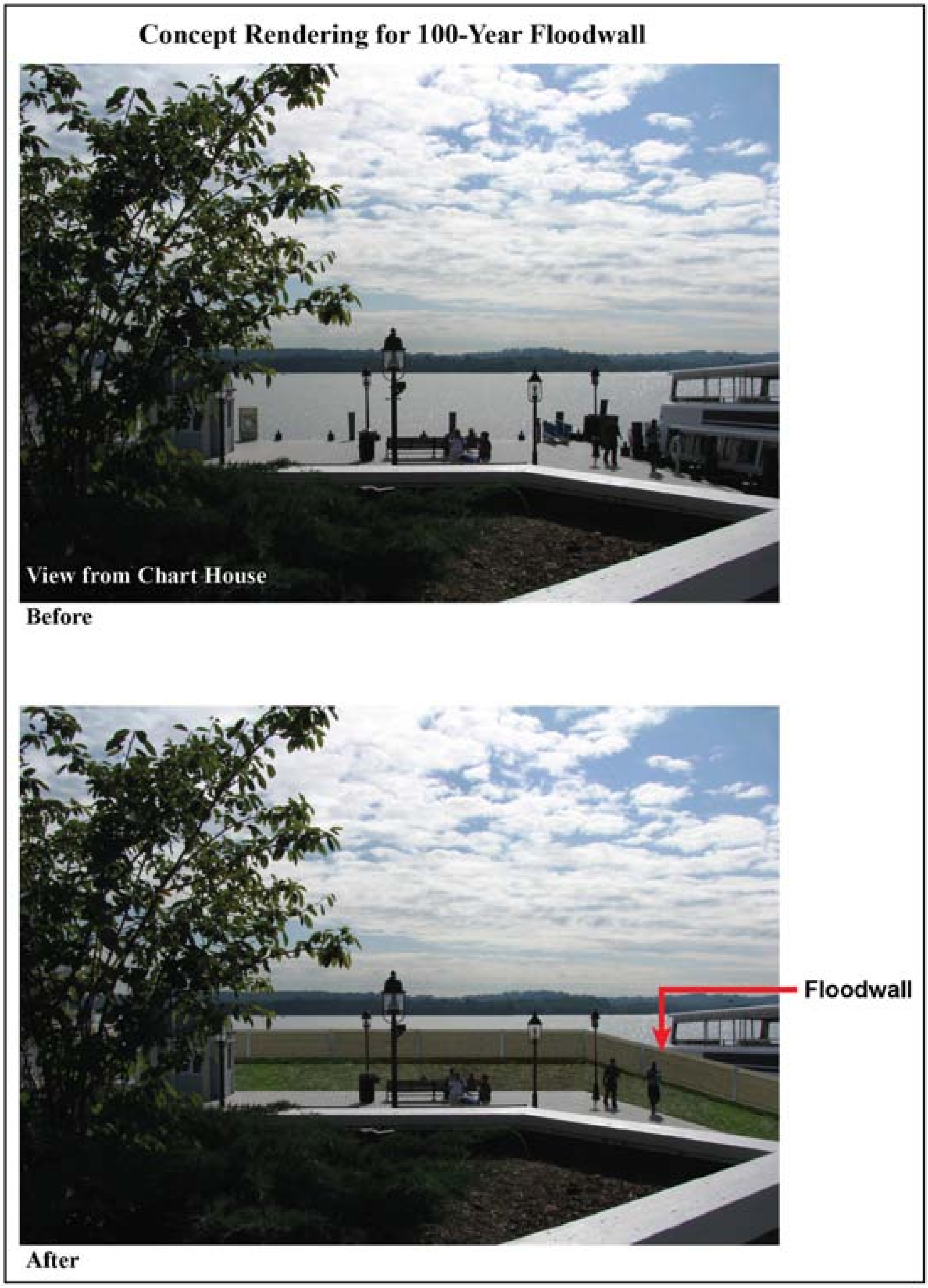

Figure 7-7: Floodwall in Front of Chart House

7.7 REPETITIVE LOSS PROPERTIES

For emphasis, recommendations that affect the repetitive loss properties are summarized in this section.

1 King Street (Boat Club)

This structure has a first-floor base elevation of 3.76 feet (NAVD 88). Because it is not recommended to floodproof a structure above a height of 3 feet, this building can be floodproofed to an elevation of approximately 6.75 feet. This will protect it from nuisance flooding, but not intermediate or extreme floods. There are at least three exterior doorways at ground level that could be floodproofed with a gate. This is a relatively inexpensive solution. However, because it is an active system, someone would have to be available to install them after the flood warning. There are no windows that are low enough to benefit from floodproofing. Additionally, the elevated walkway would provide protection for this structure against nuisance flooding.

6 King Street (Mai Thai / Starbucks)

This structure has a first-floor base elevation of 3.51 feet (NAVD 88). Because it is not recommended to floodproof a structure above a height of 3 feet, this building can be floodproofed to an elevation of approximately 6.5 feet. This will protect it from nuisance flooding but not intermediate or extreme floods. There are four doorways to this structure that could be floodproofed with a gate. This is a relatively inexpensive solution. However, because it is an active system, someone would have to be available to install them after the flood warning. This building has approximately 10 windows that appear low enough to benefit from floodproofing.

101 King Street (Conrad's Furniture)

This building has a first floor elevation of 5.01 feet (NAVD 88). This means that it is not impacted by nuisance flooding. It can be floodproofed up to the intermediate flood elevation, but it will not be protected from the extreme flood event. Three doorways on the southern side, one doorway on the eastern side of this building, and one window on the eastern side would all need to be floodproofed. Additionally, the elevated walkway would provide protection for this structure against nuisance flooding.

104 South Union

The first floor of this building is at 4.5 feet (NAVD 88). Therefore, it is not affected by nuisance flooding. It can be floodproofed up to approximately 7.5 feet and, therefore, cannot be fully protected from the intermediate and extreme flood events. Nevertheless, floodproofing can significantly reduce the probability of flood-related damages to this property. Floodproofing of the structure openings including a doorway on the northern side and a doorway on the western side of this building is recommended. Three low windows on the western side of the structure would also need to be floodproofed. Additionally, the elevated walkway would provide protection for this structure against nuisance flooding.

120 Cameron Street

As mentioned previously, the first floor of this structure is above the extreme flood elevation. Based on our review of available data, the first floor is elevated more than 3 feet above the ground with storage space underneath. However, since this property is identified by FEMA as a repetitive loss structure, floodproofing of the openings is recommended.

7.8 NONSTRUCTURAL FLOOD MITIGATION MEASURES

In addition to the structural flood mitigation measures recommended for implementation, nonstructural flood mitigation measures are also recommended for implementation. The recommendations consist of action items under three nonstructural mitigation measures selected for further evaluation, as described in Section 2. The following list provides a summary of the recommendations. Additional detail on the recommendations is provided in Section 3.

Improve Floodplain Zoning Ordinances

- **Cumulative Substantial Improvements** – It is recommended that the City interpret the 50 percent improvement threshold as cumulative. Implementing this measure will result in increased CRS points.
- **Lower Substantial Improvements –** It is recommended that the City consider lowering the improvement threshold for substantial improvements to less than 50 percent.
- **Protection of Critical Facilities –** If the GIS data reviewed is accurate and there are no plans to build new critical facilities within the 500-year floodplain, implementing this measure will result in increased CRS points.
- **Staff Training –** It is recommended that staff involved in reviewing plans and issuing permits for floodplain development and conducting field inspections become CFMs. Implementing this measure will result in increased CRS points.
- **Permitting and Inspection –** It is recommended that the City increase the frequency of inspecting new construction to ensure that the work is being done according to the provisions of the floodplain ordinance. The ordinance can also be amended to give the floodplain administrator the right to issue a stop work order or revoke building permits if the inspections show that a violation has taken place.
- **Accessory Structures –** It is recommended that additional regulations regarding accessory structures such as sheds and garages be added to strengthen the existing ordinances to prevent accessory structures from being constructed in the floodplain,
- **Variances –** Although the City does not grant variances related to floodplain protection often, it is recommended that the City consider strengthening language to ensure that future floodplain variances are discouraged.
- **Requiring 1 Foot of Freeboard –** It is recommended that the City require 1 foot of freeboard above the flood elevation for new construction. This consistent with the City of Alexandria building code which references the Virginia Uniform Statewide Building Code

(USBC) and International Building Code (IBC). The IBC requires 1 foot of freeboard above the FFE.

Elevation of Supplies and Goods

- Elevation of supplies and goods is recommended for eight commercial structures that experience nuisance flooding. These structures are listed in Table 3-1. Another important component of this solution is outreach and education to residents and business owners who could benefit from elevation of supplies and goods.

Sandbagging and Other Temporary Measures

- The City currently maintains a sandbag distribution guidelines for affected businesses and residential areas within the Potomac River waterfront area. It is recommended that the City maintain the sandbag program and consider the following changes to the current sandbag policy:
  - Expand the sandbag service areas to include a self-serve sand drop off point at 400 North Union Street.
  - Document a set of guidelines for City managers to use as a framework for determining when to initiate sandbag distribution.
  - Provide guidance on the City Web page for residents outside of the distribution areas that they may need to make their own provisions for sandbag procurement.
  - Modify the City's Web page search tool so that the Flooding Information page can be accessed using the search feature on the City's Web page.

7.9 ADDITIONAL RECOMMENDATIONS

The preceding sections summarize flood mitigation measure recommendations for the ten flood mitigation measures that were selected for detailed evaluation. Within the original comprehensive list of 27 potential mitigation measures, several potential measures provide flood benefits, but didn't score high enough to warrant further assessment. However, some of these measures merit consideration for implementation. For the most part, these measures are not large structural projects. Further information and specific recommendations for the following measures are provided in Appendix C.

- Improve flapgate operation at outflow points
- Add backflow preventers in homes to prevent stormwater and sewer backups
- Isolate gas and electrical service lines
- Relocate external electrical boxes
- Inform businesses and residents about NFIP contents coverage
- Improve/enhance existing business identification system
- Provide updated information to residents

- Provide education to area media outlets

7.10 POTENTIAL FEDERAL FUNDING OPTIONS

A number of the flood mitigation activities recommended in this study carry significant capital improvement costs and operation and maintenance expenditures. Opportunities exist for the City to pursue Federal Government grants to supplement City funding for implementation of mitigation measures. An overview of FEMA grant programs is provided below. A more detailed discussion regarding funding options and federal grants is provided in Appendix L.

FEMA's Hazard Mitigation Assistance (HMA) program includes five individual grant programs that can be used for flood mitigation projects including:

- Hazard Mitigation Grant Program (HMGP)
- Pre-Disaster Mitigation (PDM)
- Flood Mitigation Assistance (FMA)
- Repetitive Flood Claims (RFC)
- Severe Repetitive Loss (SRL)

While the HMA grant programs are administered by FEMA, an individual community must apply for these grants through its State government. The Virginia Department of Emergency Management is responsible for this process for the Commonwealth of Virginia. The (VDEM) Web site provides guidance on the application process for HMA grant opportunities. (Web site: http://www.vaemergency.com/grants/index.cfm)

The PDM, FMA, REC, and SRL grant programs are not disaster specific and are subject to the availability of appropriation funding. HMGP grants are only available after a major disaster declaration in the State or Commonwealth; however, the focus of the grant application can be unrelated to the disaster that caused the declaration. FEMA posts disaster declarations on its Web site: http://www.fema.gov/news/disasters.fema. Typically a major disaster declaration is active for 12 months. The City of Alexandria may submit grant applications to FEMA through VDEM. VDEM has internal deadlines for the acceptance of grant applications. As of July 2010, it appears that VDEM is not currently accepting HMGP applications.

7.11 CONCLUSIONS

This report provides detailed information on potential flood mitigation measures for the Potomac River waterfront area. Rather than a single flood mitigation solution, a series of measures are recommended to provide protection against flood events on the Potomac River. These measures require significant capital expense and cooperation from private property owners. In addition, it will take significant effort to comply with applicable regulations. However, proceeding with implementation of the recommended flood mitigation measures is essential to reduce the extensive flood damages in the City.

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Appendix A

Initial Ranking of Potential Flood Mitigation Solutions

Potomac River Waterfront Flood Mitigation Study
Ranking of Potential Flood Mitigation Solutions

	Criteria -->	Aesthetics	Cost Considerations	Constructability	Cost of Flood Insurance	Cost to Property Owners	City Liability	Property Ownership	General Environmental Impacts	Level of Protection for Extreme Flooding	Level of Protection for Nuisance Flooding	Extent of Flood Protection	Long Term and Maintenance Costs	Reduces Flood Damages	Reduces Flooding Extent	Loss of Business Revenue	Loss of Recreational Use	Potomac River View Shed	Historical/Archeological Resources	Private Property Acquisition	Regulatory Requirements	State/Federal Funding	Rep Loss Property Mitigated	TOTAL SCORE	RANK
	Criteria Number -->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		
	Weighting Factor -->	**3**	**3**	**3**	**1**	**5**	**3**	**1**	**1**	**5**	**10**	**10**	**3**	**5**	**5**	**5**	**1**	**3**	**1**	**3**	**1**	**1**	**3**		
1	**PP1**	5	5	5	5	5	5	5	10	1	5	2	5	10	1	5	5	5	5	10	10	5	1	348	11
2	**PP2**	1	5	5	10	5	5	5	10	5	5	2	10	10	1	10	5	5	5	10	5	5	1	396	7
3	**PP3**	5	10	10	5	10	5	5	10	1	5	2	5	5	1	5	5	5	10	10	10	1	1	379	9
4	**PP4**	5	5	5	5	10	5	10	10	1	1	1	10	10	1	1	5	5	10	10	10	1	1	324	14
5	**PP5**	5	1	5	10	1	10	1	10	10	10	2	10	10	1	10	5	10	5	1	1	5	10	473	3
6	**PP6**	1	5	1	10	1	5	1	10	10	10	2	10	10	1	10	5	5	5	10	5	5	1	435	6
7	**S1**	1	1	1	10	10	1	5	5	10	5	10	1	10	10	10	5	1	1	5	1	10	10	500	1
8	**S2**	5	1	1	10	10	1	5	5	10	5	10	1	10	5	10	5	5	1	5	1	10	10	499	2
9	**S3**	5	1	1	5	10	5	7	10	1	10	5	5	10	1	5	5	5	10	10	5	1	5	439	5
10	**S4**	5	5	1	5	10	5	7	10	1	1	1	1	5	1	1	5	5	10	10	5	1	1	252	24
11	**S5**	5	5	5	5	10	5	7	10	1	1	1	1	1	1	1	5	5	10	10	5	1	1	244	25
12	**S6**	5	5	5	5	10	5	7	10	1	5	5	1	1	5	5	5	5	10	10	5	1	5	376	10
13	**S7**	5	5	5	5	10	5	7	10	1	1	2	1	1	1	1	5	5	10	10	5	1	1	254	23
14	**S8**	5	1	1	5	10	5	7	10	1	1	1	5	1	1	1	5	5	5	10	5	1	1	227	27
15	**S9**	1	1	1	5	10	5	7	5	1	1	1	5	1	1	1	5	5	5	10	5	1	1	210	28
16	**S10**	5	1	5	5	10	5	10	5	1	1	1	5	1	1	1	5	5	10	10	5	1	1	242	26
17	**PR1**	5	10	5	5	5	5	5	10	1	5	1	10	5	1	5	5	5	10	10	5	1	1	339	12
18	**PR2**	5	10	10	10	10	5	10	10	5	5	1	10	5	1	1	5	5	10	10	5	1	1	389	8
19	**ES1**	5	5	10	5	10	5	10	10	1	1	1	10	1	1	10	5	5	10	10	5	1	1	334	13
20	**ES2**	5	5	10	5	10	5	10	10	1	1	1	5	1	1	5	5	5	10	10	10	5	1	303	18
21	**ES3**	5	5	10	5	10	5	10	10	1	1	1	5	1	1	5	5	5	10	10	10	5	1	303	18
22	**ES4**	5	5	10	5	10	5	10	10	1	1	1	10	1	1	5	5	5	10	10	10	10	1	323	15
23	**ES5**	5	5	10	5	10	5	10	10	1	5	5	5	5	1	10	5	5	10	10	10	1	15	466	4
24	**ES6**	5	5	10	5	10	5	10	10	1	1	1	5	1	1	5	5	5	10	10	10	1	1	299	20
25	**EA1**	5	10	10	5	10	5	10	10	1	1	1	5	1	1	1	5	5	10	10	10	1	1	294	21
26	**EA2**	5	5	5	5	10	5	10	10	1	1	1	10	1	1	1	5	5	10	10	10	1	1	279	22
27	**EA3**	5	10	10	5	10	5	10	10	1	1	1	10	1	1	1	5	5	10	10	10	1	1	309	16
28	**Do Nothing**	5	10	10	5	10	5	10	10	1	1	1	10	1	1	1	5	5	10	10	10	1	1	309	16

Appendix B

Ordinance and Sandbag Information

Exhibit 1-1. Sample ordinance from the City of Charlotte, Mecklenburg County, NC regarding permitting for new construction and improvements and construction inspection.

Section. 9-17. Administrative procedures.

a. Inspections of work in progress. As the work pursuant to a permit progresses, the local administrator shall make as many inspections of the work as may be necessary to ensure that the work is being done according to the provisions of the local ordinance and the terms of the permit. In exercising this power, the administrator has a right, upon presentation of proper credentials, to enter on any premises within the territorial jurisdiction at any reasonable hour for the purposes of inspection or other enforcement action.

b. Stop orders. Whenever a building or part thereof is being constructed, reconstructed, altered or repaired in violation of this ordinance, the administrator may order the work to be immediately stopped. The stop order shall be in writing and directed to the person doing the work. The stop order shall state the specific work to be stopped, the specific reasons for the stoppage and the conditions under which the work may be resumed. Violation of a stop work order constitutes a misdemeanor.

c. Revocation of permits. The local administrator may revoke and require the return of the floodlands development permit by notifying the permit holder in writing stating the reason for the revocation. Permits shall be revoked for any substantial departure from the approved application, plans or specifications; for refusal or failure to comply with the requirements of state or local laws; or for false statements or misrepresentation made in securing the permit. Any permit mistakenly issued in violation of an applicable state or local law may also be revoked.

d. Periodic inspections. The local administrator and each member of his inspections department shall have a right, upon presentation of proper credentials, to enter on any premises within the territorial jurisdiction of the department at any reasonable hour for the purposes of inspection or other enforcement action.

e. Violations to be corrected. When the local administrator finds violations of applicable state and local laws, it shall be his duty to notify the owner or occupant of the building of the violation. The owner or occupant shall each immediately remedy the violation of law in the property he owns or occupies.

f. Actions in event of failure to take corrective action. If the owner or occupant of a building or property shall fail to take prompt corrective action, the administrator shall give him written notice, by certified or registered mail to his last known address or by personal service:

1. That the building or property is in violation of the Floodplain Regulations;

2. That a hearing will be held before the local administrator at a designated place and time, not later than ten (10) days after the date of the notice; at which time the

owner or occupant shall be entitled to be heard in person or by counsel and to present arguments and evidence pertaining to the matter; and

3. That following the hearing, the local administrator may issue such order to alter, vacate or demolish the building, or to remove fill, as appears appropriate.

g. Order to take corrective action. If, upon a hearing held pursuant to the notice prescribed above, the administrator shall find that the building or development is in violation of the Floodplain Ordinance, he shall make an order in writing to the owner, requiring the owner to remedy the violation within such period, not less than sixty (60) days, the administrator may prescribe; provided that, where the administrator finds that there is imminent danger to life or other property, he may order that corrective action be taken in such lesser period as may be feasible.

h. Appeal. Any owner who has received an order to take corrective action may appeal from the order to the City Council by giving notice of appeal in writing to the administrator and the clerk within ten (10) days following issuance of the final order. In the absence of an appeal, the order of the administrator shall be final. The City Council shall hear an appeal within a reasonable time and may affirm, modify and affirm or revoke the order. All such decisions of the City Council are subject to review by the Mecklenburg County Superior Court as provided in N.C.G.S. 143-215.57 (c) as such statute may be amended from time to time.

i. Failure to comply with order. If the owner of a building or property fails to comply with an order to take corrective action from which no appeal has been taken, or fails to comply with an order of the City Council following an appeal, he shall be guilty of a misdemeanor and shall be punished in the discretion of the court.

Exhibit 1-2. Sample ordinance from Charlotte, Mecklenburg County, NC regarding accessory structures.

8. Accessory Structure. When accessory structures (sheds, detached garages, etc.), are to be placed in the floodplain the following criteria shall be met:

    a. Accessory structures shall not be used for human habitation;

    b. Accessory structures shall be designed to have a low flood damage potential;

    c. Accessory structures shall be firmly anchored in accordance with Article V, Section 20 (1); and

    d. Service facilities such as electrical and heating equipment shall be elevated in accordance with Article V, Section 20 (43).

Exhibit 1-3. Sample ordinance from Roseville, CA regarding variances.

9.80.300 Nature of variances.

The variance criteria set forth in this section are based on the general principle of zoning law that variances pertain to a piece of property and are not personal in nature. A properly issued variance is granted for a parcel of property with physical characteristics so unusual that complying with the requirements of this chapter would create an exceptional hardship to the applicant or the surrounding property owners. The characteristics must be unique to the property and not be shared by adjacent parcels. The unique characteristic must pertain to the land itself, not to the structure, its inhabitants, or the property owners.

It is the duty of the city to help protect its citizens from flooding. This need is so compelling, and the implications of the cost of insuring a structure built below flood level are so serious that variances from the flood elevation or from other requirements in the flood chapter are quite rare. Therefore, the variance guidelines provided in this chapter are more detailed and contain multiple provisions that must be met before a variance can be properly granted. The criteria are designed to screen out those situations in which alternatives other than a variance are more appropriate. (Ord. 3066 § 1 (part), 1997: Ord. 2374 § 1 (part), 1990.)

9.80.310 Variance procedure.

A. The city council of the City of Roseville shall hear and decide appeals and requests for variances from the requirements of this chapter. Applications for a variance shall be made in the usual manner provided for Zoning Ordinance variances and shall include the standard variance application fee.

B. The city council shall hear and decide appeals when it is alleged there is an error in any requirement, decision, or determination made by the floodplain administrator in the enforcement or administration of this chapter.

C. In passing upon such applications, the city council shall consider all technical evaluations, all relevant factors, standards specified in other sections of this chapter, and:

1. The danger that materials may be swept onto other lands to the injury of others;

2. The danger of life and property due to flooding or erosion damage;

3. The susceptibility of the proposed facility and its contents to flood damage and the effect of such damage on the existing individual owner and future owners of the property;

4. The importance of the services provided by the proposed facility to the community;

5. The necessity to the facility of a waterfront location, where applicable;

6. The availability of alternative locations for the proposed use which are not subject to flooding or erosion damage;

7. The compatibility of the proposed use with existing and anticipated development;

8. The relationship of the proposed use to the comprehensive plan and floodplain management program for that area;

9. The safety of access to the property in time of flood for ordinary and emergency vehicles;

10. The expected heights, velocity, duration, rate of rise, and sediment transport of the flood waters expected at the site; and,

11. The costs of providing governmental services during and after flood conditions, including maintenance and repair of public utilities and facilities such as sewer, gas, electrical, and water systems, and streets and bridges.

D. Any applicant to whom a variance is granted shall be given written notice over the signature of a community official that (1) the issuance of a variance to construct a structure below the base flood level will result in increased premium rates for flood insurance up to amounts as high as $25.00 for $100.00 of insurance coverage and (2) such construction below the base flood level increases risks to life and property. A copy of the notice shall be recorded by the floodplain board in the office of the Placer County recorder and shall be recorded in a manner so that it appears in the chain of title of the affected parcel of land.

E. The floodplain administrator will maintain a record of all variance actions, including justification for their issuance, and report such variances issued in its biennial report submitted to the Federal Insurance Administration, Federal Emergency Management Agency. (Ord. 3066 § 1 (part), 1997: Ord. 2374 § 1 (part), 1990.)

9.80.320 Conditions for variances.

A. Generally, variances may be issued by the city council for new construction, substantial improvement and other proposed new development to be erected on a lot of one-half acre or less in size contiguous to and surrounded by lots with existing structures constructed below the base flood level, providing that the procedures of Sections

9.80.130 through 9.80.150, inclusive, have been fully considered. As the lot size increases beyond one-half acre, the technical justification required for issuing the variance increases.

B. Variances may be issued for the repair or rehabilitation of "historic structures" upon a determination that the proposed repair or rehabilitation will not preclude the structure's continued designation as a historic structure and the variance is the minimum necessary to preserve the historic character and design of the structure.

C. Variances shall not be issued within any designated floodway if any increase in flood levels during the base flood discharge would result.

D. Variances shall only be issued upon a determination that the variance is the "minimum necessary," considering the flood hazard, to afford relief.

E. Variances shall only be issued upon (1) a showing of good and sufficient cause; (2) a determination that failure to grant the variance would result in exceptional "hardship" to the applicant; and (3) a determination that the granting of a variance will not result in increased flood heights, additional threats to public safety, extraordinary public expense, create "nuisances" cause "fraud or victimization" of the public, or conflict with existing local laws or ordinances.

F. Variances may be issued for new construction, substantial improvement and other proposed new development necessary for the conduct of a functionally dependent use provided that the provisions of Sections 9.80.320(A)—(E) are satisfied and that the structure or other development is protected by methods that minimize flood damages during the base flood and create no additional threats to public safety.

G. Upon consideration of the factors of Section 9.80.310(C) and the purposes of this chapter, the city council may attach such conditions to the granting of variances as it deems necessary to further the purposes of this chapter. The decision of the city council shall be final. (Ord. 3066 § 1 (part), 1997: Ord. 2374 § 1 (part), 1990.)

Appendix C

Non-Prioritized Measures

As explained in Section 3.3 of the report, these mitigation measures were not in the top 9 rated measures for the study, but since they are inexpensive and may be easy to implement, the information is being provided for the City.

Improve flap gate operation at outflow points

There are two locations in the study area where the manholes and inlets are lower than 4 feet, which is the defined nuisance flooding elevation. With a 4-foot tide, it is possible that the tide waters could back up the drain pipes and flood the area surrounding these low manholes and inlets. Increasing the inlet and road elevations is addressed in Section 6.4.

This mitigation solution addresses a different aspect of this problem - the flap gates at the outflow points. During high tides, the existing flap gates at the outflow points in the Potomac River should close to prevent tidewater from backing up the stormwater pipes. A September 26, 2007 conversation with Roy Worell and George Guiseppe in the City of Alexandria Maintenance Department indicated that the City already has a program to clean the flap gate areas prior to storm events, but storm flows bring debris though the system which blocks the flap gates again.

To address this problem, we suggest switching from standard flap gates to duckbill check valves at the King Street and Prince Street outfall locations. A conversation with Lalit Sharma of the City of Alexandria Department of Environmental Quality said that the City once tried a duckbill type of check valve, but it didn't appear to work properly. He concluded that the problem was not with the duckbill check valve but was probably caused by an improperly sized valve.

Duckbill check valves have many advantages: they don't rust and greatly reduce clogging. Additionally, they only need as little as 1 inch of head water to allow stormwater outflow. The data from the City's GIS layers show that a 21-inch diameter duckbill check valve would be needed at the King St outfall and a 24-inch diameter duckbill valve would be needed at the Prince St outfall. These check valves cost around $5,500 plus installation. The benefits of this would be a reduction in maintenance costs and a reduction in nuisance flooding in the downtown area from water backing up the storm sewers.

Figure 1: Duckbill Check Valve

A typical duckbill check valve is shown in Figure 1 in the open and closed positions.

Add backflow preventers to prevent stormwater and sewer backups.

There has been one reported case of internal flooding caused by sewer backup at a residence at the intersection of Royal and Pendleton Streets. This location is not in the study area, but is near the northwest border of the study area. There are combined sewers running through a portion of the study area along Pendleton, Union, South Royal, and South Pitt Streets. Along theses locations, there is the possibility for flooding caused by sewer backups.

Adding backflow preventers to homes is an easy way to prevent this type of internal flooding. The City of Alexandria sponsored a program in 2006 in the Commonwealth area of the City outside this study area to provide some financial assistance to residents who chose to install backflow preventers. The program mailed brochures about this program to residents and received many calls asking about more details. Only 20 residents applied for and received financial assistance from the City. The backflow preventers have been effective and all residents who installed them have reported no further problems.

We recommend that the City revise and reissue the brochures to focus on and around the study area and offer assistance to residents along Pendleton, Union, South Royal, and South Pitt Streets. The residents could contract any capable plumber to undertake the work, and the City may consider reimbursing the residents for a portion of the cost. In the 2006 program, the City offered residents up to $500 towards the cost of the backflow preventer and the labor to install it.

Since the brochures are essentially prepared and there is a staff member familiar with the program, the costs to implement this measure will be minimal. The costs will be to mail the brochures to an estimated 150 buildings as well as setting aside money to offer to residents. In the previous program, approximately $10,000 was given to City residents to help defray the cost of the installation. Residents would have to contribute some of their own money as well, but would receive the benefits of avoiding future sewer backups.

Isolate gas and electrical services

Returning power and gas to homes and businesses affected by flooding is a top priority for both Washington Gas and Dominion Power.

Washington Gas has several main valves which provide gas to residents and businesses within the waterfront area of the City. Once water enters a structure the main valve line will be turned off which could affect other buildings. Washington.Gas has been working to isolate as many lines as possible by adding isolation valves. They have also been raising meters and vent lines in low lying areas.

It is in Washington Gas's best interest to isolate as many structures as possible since before the main valve can be turned back on, the meters/valves at each structure must be turned on and gas lights must be relit by the Gas Company for safety purposes. This is a labor intensive job for their employees; and for residents and businesses in the area, this means that gas service is down until a company representative can visit every structure.

Washington Gas has indicated that they have an extensive operations and management plan and can meet with the City if they want to discuss a particular line, although since Washington Gas is a private company, ultimately they decide which lines will be isolated.

Dominion Power reports that there are no significant power issues due to flooding along the waterfront and that it is very rare for the power to be turned off due to flooding. Most of the transformers in the waterfront area are on the roof and those that are submersible are protected.

The power is mainly affected during storm events that cause feeder issues due to wind and rain. If it is a small event, the Dominion Power will fix the issue as soon as possible. If a significant storm or hurricane is active or anticipated, the Emergency Operations Center of the Power Company is in constant contact with the City of Alexandria Emergency Operations Center, usually the Fire Marshalls. It doesn't happen often, but the Fire Marshalls could direct the Power Company to turn off the power. When the power is knocked out, Dominion Power would first respond to the Critical Infrastructure and then to the largest areas without power.

Dominion Power is always looking at improving the reliability of the system. They often perform maintenance on equipment and within the past few years, the underground cables at the Torpedo Factory were replaced. Although Dominion Power feels that there is not one specific area along the waterfront that has continuous power issues, they welcome future discussions with the City about their priorities.

Relocate external electrical boxes

Elevating external electrical boxes above extreme flooding elevations would help prevent electrical outages during storms. It could also help return power to the City more quickly after a storm since the electrical components of that particular building would not have to be checked.

City residents and businesses would be responsible for contracting a licensed electrician to move these components, but the City could help in several ways. They could publish a brochure or have information about floodproofing utility systems on the website under a proposed new section of the Emergency Preparedness page for Flooding. If the City wants to encourage residents to floodproof their utility systems, the City might consider offering financial help similar to the backflow preventer program described earlier in this document. Elevating internal outlets, light sockets, junction boxes, electric motors, and breakers or fuse boxes would also help with this goal.

Additional information on floodproofing utility systems can be found in Appendix K, Exhibit 3.

Inform businesses and residents about NFIP contents coverage

Even a few inches of water can cause thousands of dollars in repair and restoration costs for homeowners and businesses. Flood insurance is “single peril” insurance, sold separately from homeowners insurance. Flood insurance protects against losses to buildings and their contents, but not the land surrounding them. The coverage applies whether the flooding results from heavy or prolonged rains, coastal storm surge, snow melt, blocked storm drainage systems, levee dam failure, or other causes. To be considered a flood, the waters must cover at least two acres or affect at least two properties.

While many residents and businesses in the City of Alexandria are aware of and may have flood insurance for their buildings, they may not be aware of the availability of contents insurance. Especially for businesses that are frequently affected by nuisance floods, obtaining contents insurance may help reduce the burden of flooding.

The City could extend an outreach program to inform residents and businesses about flood insurance options. This information would be distributed through hand-outs, mailings, and the City’s website.

This outreach program could be done at a minimal cost to the City. The City could develop a small brochure and add content to their website. There would be additional costs for the distribution of these materials. City residents and business owners could decide how to respond, but will hopefully would purchase contents insurance, which would reduce their liability after a flood.

Improve/enhance existing business identification system

There is currently no identification/badge (ID) system in place for the Old Town area of Alexandria to facilitate quicker returns to residences and businesses after a flood. Right now, the business owners make a list of employees and give that to the people who are manning the check points; people on the list are then let through the check points.

Since some business owners have expressed frustration with this system, a system that includes creation of permanent IDs could help people pass more quickly through check points. If the City does not already have a machine to make badges, it could invest from $1,000 to $2,500 dollars for a simple machine. Since employee turnover is high for some businesses, we do not suggest photo IDs. Rather, we suggest the City make several IDs for each business that list the business name and address. The City could allow the businesses a small number of free badges and charge for additional copies. The business owner will be responsible for distributing these to employees who can use them to get through the check points. For residents, a government issued ID with current address should be sufficient to pass through the check point.

Provide Updated Information to Residents

The City of Alexandria has developed a flood warning system for areas that are within the floodplain. Warnings are disseminated by local radio (WMAL-630 AM, WWRC-1260 AM, WTOP-103.5 FM, WKYS-93.9 FM), TV, weather radios, and by police equipped with public address systems. The flood warning system is intended to provide up to 0.5 hour advance warning of a flood hazard. The City's website provides links to three USGS river gauges in the immediate region.

Additionally, the Emergency Operations department receives weather forecasts from the National Weather Service. If a flood is impending, that group goes door-to-door in the study region to pass out flyers or leave them on the door. The flyers warn people about the impending flooding and let them know if sandbags will be available for pick up or if they will be dropped off at the businesses.

In other parts of the City, when flooding is expected they have a phone notification system in place. They use a GIS database with phone numbers coded in by address. A polygon of the expected extent of flooding is created and their program extracts all the numbers within that area and leaves a pre-recorded message about the flood event. This system is not currently used in the study areas as the precedence set is that the residents and business owners are visited by City workers. It is recommended that the phone notification system be used within the study area. This modification will save money and allow City workers to focus on other pre-flooding preparations.

The City of Alexandria also has an eNews service that sends emails or text messages about the latest information regarding City services and emergency alerts. It is recommended that the City conduct outreach activities to encourage residents and business owners to sign up for this free service to receive flood warnings.

Last, Hurricane Preparedness information is provided on the Emergency Preparedness section of the City's website, but more flooding information could be easily added. For example, this site could include the latest news alerts and tide gage information. The cost to change the website is minimal.

Provide Education to Area Media Outlets

Businesses in the City of Alexandria, particularly in the Old Town area, report lost revenue from tourists due to the media hype over pending flooding. TV stations often find the picturesque backdrop perfect for their field reporters, who then report that flooding is imminent. While the City welcomes the media to use the town as a backdrop, they would like to see more accurate reporting.

While it may seem like a struggle to limit the misreporting, the City can improve the way flood risks are communicated to the media and to the public. The following list gives several suggestions on how to provide accurate information to the media.

- Provide alternative ways for visitors and consumers to obtain information about the flood conditions by looking beyond traditional media (City's web site or another web site with maps highlighting areas open and accessible to the public).
- Create an editorial board to help reporters and editors understand the issues.
- Create "new media" news releases that get distributed to print and broadcast media outlets that would give them the real story about the flooding. This could be set up through an RSS feed to push the stories to the outlets directly.
- Create a "media card" with information about who to contact for accurate and up-to-date information about flooding conditions.
- Give the media something different to report. Innovative campaigns will catch their attention. Flashy signs will create interesting backdrops for reporters.

Appendix D

Data Collection

Potomac River Waterfront Flood Mitigation Study

Exhibit 1: Survey Data

FID Buildings	Address	Description	Landuse	Number of Floors	Z_ELEV
76	211 N UNION ST	Garage with Offices on top	Commercial	4	3.7
764	120-130 CAMERON ST	Condos	Residential	4	9.2
767	110-120 CAMERON ST	Condos	Residential	4	4.6
802	102-160 N UNION ST	Residences At Torpedo Factory	Residential	4	4.0
819	211 STRAND ST	Mystic Jewellers	Commercial	1	6.0
828	220 S UNION ST	Art League	Commercial	1	6.0
905	115 S UNION ST	Structure On Garage	Commercial	2	4.1
1398	100 CAMERON MW	Cameron Mews	Residential	3	4.0
1404	104 S UNION ST	The Virginia Shop	Commercial	3	3.9
1419	1 WALES AL	Shops	Commercial	4	2.2
1465	115 N LEE ST	Residences Of Torpedo Factory Condominium	Residential	4	6.0
1468	104 CAMERON MW	Cameron Mews	Residential	3	7.6
1479	105 CAMERON MW	Cameron Mews	Residential	3	8.0
1481	101 CAMERON MW	Cameron Mews	Residential	3	4.0
1497	109 QUEEN ST	Row house	Residential	3	8.0
1498	113 QUEEN ST	Row house	Residential	3	8.0
1506	100 QUAY ST	Row Houses With Garage / Appeared Split Level With A Walkdowm Living Space	Residential	3	8.0
1575	430 N UNION ST	Row Houses With Garage	Residential	3	8.0
1577	426 N UNION ST	Row Houses With Garage	Residential	3	8.0
1579	422 N UNION ST	Row Houses With Garage	Residential	3	8.8
1584	412 N UNION ST	Row Houses With Garage	Residential	3	9.6
1587	406 N UNION ST	Row Houses With Garage	Residential	3	9.7
1590	400 N UNION ST	Row Houses With Garage	Residential	3	9.6
1599	101 QUAY ST	Row House With Garage	Residential	3	8.9
1600	100 PRINCESS ST	Row Houses With Garage / Appeared Split Level With A Walkdowm Living Space	Residential	3	9.5
1636	221 N LEE ST	Row Hourses On Parking Garage	Residential & Commercial	2	4.2
1674	102 PRINCE ST	Row House	Residential	1	7.3
1692	109 PRINCE ST		Residential	2	9.0
1697	215 S UNION ST	The Carraige House Coffee Shop	Commercial	2	8.1
1699	204 S UNION ST	Business	Commercial	3	4.7
1700	206 S UNION ST	Business	Commercial	3	5.7
1938	830 S LEE ST	Business	Residential	2	9.9
2017	827 S ROYAL ST	Business	Residential	1	12.4
2038	201 KING ST	Business	Commercial	3	10.2
0	409 S UNION ST	Semi-Detached House	Residential	1	10.4

Exhibit 2: Field Visit Summary – July 23, 2009

All elevations noted in the field visit summary are referenced to NAVD88.

Area No 1 – Structures along N Union Street between Oronoco St and Princess St

All structures in this area are Residential, row houses with garages. All garages are approximately at the road elevation, which is about 8.0 ft. structures have 3-4 steps up to the door way (Refer figure A1-1). The lowest point of entry (LPE) for these structures is at the garage elevation. The first floor elevation appears to be lower than the LPE. Corner units (observed at Union and Princess Intersection) have side windows which show that these houses have living space lower than the garage elevation. (5 +/- ft) However it appears that the structures have split floors (3-4 floors), so when you enter the house through the main front door, there is a staircase leading upstairs to a living area and stairs leading downstairs. Downstairs probably there is an escape window lower than the elevation at the entrance; however the water might not be able to go around these structures, to the backyard. 430 N Union St appears to be abandoned.

Figure A1-1

Structures on Princess Street are most likely to follow the same trend but with 1 step up to the doorway. There appeared to be a jump in the first floor elevations at 113/115 and also at the 117/119 princess st. (Refer Figure A1-12)

Figure A1-12

There are no existing flood control measures but the mitigation measures for this area should extend up to 121 Princess St. (structures West of this don't have any flood problem as they are high enough).

Area No 2 – Robinson Terminal

This is a warehouse located at the Oronoco and Union Street intersection. Garage located at the ground level. They have 2 buildings with loading docks approximately 3.5 ft above the ground. (Refer figures A2-1 and A2-4) Both buildings have first floors located at the dock level, which appears to be at 12 ft and flooding is not a problem to these buildings. No major flood protection measures are required for these buildings, however acquire these buildings would provide great aesthetics, recreational and environmental benefits to the city.

Figure A2-1

Figure A2-4

Area No 3 – Structures along N Union Street between Princess St and Quay St.
All the structures have garages at the road elevation and the Lowest Point of Entry is at the garage level for most of these structures. Main door way is at the garage elevation or 1-2 steps above the garage level. (Refer Figure A3-1)

Figure A3-1

Figure A3-3

These structures appeared to have a living area lower than garage elevation. (Appeared as split level with a walk down living space- Refer Figure A3-3, same as area 1)
Based on the information from one of the residents (112 Princess St), this street has never been flooded.

Once flood risk will be confirmed by surveyed elevations, flood proofing may be a suitable mitigation option for these properties, which may be removable household products, such as flood boards, air brick covers, which are fitted temporarily to individual properties to form a barrier to stop water coming in. Also should consider how the fabric of the walls, services, floors etc will respond to the pressure of the floodwater, including making walls more water resistant and repairing and sealing cracks.

Area No 4: Structures along N Union between Quay and Queen Streets

This area is similar to Area no 3. Some of the structures have garages and doors at ground elevation where as others have their door way 1 or 2 steps above the garage level. (Refer Figure A4-1) LPE for all the structures is at the garage level. Based on the information from one of the residents staying at 106 Quay Street, most of the structures have family room /living space below the garage level. (A window at the lower living space can be observed from figure A4-4).There was no flooding in this street during Isabel. It appears that the first floor elevations were taken at the door level for these structures. (Actual first floor starts below the garage elevation, which due to the split floor design). Flood proofing would be a suitable mitigation option for these properties, which will need to include sealing any windows lower than entrance level located in the back.

Figure A4-1

Figure A4-4

Area No 5: Queens Row (Along Queen St between N Union and N Lee St)

These are 3 level Residential row houses with located on a private parking garage. (Refer figure A5-1) Elevated structures with the LPE as well as the first floor elevation approximately 8 feet above ground. (Refer figure A5-5)Vents appearing below the main door belong to the parking garage.

No flood mitigation measures are needed for this area as the buildings are located high.
The residents park their vehicles in the parking lot located behind their buildings. GIS layer seems to be incorrect; 220 N Union St is the entrance to the garage instead of a vacant land.

Figure A5-1

Figure A5-5

Area No 6 (6A -6G):
Commercial Structures long N Union St between Queen and King St)

Most of the buildings in the area would flood from the 10.2 ft flood event. Flood proofing or seawall would be a suitable option. However aesthetics would be an issue with the seawall as the flood water elevation would be high. Unless it was a wall that could be moved up in a flood event would be a suitable solution. Also a temporary free-standing barrier might be a suitable solution for some of the buildings (depending on the flood elevation).

6A: Commercial space above parking garage. First floor elevation at 11.6 ft. No flood protection is needed as the structure is above the garage.

←Figure A6a-1

6B: Alexandria Seaport Foundation located along the water. May need some flood proofing options for the boat building and their office.

← Figure A6b-1

6C: Chart house – Restaurant located on the storage space. (Refer figure A6c-2) Storage space about 3 ft above the lowest elevation. (Refer Figure A6c-4) All A/C appeared to be at the storage level. Survey was requested for this structure.

Figure A6c-2 Figure A6c-4

6D: Food Pavillion – floor elevation approximately at elevation 12. No flooding problems. No mitigation measures needed for this structure.

←Figure A6d-1

6E: First floor elevation is 8.62 which starts at the door elevation. Flood proofing (mitigation) would be required for extreme (1% annual probability) flood events.

←Figure A6e-2

6F: Torpedo factory

The building is used for art display, concerts, and studios. It has a historical significance as it used to be a torpedo factory.

The main building has a finished first floor at 7.03ft NAVD and the extension on the south is at 6.94 ft NAVD. Extension doesn't have any garages but the windows and door way are at the same elevation. (Refer figure A6f-2) Display portions of the windows are located below the flood elevation level. (refer to figure A6f-4)

Need to consider the art display portions since they are almost close to the ground elevation. Might consider raising the display portions to the floor elevation as part of the mitigation measures as the ceiling appears to be at a high elevation and also the doors and windows need to be flood proofed or temporary flood barriers to the windows and doors can protect the building from flooding.

Figure A6f-2

Figure A6f-4

6G Old Dominion Boat Club

First floor elevation is 3.75ft at ground level. (Refer figure A6g-2, may be between 4-5). Sandbags located in front of the entrance, which confirms frequent flooding of the building. Damaged during Isabel. It is not clear what is at the first floor. It appears that the bar and the party room are located upstairs. Perhaps the first floor is not in use. No basements to this structure. Flood protection, might be required. However it is a boathouse, so the structure might be designed to flood.

←Figure A6g-2

Area No 7 – Cameron Mews

Structures with no garages. First floor of the **structure is at ground level on the back side.** Structures have a pedestrian court yard on the front side. Front side door located 4 steps above courtyard. All the structures have a brick compound wall on the Cameron Street (back side of the structures) with gates to individual units. (refer to figure A7-3). On the tax assessors website up to 105 and 106 Cameron MW has no finished basements, however rest of the houses do have finished basements.

Flood protection is necessary for these structures as they are located on the ground level and the back of the houses are located in the 8ft flood elevation. Might consider making the privacy wall as a localized flood barrier but also need to consider the drainage pipes located in the backyard. (can be observed from figure A7-5) Dry flood proofing might be an option here.

Figure A7-3

Figure A7-5

Area No 8 – Torpedo Factory Condominiums

Condos built over a parking garage. Four apartments closest to the water have had repetitive loss. The finished flood appears to be high here; however survey was requested for these apartments. (refer to figure A8-2)

←Figure A8-2

Area No 9 – Businesses along King Street (West of Union Street)

New construction was taking place at King and Union intersection. The owner is the builder of the property. (refer to figure A9-1) The first floor for all the businesses along the street appeared to be the grade or 1 to 2 steps above the grade (refer figure A9-2). No structures have basements. All structures along King Street between Union and Lee Street would require flood protection; one of these options would be removable household products, such as flood boards, air brick covers, which are fitted temporarily to individual properties to form a barrier to stop water coming in. Also should consider how the fabric of the walls, services, floors etc will respond to the pressure of the floodwater, including making walls more water resistant and repairing and sealing cracks. Ceilings appear to be high, so internal elevation in combination with other solutions could be a good mitigation option. Structures have A/C systems backside of the street, those will need to be elevated on the concrete slab. Other mitigation options might be flood wall, or temporary flood barrier.

Figure A9-1

Figure A9-2

Area No 10 – (10A – 10C)
(Businesses Southwest of King and Union intersection, along King Street)

10A: These are all commercial structures located along union and King Street. The ones on the union street appear to have 2 – 3 steps up to the door way and are about 2 ft high from the ground. (figure A10a-8). Spoke to one of the representatives from 107 S Union Street business. This structure received 4 ft of water during Isabel. Same mitigation options should be considered as for Area 9.

Figure A10a-8 →

Structures along King Street are about a foot higher than the ground. They don't have basements and the door ways are at grade level (figure A10a-3).

Figure A10a-3

10B: business store along S Union Street

Structure located on the garage, the front of the building has few shops, with stairs leading up to the shops. The water is not likely to reach the floor above the garage, therefore no mitigation needed for this structure.

10C: (Intersection of Prince and S Union Street – structures along Union Street)

Door ways/first floors located at the grade level or 1 step above for businesses. Christmas Attic's first floor appeared to be a foot above the grade. These shops appears to have high ceilings, might be suitable for the same mitigation options as Area 9.
Residential structures along Prince Street also have 1-2 steps above the grade. First floor appeared to be around 2ft above the road. (Can be observed in Figure A10c-3)

Figure A10c-3 →

Area No 11- Southwest of Union and Prince Intersection

All these residential structures along Prince Street don't have any basements and also just about 10 inches above the road. 110 Prince St is outside the 10.2ft flood boundary, but flooded 22 inches from the toilet. Dry flood proofing may be an option here if there are no basements.

The GIS database shows a misleading floor elevation for this structure. First floor for this structure appeared around 7.0 (refer figure A11-1 below)

Fig A11-1→

There are other commercial structures / shops located along S Union Street. Many of them will require flood protection, as the FFE is between 6-7 ft. There are no current flood protection measures for all these structures. The Carriage House Shop is about a foot above the grade (3 steps). (Refer figure A11-3) survey was requested. Dry flood proofing or internal elevation may be an option.

Figure A11-3→

Structure to the south of The Carriage House coffee shop is an elevated structure built above a garage, no mitigation would be required.

Area 12 – Structures along S Union Street between Duke St and Wolfe Street

Structures don't have any basements. Most of the Residential structures along Duke Street have their door ways a step above the grade (figure A12-3). First floor elevations look fine in the database. Some of the structures along the Union street have their garages below the first floor elevation. (Refer figure 12-1) The adjacent grade is located at 12. According to the information from the resident of 303 S Union Street, the structure was never flooded and the first floor appeared to be approximately at 15. (Refer figure A12-5). No flood mitigation is required.

Figure A12-3

Figure A12-5

Area 13 – Residential structures just South side of Wolfe Street

Structures have no basements and garages and the first floor appeared to be about 1.5 feet above the grade. GIS elevation data looks correct. (Refer figure A13-3) No flood mitigation is required.

←Figure A13

Area No 14 – Harborside Development

All the structures in this development are located on the parking garage. (Refer figure A14-1) and the first floor appeared to be a minimum of 3 feet above the grade everywhere. Some also have a privacy wall on the water side and are located high. (Figure A14-6). No flood mitigations are required for this development.

Figure A14-1

Figure A14-6

Area No 15 – Robinson South Terminal

The loading dock is 3 feet above the grade and first floor is at 14 for this building (Figure A15-2). **No flood mitigation measures are required for this structure. Loading dock appears to be at grade?**

← Figure A15-2

Area No 16 – Commercial stores East of South Union Street between Duke and Prince Street

Area consists of the Art league, Chadwick's place restaurant, Potomac River Boat Company etc. Mystic Jewelers is an elevated structure and its fist floor is at 10.6. The first floors are at the grade for these structure or 1 or 2 steps above the grade. The first floor values for big wheel bikes, gem shop and the empty office at the corner is bellow 8ft. (Figure A16-3)
The first floor elevations for the Potomac River boat company appear to be around 6 and for Art league about 10, we requested surveys for these structures. (Figure A16-1) There is a low point of entry to the Art League in the east side of the building. Dry flood proofing or internal elevation would be an option here. It's possible that the first floor is already elevated. Survey will tell.

Figure A16-1

Figure A16-3

Area No 17 – (ex) Olson's book store FFE is at 5.87. The property flooded several times in the past and at the site visit in July 2009 the building was vacant. It might be a suitable property for the city to acquire, however there might be structural limitation to it. Alternatively a combination of mitigations could be provided. These could be, raising the ground internally, sealing the walls, window, blocking the doors with removable boards.

Area No 18 - structure at the corner of Wales and Strand Street is about 3 ft.
All the first floors appeared to be at the grade or a step above that. (Figure A18-1) survey is being requested for these units. For Starbucks and Mai Thai, flood mitigation will be required, both had repetitive loss claims and the FFE is between 6-7ft. The Mai Thai is already elevated internally. The first floor is concrete for both places. For this block of buildings buying out would be a suitable option as the street and the buildings floods regularly as well as dry flood proofing would be an option here.

Figure A18-1 →

Area No 19 and 20 – Backyard Boats
First floor elevation and the lowest point of entry are 2 to 3 steps above the grade. (Figure A19-5). Structures on the Alexandria Street have their lowest point of entry as well as first floors at the grade. (Figure A19-9)

Figure A19-5

figure A19-9

Structures west of South Union Street are on the garages and there appeared to be a flood gate at the entrance of the garage. (Refer figure A20-3). Also one of the structures in this building has its first floor lower than the ground. Stairs appeared at the entrance. (Figure A20-1) Peter Chaput mentioned that a private contractor was hired to flood proof these buildings, so no mitigation is needed.


Figure A20-1 figure A20-3

Area 21

This is the most southern part of the study area, located just to the north of I495. There is a forest between I-495 and properties. Most of the buildings have finished basements and somewhat elevated. However some of them have low point of entry to the lowest floor. See Figure 21-1, 21-2. Also found some sandbags in front of 211 Lee Ct, see figure 21-3 bellow.

Figure 21-1

Figure 21-2

Figure 21-3

210 Lee Ct seems to be abandoned, only built in 1961. It is located in the 8 ft Flood Plain and the first floor seems to be 1 step above ground. The FFE is 8.74. See picture 21-3. There is a wall next to the building, but not behind where the water would be coming from, see picture 21-4. Also a swimming pool located next to the building.

Figure 21-3

Figure 21-4

Perhaps buy out would be a feasible solution for 210 Lee Ct. It would not only provide final solution to the flooding problem, but also it would provide environmental benefits, as it is located next to the forest(park), which could be extended. However also elevation, flood proofing would probably be suitable. Alternatively Area 21 a small flood wall could provide protection as well.

Exhibit 3: Rainfall Data

TR-20 was used and the online version of the National Oceanic and Atmospheric Administration's (NOAA) Atlas 14 were averaged to get the rainfall precipitation frequency estimates used for our study as shown in Table 1.

Average rainfall data was determined from the Windows version of TR-20. Screen shots from TR-20 and Atlas 14 are shown in Figures 1 and 2 below.

Table 1: Rainfall precipitation frequency data used for study

Precipitation (inches)			
Frequency	**Win TR-55**	**NOAA**	**Average**
10-year	5.5	4.76	5.13
25-year	6.0	5.96	5.98
50-year	7.0	7.01	7.01
100-year	7.7	8.21	7.96

Figure 1: Screen shot from Win TR-20

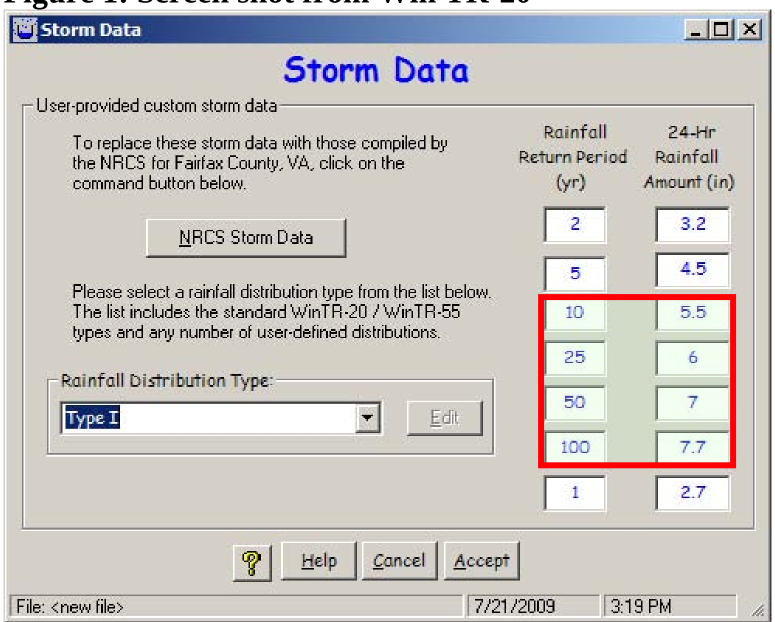


Figure 2: Screen shot from NOAA Atlas 14

Pop-up blocked. To see this pop-up or additional options click here...

POINT PRECIPITATION FREQUENCY ESTIMATES FROM NOAA ATLAS 14

Virginia 38.8088 N 77.06364 W 95 feet

from "Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 2, Version 3
G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley
NOAA, National Weather Service, Silver Spring, Maryland, 2004

Extracted: Tue Jul 21 2009

Confidence Limits | Seasonality | Location Maps | Other Info. | GIS data | Maps | Docs

Precipitation Frequency Estimates (inches)

ARI* (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
1	0.36	0.57	0.71	0.98	1.22	1.41	1.51	1.84	2.21	2.56	2.98	3.32	3.84	4.39	5.93	7.30	9.17	10.90
2	0.43	0.69	0.86	1.19	1.50	1.72	1.83	2.22	2.67	3.10	3.60	4.01	4.62	5.28	7.06	8.64	10.81	12.82
5	0.51	0.82	1.03	1.47	1.88	2.18	2.32	2.81	3.39	3.98	4.62	5.13	5.84	6.59	8.53	10.27	12.64	14.81
10	0.57	0.91	1.15	1.67	2.17	2.53	2.71	3.29	4.01	4.76	5.49	6.09	6.89	7.68	9.72	11.59	14.04	16.32
25	0.65	1.03	1.30	1.93	2.57	3.04	3.27	4.00	4.96	5.96	6.81	7.53	8.45	9.28	11.39	13.40	15.89	18.26
50	0.70	1.12	1.42	2.13	2.89	3.44	3.73	4.61	5.78	7.01	7.96	8.78	9.79	10.62	12.73	14.84	17.30	19.70
100	0.76	1.20	1.52	2.33	3.21	3.88	4.21	5.26	6.70	8.21	9.23	10.17	11.27	12.06	14.13	16.31	18.68	21.08
200	0.81	1.29	1.62	2.53	3.55	4.32	4.73	5.97	7.72	9.57	10.65	11.72	12.91	13.61	15.58	17.82	20.03	22.39
500	0.88	1.39	1.75	2.79	4.01	4.96	5.47	7.01	9.27	11.65	12.80	14.04	15.35	15.90	17.59	19.87	21.78	24.05
1000	0.94	1.47	1.85	3.00	4.37	5.48	6.08	7.88	10.62	13.47	14.64	16.03	17.42	17.80	19.17	21.47	23.07	25.25

* These precipitation frequency estimates are based on a partial duration series. ARI is the Average Recurrence Interval.
Please refer to NOAA Atlas 14 Document for more information. NOTE: Formatting forces estimates near zero to appear as zero.

Appendix E

Economic Valuation Results

Potomac River Waterfront Flood Mitigation Study
Benefit Cost Summary for All Structural Projects

BENEFITS	Flood Wall[1]	Flood Proofing[2]	Acquisition[3]	Walkway[4]	Berm[5]
King Street	$ 1,017,062	$ 7,470,452	$ 4,227,045		N/A
Waterfront Commercial	$ 11,022,291	$ 6,727,889	$ 7,336,054	$ 14,745,415	N/A
N Union St	$ 156,934	$ 733,539	$ 608,916		N/A
Jones Point	N/A	$ 230,843	$ 197,424	N/A	$ 236,410
Total:	$ 12,196,287	$ 14,931,880	$ 12,172,015	$ 14,745,415	$ 236,410
COST	**Flood Wall**	**Flood Proofing**	**Acquisition**	**Walkway**	**Berm**
King Street		$ 1,180,560	$ 90,826,273		N/A
Waterfront Commercial	$ 18,863,273	$ 2,790,754	$ 104,375,470	$ 6,072,490	N/A
N Union St		$ 1,084,100	$ 19,865,796		N/A
Jones Point	N/A	$ 238,050	$ 11,279,417	N/A	$ 5,491,975
Total:	$ 18,863,273	$ 5,055,414	$ 215,067,539	$ 6,072,490	$ 5,491,975
BCR	**Flood Wall**	**Flood Proofing**	**Acquisition**	**Walkway**	**Berm**
King Street		6.33	0.05	2.43	N/A
Waterfront Commercial	0.65	2.41	0.07		N/A
N Union St		0.68	0.03	no protection	N/A
Jones Point	N/A	0.97	0.02	no protection	0.04

[1]Structure lifetime is 50 years, and provides protection to the 100 year flood event

[2] Floodproofing lifetime is 30 years

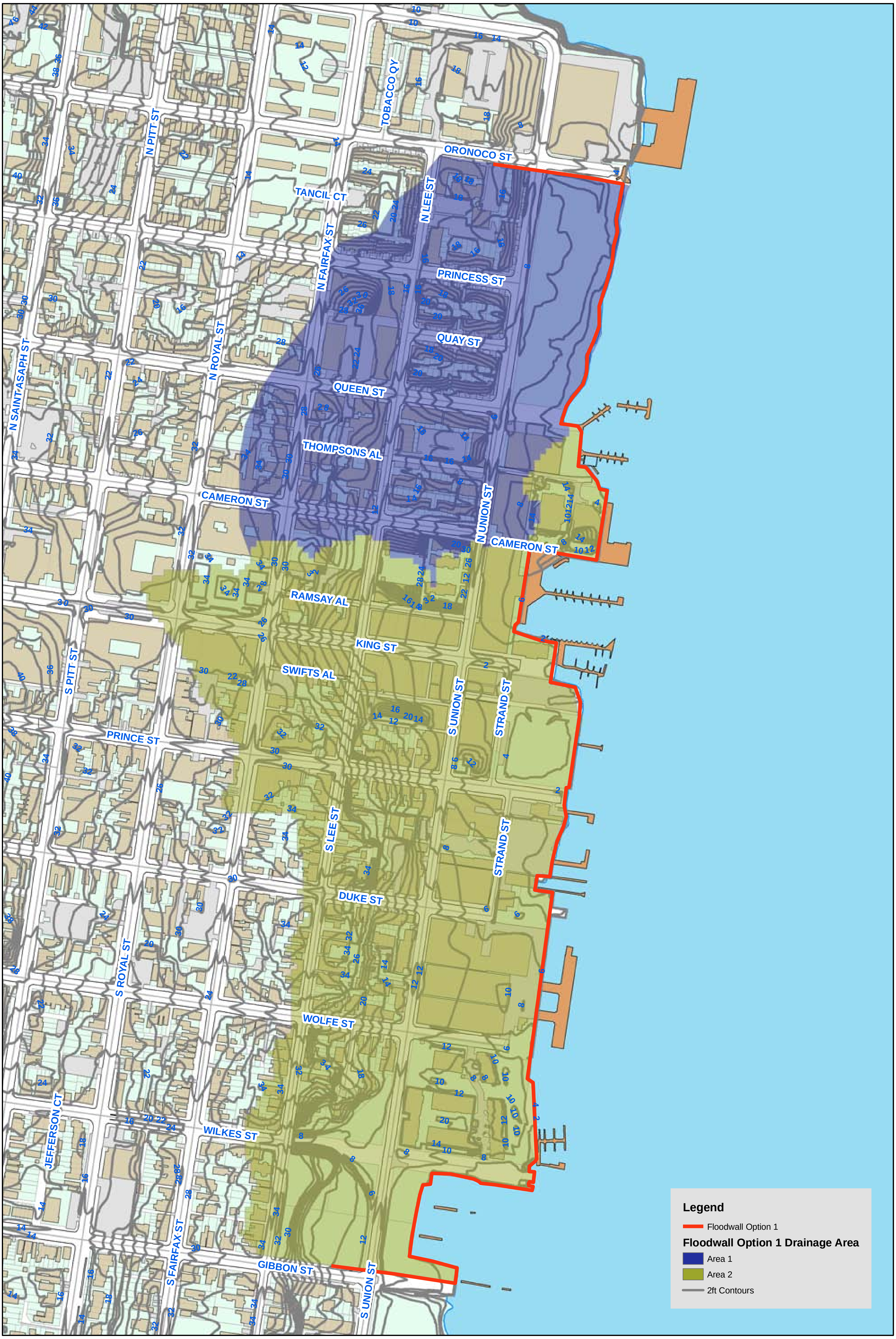
[3] Acquisition lifetime is 100 years

[4] Walkway lifetime is 50 years

[5] Berm lifetime is 50 years

Appendix F

Floodwall



CLIENT	City of Alexandria			TITLE	Floodwall Layout Option 1
PROJ	Potomac River Waterfront Flood Mitigation Study				
REVISION NO 0	DES BY	CJL	09/11/09	URS 200 Orchard Ridge Drive Gaithersburg, MD 20878	PROJ NO 15298592
SCALE 1 inch = 300 feet	DR BY	CJL	09/24/09		EXHIBIT 1-1
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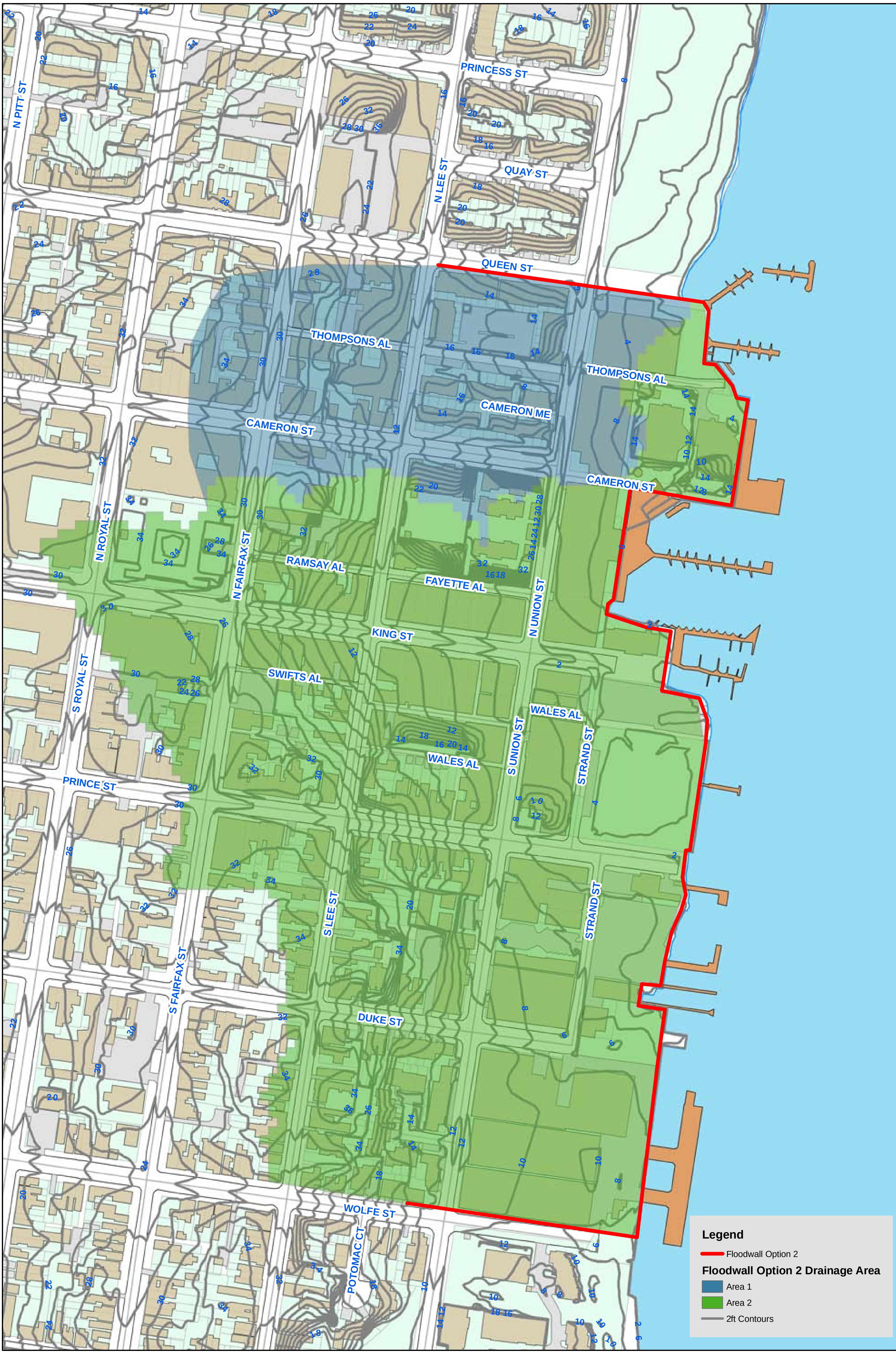
N

0 75 150 300 Feet



CLIENT	City of Alexandria			
PROJ	Potomac River Waterfront Flood Mitigation Study			
REVISION NO	0	DES BY	CJL	09/11/09
SCALE	1 inch = 200 feet	DR BY	CJL	09/24/09
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N

0 50 100 200 Feet

TITLE

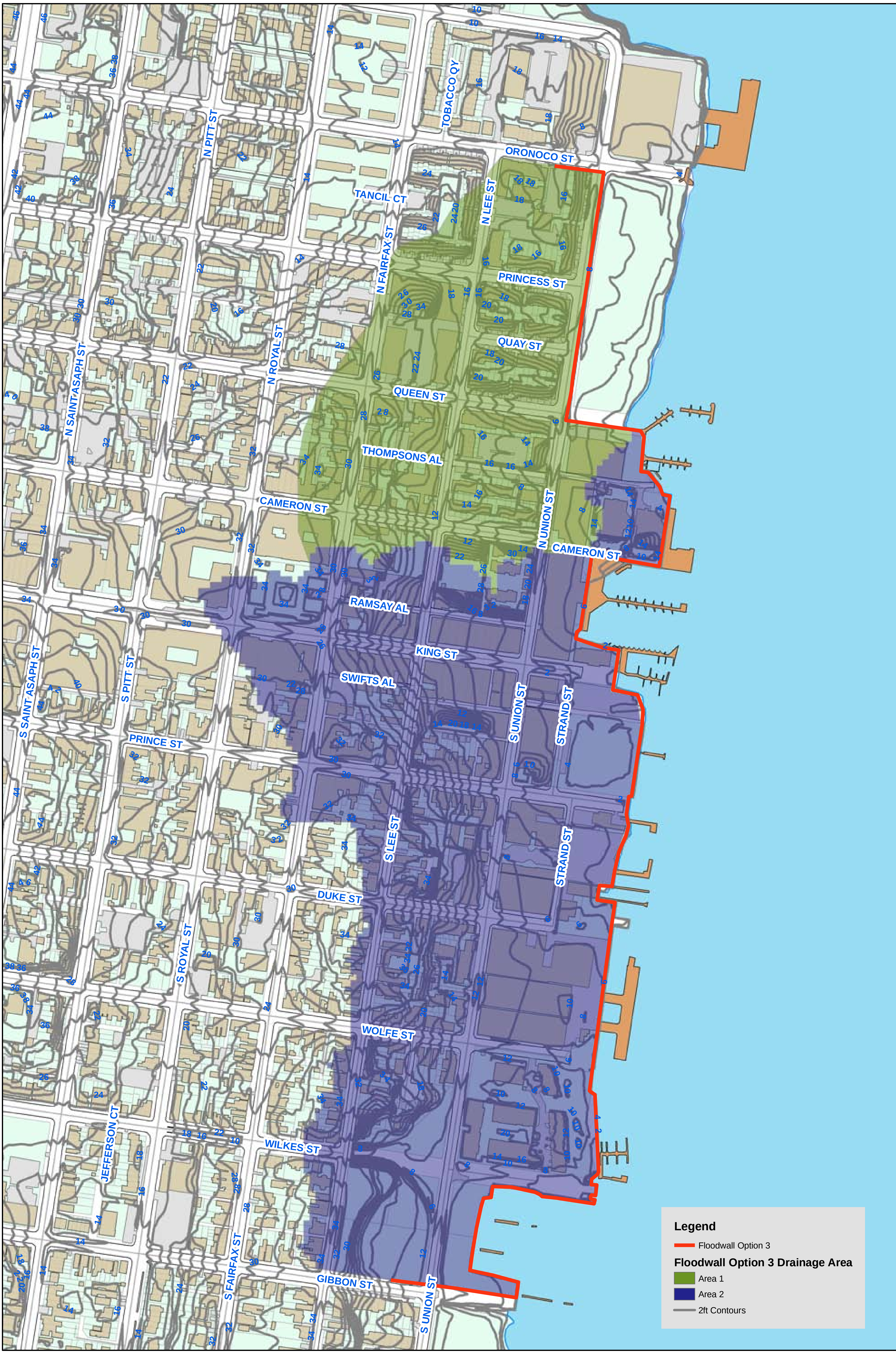
Floodwall Layout Option 2

URS

200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO 15298592

EXHIBIT 1-2



CLIENT	City of Alexandria			TITLE	Floodwall Layout Option 3
PROJ	Potomac River Waterfront Flood Mitigation Study				
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SCALE 1 inch = 300 feet	DR BY	CJL	09/24/09		EXHIBIT 1-3
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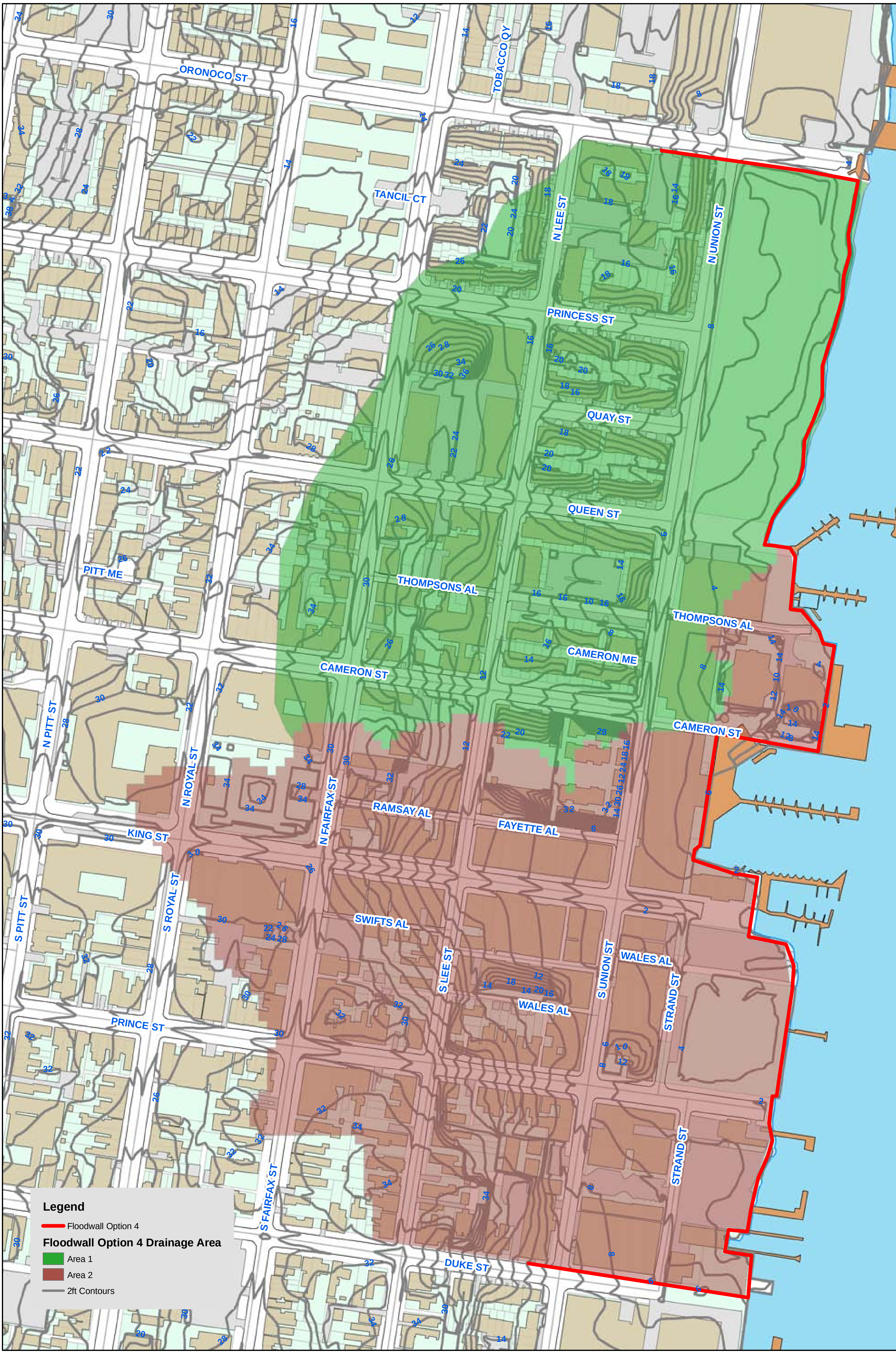

CLIENT	City of Alexandria			TITLE	Floodwall Layout Option 4
PROJ	Potomac River Waterfront Flood Mitigation Study				
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SCALE	1 inch = 200 feet	DR BY	CJL	09/24/09	EXHIBIT 1-4
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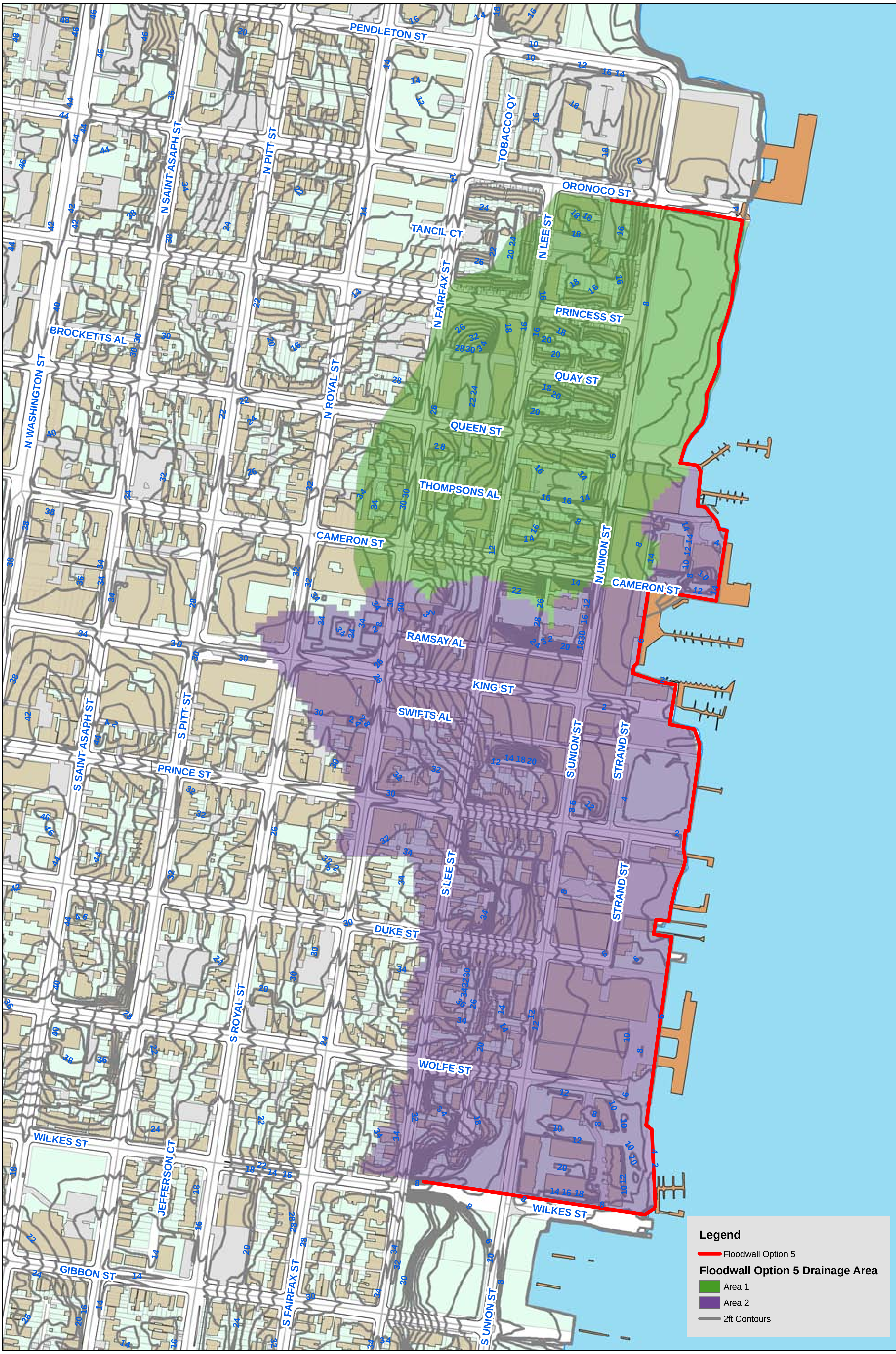
N

0 50 100 200 Feet

URS

200 Orchard Ridge Drive
Gaithersburg, MD 20878



CLIENT	City of Alexandria			TITLE	Floodwall Layout Option 5
PROJ	Potomac River Waterfront Flood Mitigation Study				
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SCALE	1 inch = 300 feet	DR BY	CJL	09/24/09	EXHIBIT 1-5
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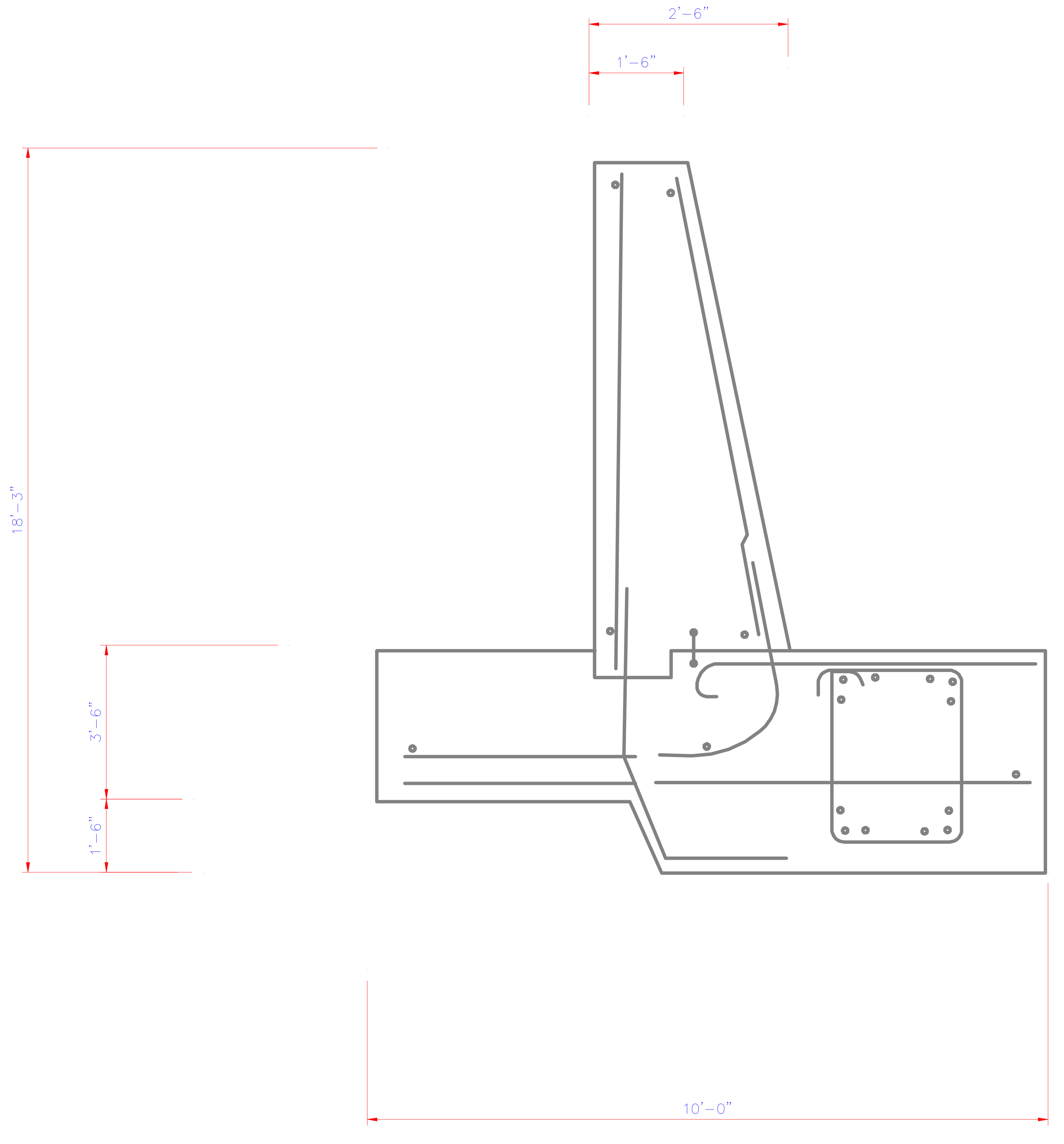
URS
200 Orchard Ridge Drive
Gaithersburg, MD 20878



CLIENT	City of Alexandria				TITLE	Floodwall - Cross Section
PROJ	Potomac River Waterfront Flood Mitigation Study					
REVISION NO	0	DES BY	CJL	09/30/09	URS 200 Orchard Ridge Drive Gaithersburg, MD 20878	PROJ NO 15298592
SCALE		DR BY	CJL	09/30/09		EXHIBIT 2-1
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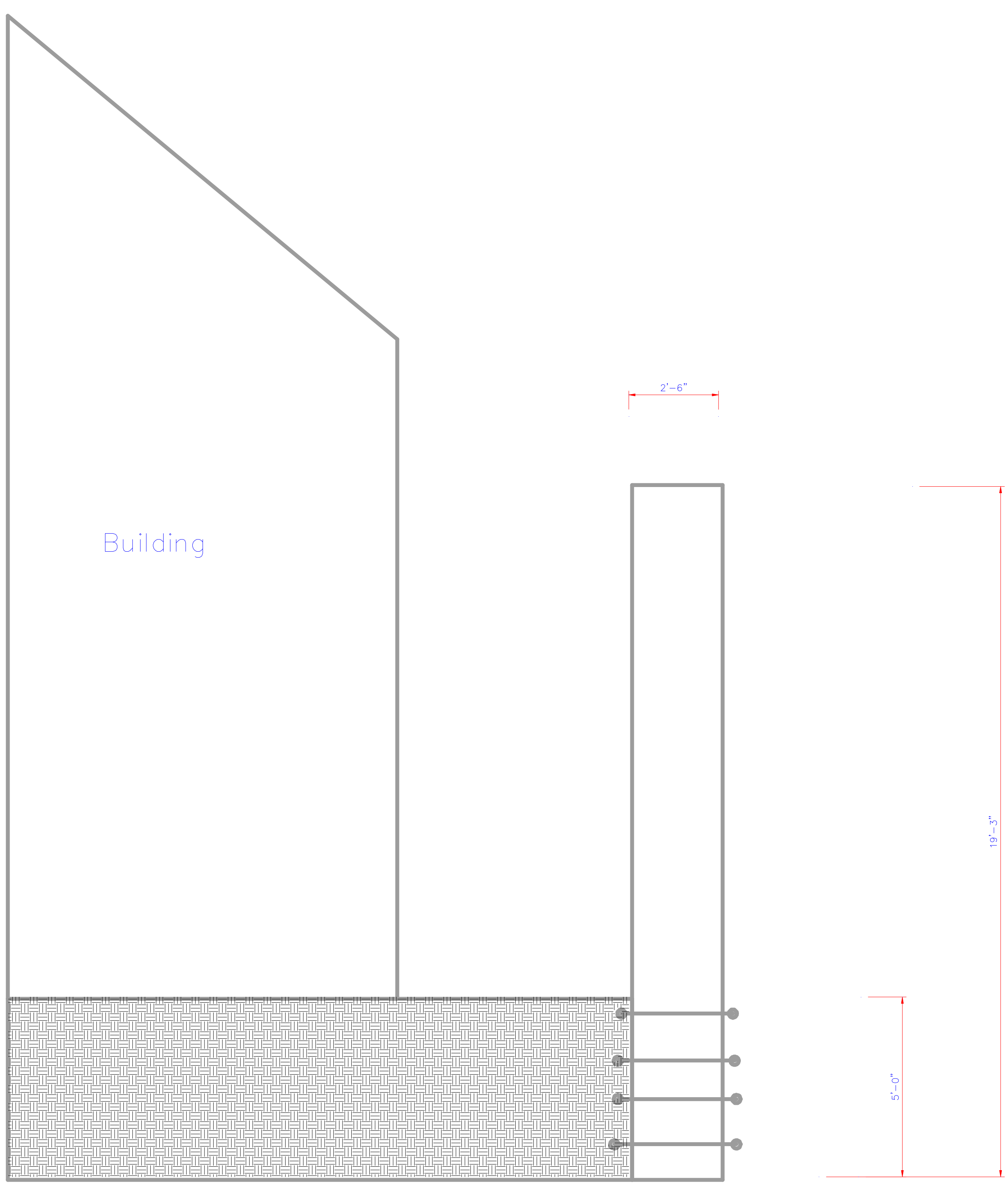


CLIENT	City of Alexandria			TITLE	Floodwall - Slab Portion Cross Section
PROJ	Potomac River Waterfront Flood Mitigation Study				
REVISION NO 0	DES BY	CJL	09/30/09	URS 200 Orchard Ridge Drive Gaithersburg, MD 20878	PROJ NO 15298592
SCALE	DR BY	CJL	09/30/09		EXHIBIT 2-2
W:\City of Alexandria\15298470 - Lower King St\Report\Draft Report\New Figures\Floodwall Figures\Floodwall_Spec.mxd	CHK BY	MER	09/10/09		

Exhibit 3: Various Floodwall Tables

Tables providing additional data for the floodwall design. Drainage area 1 is 11 acres with a time of concentration of 12 minutes. Drainage area 2 is 39 acres with a time of concentration of 16 minutes. Computations for time of concentrations are provided as Exhibit 4 in this appendix.

Table 1: Peak discharges and pipe sizes for floodwall drainage area 1

Recurrence interval	Intensity (in/hr)	C	Q (cfs)	Q (gpm)	Diameter of the pipe required (ft)
10 year	5.52	0.95	56.4	25,303	2.82
25 year	6.45	0.95	65.8	29,566	2.99
50 year	7.23	0.95	73.8	33,141	3.12
100 year	7.95	0.95	81.2	36,441	3.23

Table 2: Peak discharges and pipe sizes for floodwall drainage area 2

Recurrence interval	Intensity (in/hr)	C	Q (cfs)	Q (gpm)	Diameter of the pipe required (ft)
10 year	4.87	0.95	180.8	81,191	4.36
25 year	5.82	0.95	216.1	97,029	4.66
50 year	6.43	0.95	238.8	107,199	4.84
100 year	7.09	0.95	263.3	118,202	5.02

Table 3: Flood runoff and volume table for floodwall

Recurrence interval	24-hour Rainfall (in)	Runoff, Q (in)	Volume (ac-ft)
10-year	5.13	3.5	14.53
25-year	5.98	4.3	17.85
50-year	7.01	5.3	21.93
100-year	7.96	6.2	25.73

Table 4: Detailed cost estimate for floodwall

Item	Description	Quantity	Unit	Unit Price	Total
Design					
	Design	1	LS	$1,970,817.72	$ 1,970,818
	Permitting	1	LS	$1,175,000.00	$ 1,175,000
				Subtotal	$ 3,145,818
Construction					
1	Concrete for base of wall	5,426	CY	$390.00	$ 2,116,111
2	Concrete for wall (13.2 ft)	2,447	CY	$390.00	$ 954,287
3	Concrete for wall (7.2 ft)	814	CY	$390.00	$ 317,460
4	Concrete for slabs (Boat Club to Chart House)	1,724	CY	$450.00	$ 776,000
6	Anchor Bolts, 1.5 ft, 36 in long	388	each	$100.00	$ 38,800
7	Aluminum Planks for Removable Floodwall at road crossings	80	LF	$750.00	$ 60,000
8	Removable floodwall base	2	each	$50,000.00	$ 100,000
7	Pump Stations and Features	3	each	$1,500,000.00	$ 4,500,000
9	Excavation	8,652	CY	$11.05	$ 95,605
10	Easements (10% of construction cost)	1	LS	$895,826.24	$ 895,826
				Subtotal	$ 9,854,089
	Construction Contingency (20%)				$ 1,970,818
	Mobilization/Demobilization/Stakeout ($50,000 min or 5%)				$ 492,704
				TOTAL	$15,463,428
	Annual Maintenance				$3,399,844
	Cost used in BCA				$18,863,273

Pump Stations and Features include costs for: Dewatering, structural, mechanical, HVAC, Electrical, Communication/Control, and site work

Mobilization cost also includes erosion and sediment control measures

Permitting costs include natural resources and cultural resources; assumes NEPA review is not required

Design cost is assumed to be 20 percent of construction costs (without contingency or mobilization)

Exhibit 4-1: Floodwall Drainage Area 1

U.S. Department of Agriculture
Natural Resources Conservation Service

FL-ENG-21B
06/04

TR 55 Worksheet 3: Time of Concentration (T_c) or Travel Time (T_t)

Project: Potomac River Waterfront Flood Mitigation St Designed By: ______ Date: ______

Location: Floodwall Option 2 - Area 1 Checked By: ______ Date: ______

Check one: Present Developed

Check one: ✓ T_c T_t through subarea ______

NOTES: Space for as many as two segments per flow type can be used for each worksheet. Include a map, schematic, or description of flow segments.

Sheet Flow (Applicable to T_c only)		Segment ID	1			
1. Surface description (Table 3-1)			short grass, pr			
2. Manning's roughness coeff., n (Table 3-1)			0.15			
3. Flow length, L (total L ≤ 100 ft)	ft		100			
4. Two-year 24-hour rainfall, P_2	in		3.1			
5. Land slope, s	ft/ft		0.040			
6. $T_t = \frac{0.007 (nL)^{0.8}}{P_2^{0.5} s^{0.4}}$		Compute T_t ... hr	0.13	+		= 0.13

Shallow Concetrated Flow		Segment ID	2			
7. Surface description (paved or unpaved)			paved			
8. Flow length, L	ft		1,000			
9. Watercourse slope, s	ft/ft		0.040			
10. Average velocity, V (Figure 3-1)	ft/s		4.0			
11. $T_t = \frac{L}{3600 V}$		Compute T_t ... hr	0.07	+		= 0.07

Channel Flow		Segment ID				
12. Cross sectional flow area, a	ft^2					
13. Wetted perimeter, P_w	ft					
14. Hydraulic radius, $r = \frac{a}{P_w}$		Compute r ... ft				
15. Channel Slope, s	ft/ft					
16. Manning's Roughness Coeff., n						
17. $V = \frac{1.49 r^{2/3} s^{1/2}}{n}$		Compute V ... ft/s				
18. Flow length, L	ft					
19. $T_t = \frac{L}{3600 V}$		Compute T_t ... hr		+		=

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19 ... hr **0.20**

Exhibit 4-2: Floodwall Drainage Area 2

U.S. Department of Agriculture
Natural Resources Conservation Service

FL-ENG-21B
06/04

TR 55 Worksheet 3: Time of Concentration (T_c) or Travel Time (T_t)

Project: Potomac River Waterfront Flood Mitigation St Designed By: ______ Date: ______

Location: Floodwall Option 2 - Area 2 Checked By: ______ Date: ______

Check one: Present Developed

Check one: ✓ T_c T_t through subarea ______

NOTES: Space for as many as two segments per flow type can be used for each worksheet. Include a map, schematic, or description of flow segments.

Sheet Flow (Applicable to T_c only)

	Segment ID	1			
1. Surface description (Table 3-1)		short grass, pre			
2. Manning's roughness coeff., n (Table 3-1)		0.15			
3. Flow length, L (total L ≤ 100 ft)	ft	100			
4. Two-year 24-hour rainfall, P_2	in	3.1			
5. Land slope, s	ft/ft	0.020			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$ Compute T_t	hr	0.17	+		= 0.17

Shallow Concetrated Flow

	Segment ID	2			
7. Surface description (paved or unpaved)		paved			
8. Flow length, L	ft	1,400			
9. Watercourse slope, s	ft/ft	0.060			
10. Average velocity, V (Figure 3-1)	ft/s	4.0			
11. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	0.10	+		= 0.10

Channel Flow

	Segment ID				
12. Cross sectional flow area, a	ft^2				
13. Wetted perimeter, P_w	ft				
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r	ft				
15. Channel Slope, s	ft/ft				
16. Manning's Roughness Coeff., n					
17. $V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$ Compute V	ft/s				
18. Flow length, L	ft				
19. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr		+		=

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19 ...... hr **0.26**

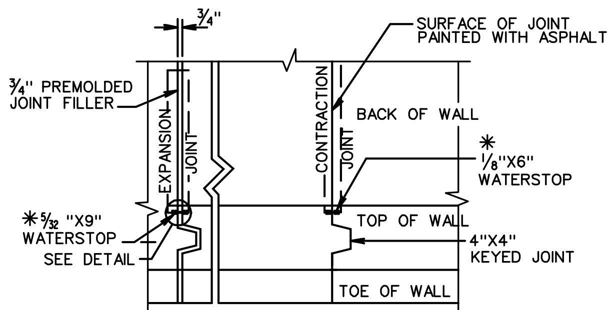
26 min

Appendix G

Elevated Walkway

Exhibit 1: Retaining Wall Specification

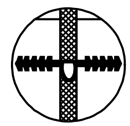
RW-3



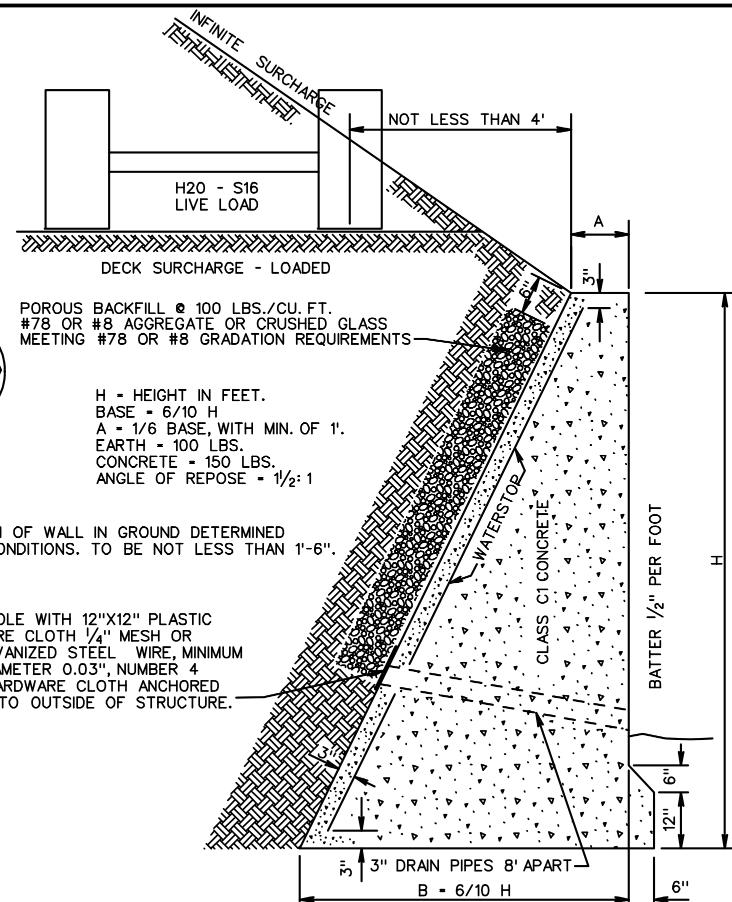
CONTRACTION JOINTS AT INTERVALS NOT EXCEEDING 30'.

EXPANSION JOINTS AT INTERVALS NOT EXCEEDING 90'.

* WATER STOPS TO BE ELASTOMERIC OR OTHER APPROVED MATERIAL. DIMENSIONS SHOWN ARE ABSOLUTE MINIMUM.



WATERSTOP DETAIL



POROUS BACKFILL @ 100 LBS./CU. FT. #78 OR #8 AGGREGATE OR CRUSHED GLASS MEETING #78 OR #8 GRADATION REQUIREMENTS

H - HEIGHT IN FEET.
BASE - 6/10 H
A - 1/6 BASE, WITH MIN. OF 1'.
EARTH - 100 LBS.
CONCRETE - 150 LBS.
ANGLE OF REPOSE - 1 1/2: 1

NOTE:
DEPTH OF WALL IN GROUND DETERMINED BY CONDITIONS. TO BE NOT LESS THAN 1'-6".

WEEP HOLE WITH 12"X12" PLASTIC HARDWARE CLOTH 1/4" MESH OR OR GALVANIZED STEEL WIRE, MINIMUM WIRE DIAMETER 0.03", NUMBER 4 MESH HARDWARE CLOTH ANCHORED FIRMLY TO OUTSIDE OF STRUCTURE.

HEIGHT OF WALL "H" IN FEET	THICKNESS AT TOP "A" IN FEET	THICKNESS AT BASE B=.6H	COMPRESSION AT TOE LBS. PER SQ. FT.	AREA OF SECTION SQ. FT.
3	1'-0"	1'-9 5/8"	856	4.83
4	1'-0"	2'-4 3/4"	1141	7.43
5	1'-0"	3'-0"	1427	10.63
6	1'-0"	3'-7 1/4"	1712	14.43
7	1'-0"	4'-2 3/8"	1997	18.83
8	1'-0"	4'-9 5/8"	2283	23.83
9	1'-0"	5'-4 3/4"	2568	29.43
10	1'-0"	6'-0"	2853	35.63
11	1'-1 1/4 "	6'-7 1/4"	3139	42.98
12	1'-2 3/8 "	7'-2 3/8"	3424	51.03
13	1'-3 5/8 "	7'-9 5/8"	3709	59.78
14	1'-4 3/4 "	8'-4 3/4"	3995	69.23
15	1'-6"	9'-0"	4280	79.38

SAFE BEARING CAPACITY OF SOIL	
ROCK MINIMUM	10,000 - 20,000 LBS. PER SQ. FT.
GRAVEL AND COARSE SAND, WELL CEMENTED	16,000 - 20,000 LBS. PER SQ. FT.
CLAY IN THICK BEDS, ALWAYS DRY	12,000 - 16,000 LBS. PER SQ. FT.
CLAY IN THICK BEDS, MODERATELY DRY	8,000 - 12,000 LBS. PER SQ. FT.
CLAY, SOFT	2,000 - 4,000 LBS. PER SQ. FT.
SAND, DRY, COMPACT, AND WELL CEMENTED	8,000 - 12,000 LBS. PER SQ. FT.
SAND, CLEAN, DRY	4,000 - 8,000 LBS. PER SQ. FT.
ALLUVIAL SOILS, ETC	1,000 - 2,000 LBS. PER SQ. FT.

NOTE: IF COMPRESSION AT TOE EXCEEDS SAFE BEARING CAPACITY OF SOIL, A SPECIAL FOOTING IS TO BE USED.

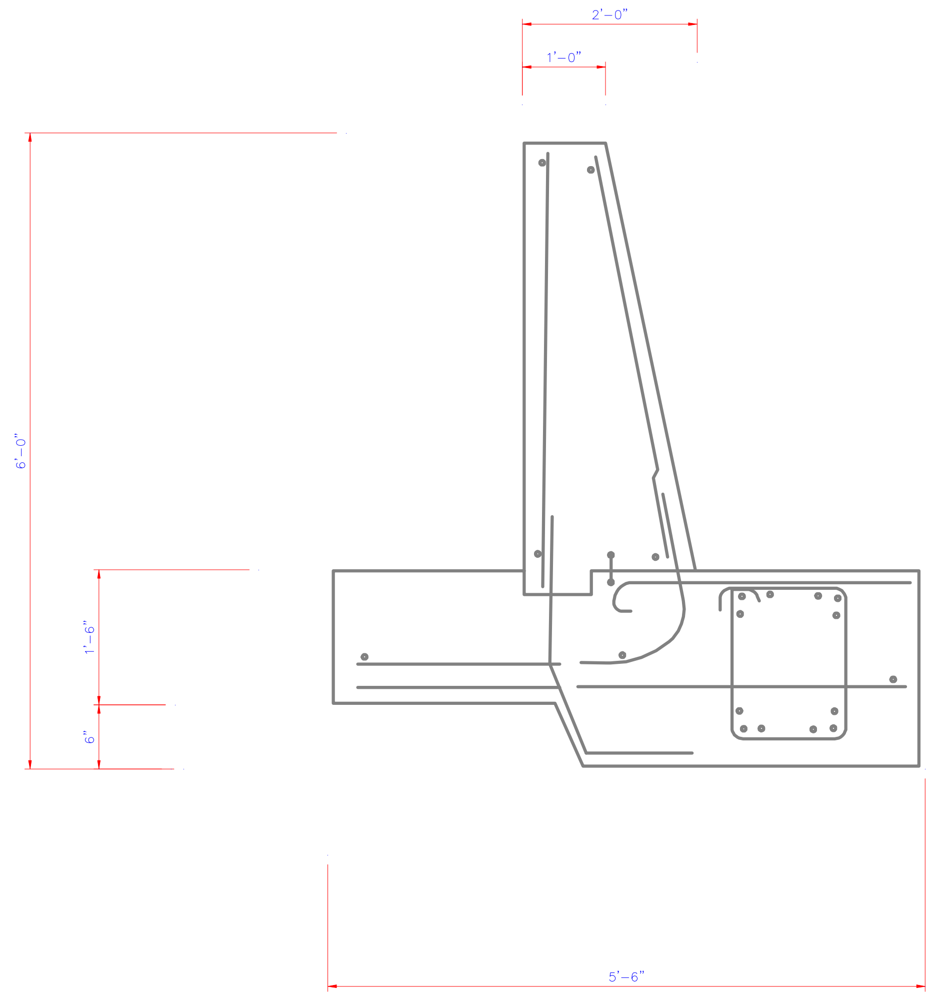
CONCRETE GRAVITY RETAINING WALLS
INFINITE SURCHARGE AND DECK SURCHARGE - LOADED

VIRGINIA DEPARTMENT OF TRANSPORTATION

REV 8/07

401.02

SPECIFICATION REFERENCE: 506



CLIENT	City of Alexandria			TITLE	Elevated Walkway - Cross Section
PROJ	Potomac River Waterfront Flood Mitigation Study			PROJ NO	15298592
REVISION NO 0	DES BY	CJL	09/30/09	EXHIBIT	2
SCALE	DR BY	CJL	09/30/09		
W:\City of Alexandria\15298470 - Lower King St\Report\Draft Report\New Figures\Elevated Walkway Figures\ElevatedWalkway_Spec.mxd	CHK BY	MER	09/10/09		

URS
200 Orchard Ridge Drive
Gaithersburg, MD 20878

Exhibit 3: Various Elevated Walkway Tables

Tables providing additional data for the 550 foot floodwall and elevated walkway design. The drainage area for the 500 foot floodwall is 3.5 acres with a time of concentration of 10 minutes. The drainage area for the walkway at King Street is 19.1 acres with a time of concentration of 11 minutes. The drainage area for the walkway at Duke Street is 4 acres with a time of concentration of 10 minutes. The drainage area for the remainder of the walkway is 4.8 acres with a time of concentration of 10 minutes. The total drainage area of the elevated walkway is 28 acres. Computations for time of concentrations are provided as Exhibit 4 in this appendix.

Table 1: Peak discharges and pipe sizes for 550 foot walkway

Recurrence interval	Intensity (in/hr)	C	Q (cfs)	Q (gpm)	Diameter of the pipe required (ft)
10-year	5.91	0.95	19.2	8,634	1.88
25-year	6.88	0.95	22.4	10,051	1.99
50-year	7.68	0.95	25.0	11,219	2.08
100-year	8.4	0.95	27.3	12,271	2.15

Table 2: Peak discharges and pipe sizes for walkway at King Street

Recurrence interval	Intensity (in/hr)	C	Q (cfs)	Q (gpm)	Diameter of the pipe required (ft)
10-year	5.7	0.95	103.5	46,489	3.54
25-year	6.65	0.95	120.8	54,237	3.75
50-year	7.45	0.95	135.3	60,762	3.91
100-year	8.18	0.95	148.6	66,716	4.05

Table 3: Peak discharges and pipe sizes for walkway at Duke Street

Recurrence interval	Intensity (in/hr)	C	Q (cfs)	Q (gpm)	Diameter of the pipe required (ft)
10-year	5.91	0.95	22.7	10,207	2.00
25-year	6.88	0.95	26.5	11,883	2.12
50-year	7.68	0.95	29.5	13,264	2.21
100-year	8.4	0.95	32.3	14,508	2.29

Table 4: Peak discharges and pipe sizes for remainder of walkway drainage area

Recurrence interval	Intensity (in/hr)	C	Q (cfs)	Q (gpm)	Diameter of the pipe required (ft)
10-year	5.91	0.95	26.8	12,048	2.13
25-year	6.88	0.95	31.2	14,025	2.26
50-year	7.68	0.95	34.9	15,656	2.35
100-year	8.4	0.95	38.1	17,124	2.43

Table 5: Flood runoff and volume table for elevated walkway

Recurrence interval	24-hour Rainfall (in)	Runoff, Q (in)	Volume (ac-ft)
10-year	5.13	3.5	8.43
25-year	5.98	4.3	10.35
50-year	7.01	5.3	12.72
100-year	7.96	6.2	14.92

Table 6: Flood runoff and volume table for 550 foot floodwall

Recurrence interval	24-hour Rainfall (in)	Runoff, Q (in)	Volume (ac-ft)
10-year	5.13	3.5	0.99
25-year	5.98	4.3	1.22
50-year	7.01	7.01	1.50
100-year	7.96	7.96	1.76

Table 7: Detailed cost estimate for elevated walkway and 550 foot floodwall

Item	Description	Quantity	Unit	Unit Price	Total
Design					
	Design	1	LS	$604,170.85	$ 604,171
	Permitting	1	LS	$650,000.00	$ 650,000
				Subtotal	$ 1,254,171
Construction					
1	Concrete for base of elevated walkway	521	CY	$390.00	$ 203,378
2	Concrete for wall of elevated walkway	379	CY	$390.00	$ 147,911
3	Concrete for base of 550 foot floodwall	130	CY	$390.00	$ 50,844
4	Concrete for wall of 550 foot floodwall	122	CY	$390.00	$ 47,667
5	Bituminous Sidewalk, 1" thick paving, 4" gravel base, 5' width	1,276	LF	$8.02	$ 10,234
6	Common earth backfill	2,269	CY	$13.46	$ 30,541
7	Pump Stations and Features	2	each	$1,150,000.00	$ 2,300,000
8	42" concrete pipe	1,470	lf	$144.00	$ 211,680
9	Curb inlet frame, grate, curb box: Large 24" x 36" heavy duty	2	each	$1,250.00	$ 2,500
10	Flap Gates	2	each	$8,050.00	$ 16,100
11	Excavation	4,067	CY	$11.02	$ 44,818
12	Easements (10% of construction cost)	1	LS	$306,567.26	$ 306,567
				Subtotal	$ 3,020,854
	Construction Contingency (20%)				$ 604,171
	Mobilization/Demobilization/Stakeout ($50,000 min or 5%)				$ 151,043
				TOTAL	$ 5,030,239
	Annual Maintenance				$1,042,251
	Cost used in BCA				$ 6,072,490

Exhibit 4-1: 550 foot Floodwall

U.S. Department of Agriculture
Natural Resources Conservation Service

FL-ENG-21B
08/04

TR 55 Worksheet 3: Time of Concentration (T_c) or Travel Time (T_t)

Project: Potomac River Waterfront Flood Mitigation St Designed By: ____________ Date: ________

Location: 550 foot Floodwall Checked By: ____________ Date: ________

Check one: Present Developed

Check one: ✓ T_c T_t through subarea ____________

NOTES: Space for as many as two segments per flow type can be used for each worksheet. Include a map, schematic, or description of flow segments.

Sheet Flow (Applicable to T_c only) — Segment ID	1			
1. Surface description (Table 3-1)	short grass, pr			
2. Manning's roughness coeff., n (Table 3-1)	0.15			
3. Flow length, L (total L ≤ 100 ft) ... ft	100			
4. Two-year 24-hour rainfall, P_2 ... in	3.1			
5. Land slope, s ... ft/ft	0.060			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t ... hr	0.11	+		= 0.11
Shallow Concetrated Flow — Segment ID	2			
7. Surface description (paved or unpaved)	paved			
8. Flow length, L ... ft	900			
9. Watercourse slope, s ... ft/ft	0.080			
10. Average velocity, V (Figure 3-1) ... ft/s	4.0			
11. $T_t = \frac{L}{3600\,V}$ Compute T_t ... hr	0.06	+		= 0.06
Channel Flow — Segment ID				
12. Cross sectional flow area, a ... ft^2				
13. Wetted perimeter, P_w ... ft				
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r ... ft				
15. Channel Slope, s ... ft/ft				
16. Manning's Roughness Coeff., n ...				
17. $V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$ Compute V ... ft/s				
18. Flow length, L ... ft				
19. $T_t = \frac{L}{3600\,V}$ Compute T_t ... hr		+		=
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) ... hr				0.17

Exhibit 4-2: Elevated Walkway - King Street

U.S. Department of Agriculture
Natural Resources Conservation Service

FL-ENG-21B
06/04

TR 55 Worksheet 3: Time of Concentration (T_c) or Travel Time (T_t)

Project: Potomac Waterfront Flood Mitigation Study Designed By: ____________ Date: ____

Location: Elevated Walkway - King Street - Post Diver Checked By: ____________ Date: ____

Check one: Present Developed

Check one: ✓ T_c T_t through subarea ____________

NOTES: Space for as many as two segments per flow type can be used for each worksheet. Include a map, schematic, or description of flow segments.

Sheet Flow (Applicable to T_c only)

Segment ID	1			
1. Surface description (Table 3-1)	short grass, pr			
2. Manning's roughness coeff., n (Table 3-1)	0.15			
3. Flow length, L (total L ≤ 100 ft) ... ft	100			
4. Two-year 24-hour rainfall, P_2 ... in	3.1			
5. Land slope, s ... ft/ft	0.070			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t ... hr	0.10	+		= 0.10

Shallow Concetrated Flow

Segment ID	2			
7. Surface description (paved or unpaved)	paved			
8. Flow length, L ... ft	1,100			
9. Watercourse slope, s ... ft/ft	0.070			
10. Average velocity, V (Figure 3-1) ... ft/s	4.0			
11. $T_t = \frac{L}{3600\,V}$ Compute T_t ... hr	0.08	+		= 0.08

Channel Flow

Segment ID				
12. Cross sectional flow area, a ... ft^2				
13. Wetted perimeter, P_w ... ft				
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r ... ft				
15. Channel Slope, s ... ft/ft				
16. Manning's Roughness Coeff., n ...				
17. $V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$ Compute V ... ft/s				
18. Flow length, L ... ft				
19. $T_t = \frac{L}{3600\,V}$ Compute T_t ... hr		+		=

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19 ... hr **0.18**

Exhibit 4-3: Elevated Walkway - Prince Street

U.S. Department of Agriculture
Natural Resources Conservation Service

FL-ENG-21B
06/04

TR 55 Worksheet 3: Time of Concentration (T_c) or Travel Time (T_t)

Project: Potomac River Flood Mitigation Study Designed By: ________ Date: ________

Location: Elevated Walkway - Prince St - Post Diversi Checked By: ________ Date: ________

Check one: Present Developed

Check one: ✓ T_c T_t through subarea ________

NOTES: Space for as many as two segments per flow type can be used for each worksheet. Include a map, schematic, or description of flow segments.

Sheet Flow (Applicable to T_c only)

	Segment 1	Segment 2	Total
Segment ID	1		
1. Surface description (Table 3-1)	short grass, pr		
2. Manning's roughness coeff., n (Table 3-1)	0.15		
3. Flow length, L (total L ≤ 100 ft) ... ft	100		
4. Two-year 24-hour rainfall, P_2 ... in	3.1		
5. Land slope, s ... ft/ft	0.070		
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t ... hr	0.10	+	= 0.10

Shallow Concetrated Flow

	Segment 1	Segment 2	Total
Segment ID	2		
7. Surface description (paved or unpaved)	paved		
8. Flow length, L ... ft	1,000		
9. Watercourse slope, s ... ft/ft	0.070		
10. Average velocity, V (Figure 3-1) ... ft/s	4.0		
11. $T_t = \frac{L}{3600\,V}$ Compute T_t ... hr	0.07	+	= 0.07

Channel Flow

	Segment 1	Segment 2	Total
Segment ID			
12. Cross sectional flow area, a ... ft^2			
13. Wetted perimeter, P_w ... ft			
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r ... ft			
15. Channel Slope, s ... ft/ft			
16. Manning's Roughness Coeff., n ...			
17. $V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$ Compute V ... ft/s			
18. Flow length, L ... ft			
19. $T_t = \frac{L}{3600\,V}$ Compute T_t ... hr		+	=

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19 ... hr **0.17**

Appendix H
Berm

Various Jones Point Berm Tables

Tables providing additional data for the Jones Point Berm design. Drainage Area 1 is 3.5 acres and Drainage Area 2 is 3.2 acres. A time of concentration of 5 minutes was assumed for both areas.

Table 1: Stage-Storage information for Drainage Area 2

Elevation (ft)	Area (sq ft)	Area (ac)	Average Area (ac)	Depth (ft)	Interval Storage (ac-ft)	Cumulative Storage (ac-ft)
6	4,780	0.110				0.000
			0.218	2.00	0.437	
8	14,249	0.327				0.437
			0.457	2.00	0.915	
10	25,604	0.588				1.352

Table 2: Peak discharges and pipe sizes for berm drainage area 1

Recurrence interval	24-hour Rainfall (in)	Runoff, Q (in)	Volume (ac-ft)
10-year	5.13	3.5	1.02
25-year	5.98	4.3	1.25
50-year	7.01	5.3	1.53
100-year	7.96	6.2	1.80

Table 3: Peak discharges and pipe sizes for berm drainage area 2

Recurrence interval	24-hour Rainfall (in)	Runoff, Q (in)	Volume (ac-ft)
10-year	5.13	3.5	0.93
25-year	5.98	4.3	1.14
50-year	7.01	5.3	1.40
100-year	7.96	6.2	1.65

Table 4: Detailed cost estimate for berm

Item	Description	Quantity	Unit	Unit Price	Total
Permitting					
	Design	1	LS	$534,233.94	$ 534,234
	Permitting	1	LS	$210,000.00	$ 210,000
				Subtotal	$ 744,234
Construction					
1	Common Earth	12,786	CY	$13.45	$ 171,972
2	Clay Fill	2,538	CY	$21.00	$ 53,298
3	Curb Inlet frame, grate, curb box: Large 24" x 36" heavy duty	4	each	$1,250.00	$ 5,000
4	36" concrete pipe	400	LF	$112.00	$ 44,800
5	48" concrete pipe	450	LF	$189.00	$ 85,050
6	36" aluminum flap gates	2	each	$5,525.00	$ 11,050
7	Pump Station and Features	2	each	$1,150,000.00	$2,300,000
				Subtotal	$2,671,170
	Construction Contingency (20%)				$ 534,234
	Mobilization/Demobilization/Stakeout ($50,000 min or 5%)				$ 133,558
				TOTAL	$4,083,196
	Annual Maintenance				$1,408,779
	Cost used in BCA				$5,491,975

Pump Stations and Features include costs for: Dewatering, structural, mechanical, HVAC, Electrical, Communication/Control, and site work

Mobilization cost also includes erosion and sediment control measures

Permitting costs include natural resources and cultural resources

Design cost is assumed to be 20 percent of construction costs (without contingency or mobilization)

Appendix I

Roadway Drainage

Roadway Drainage Additional Data

Table 1: Detailed cost estimate for roadway and inlet improvements

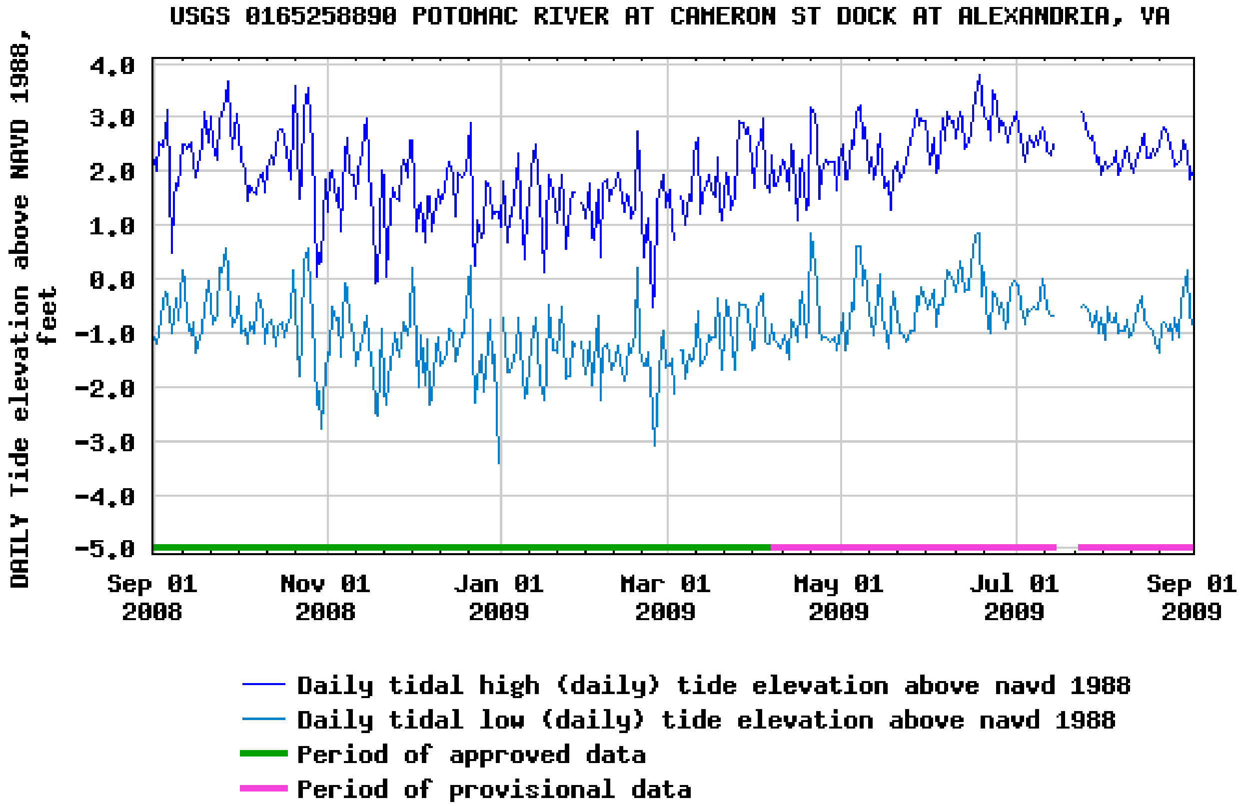
Item	Description	Quantity	Unit	Unit Price	Total
Design					
	Design	1	LS	$56,523.78	$ 56,524
	Permitting	1	LS	$120,000	$120,000
				Subtotal	$176,524
Construction					
1	Pavement Removal, bituminous roads, 4" to 6" thick	2,633	SY	$7.90	$ 20,801
2	Grading Subgrade for base course	2,633	SY	$0.42	$ 1,106
3	Asphaltic Concrete Pavement, Binder, coarse, 4" thick	2,633	SY	$15.54	$ 40,917
4	Common Earth fill (for road elevation)	3,950	CY	$13.45	$ 53,128
4	Cement Concrete Curb and Gutter, steel forms, 6"x18", straight	1,220	LF	$9.90	$ 12,078
5	Manhole/inlet frames and covers, including row of brick, concrete collar	8	each	$265	$ 2,120
6	Storm Drainage Manholes, Frames and Covers, Brick 4' deep	8	each	$1,325	$ 10,600
6	Brick Paving for sidewalk replacement	6,100	SF	$12.10	$ 73,810
7	Trench Drain	83	LF	$820	$ 68,060
				Subtotal	$282,619
	Construction Contingency (20%)				$ 56,524
	Mobilization/Demobilization/Stakeout ($50,000 min or 5%)				$ 50,000
				TOTAL	$565,666
	Annual Maintenance Cost used in BCA				$565,666

Permitting costs include natural resources and cultural resources.

Mobilization cost also includes erosion and sediment control measures.

Design cost is assumed to be 20 percent of construction costs (without contingency or mobilization).

Figure 1: USGS Gage Data



Appendix J

Property Acquisition

Exhibit 1. Additional Costs for Acquisition

Administrative Costs for each Focus Area

The Administrative costs were based on a sliding scale provided by the FEMA Property Acquisition Handbook, as shown in Figures 1 and 2 below. They include the extraordinary costs the community may incur to administer funding, such as the cost of preparing reports, overtime, and incidental expenses.

Figure 1:

Sliding Scale

Project Costs	Percent
first $100,000	3%
next $900,000	2%
next $4,000,000	1%
costs over $5,000,000	½%

Figure 2:

Project Costs	Scale	Administrative Costs
$6,000,000	$100,000 x 3%	$3,000
($6,000,000-$1000,000) $5,900,000	$900,000 x 2%	$18,000
($5,900,00-$900,000) $5,000,000	$4,000,000 x 1%	$40,000
($5,000,00-$4,000,000) $1,000,000	$1,000,000 x ½%	$5,000
Total Administrative Costs		**$66,000**

Appraisals
Based on data from AppraiserUniverse.com, residential appraisals in Virginia are $350 on average.

An average of $3500 was used for the commercial calculations based on a phone call to Northern Virginia Appraisal Services.

Property Survey
Based on information from a CNNMoney.com article, property surveys will typically cost between $500 and $1500. Property surveys may be more costly for larger properties. We used $250 for residential properties and $3500 for commercial properties in our cost estimates.

Closing
Based on information from various real estate websites, closing costs in Virginia are between 2-3% of the property sale price, so 2.5% was used in our computations.
http://www.zimbio.com/Real+Estate/articles/414/Purchaser+Closing+Costs+Virginia

Demolition
Demolition fees for structures in Virginia average between $6 and $15 per square foot. If asbestos is present, demolition will be an additional $2-$3 per square foot.
Source: phone calls to Aceco LLC and Demolition Services Inc.

Relocation
Residential: $3,500 per building
Source: phone calls to Jk Moving and Storage, Twins moving and storage

Commercial: $ 121,751

Table 1: Estimate of Average Commercial Relocation Expenses

SBA Referenced Example Costs[1]	Estimated Costs
Legal/Licenses/Permits	$1,000
Printed materials	$7,500
Consultants	$15,000
Insurance	$250
Research and Development	$1,000
Expensed Equipment	$3,500
Other	$5,000
Loss of Revenue[2]	$32,501
Utility fees	$1,000
Additional marketing	$5,000
Retrofit costs	$20,000
Moving Company[3]	$30,000
TOTAL	$121,751

[1] The Small Business Administration directs users looking for commercial startup costs to the PaloAlto Startup Cost Estimator. PaloAlto provided an example of startup costs for businesses at the following link: http://articles.bplans.com/starting-a-business/estimating-realistic-start-up-costs.
[2] Loss of Revenue assumed average loss of business for one week of interrupted time.
[3] Based on estimate for average commercial area for the project of 15215 square feet. Made calls to two local moving companies using assumption of move of less than 50 miles on 2nd floor of a building without elevator access. One quote was for $15,000 and another was for $45,000. The average of $30,000 was used.

Please note that the values are only approximate. Most of the cost in property acquisition is the FMV of the property.

Exhibit 2. Total Other Costs for Property Acquisition

The following tables list the other projects costs (outlined in Exhibit 1) for each study area. These costs were used to calculate the total cost of property acquisition.

Table 1: Jones Point Residential Acquisition Costs

Project Costs		
Appraisal		4,550
Relocation Assistance		45,500
Closing		21,059
Demolition		192,083
Property Survey		3,250
Total Project Costs		**$266,442**
Administrative Costs		
Project Cost (10,950,643 + 266,422 = $11,217,085)	*Percent*	
100,000	0.03	3,000
900,000	0.02	18,000
4,000,000	0.01	40,000
6,217,085	0.005	31,085
Total Administrative Costs		**$92,085**
TOTAL OTHER COSTS		**$358,527**

Table 2: King Street Commercial Acquisition Costs

Project Costs		
Appraisal		80,500
Relocation Assistance		2,800,273
Closing		2,025,961
Demolition		1,160,880
Property Survey		57,500
Total Project Costs		**$6,125,114**
Administrative Costs		
Project Cost (85,319,319 + 6,125,144 = 91,444,433)	*Percent*	
100,000	0.03	3,000
900,000	0.02	18,000
4,000,000	0.01	40,000
86,444,433	0.005	432,222
Total Administrative Costs		**$493,222**
TOTAL OTHER COSTS		**$6,618,336**

Table 3: King Street Residential Acquisition Costs

Project Costs		
Appraisal		1,750
Relocation Assistance		17,500
Closing		107,022
Demolition		76,410
Property Survey		1,500
Total Project Costs		**$204,182**
Administrative Costs		
Project Cost (85,319,319 + 204,182 = 85,523,501)	*Percent*	
100,000	0.03	3,000
900,000	0.02	18,000
4,000,000	0.01	40,000
80,523,501	0.005	402,618
Total Administrative Costs		**$463,618**
TOTAL OTHER COSTS		**$667,800**

Table 4: North Union Acquisition Costs

Project Costs		
Appraisal		11,900
Relocation Assistance		119,000
Closing		462,654
Demolition		690,105
Property Survey		8,500
Total Project Costs		**$1,292,159**
Administrative Costs		
Project Cost (18,506,176 + 1,292,159 = 19,798,335)	*Percent*	
100,000	0.03	3,000
900,000	0.02	18,000
4,000,000	0.01	40,000
14,798,335	0.005	73,992
Total Administrative Costs		**$134,992**
TOTAL OTHER COSTS		**$1,427,151**

Table 5: Waterfront Commercial Acquisition Costs

Project Costs		
Appraisal		77,000
Relocation Assistance		2,678,522
Closing		2,475,027
Demolition		3,974,049
Property Survey		55,000
Total Project Costs		**$9,259,598**
Administrative Costs		
Project Cost (99,001,085 + 9,259,598 = 108,260,683)	*Percent*	
100,000	0.03	3,000
900,000	0.02	18,000
4,000,000	0.01	40,000
103,260,683	0.005	516,303
Total Administrative Costs		**$577,303**
TOTAL OTHER COSTS		**$9,836,901**

Exhibit 3. Method for Calculating the Fair Market Value

Market Data Method or sales comparison method was used for calculating the Fair Market Value (FMV). The market data estimate of FMV is obtained by comparing the subject property with "comparable" properties that have been sold. The properties need to have similar location, physical features, condition, etc. in order to be suitable to use to obtain an accurate FMV.

The following data was collected from http://realestate.alexandriava.gov

1. Assessed Land Value [Land_Value]
2. Assessed Building Value [Building_Value]
3. Sale Date [Sale_Date]
4. Sale Price [Sale_Price]
5. Assessed Value at time of the sale - up to year 2000 [Ass_at_sal]
6. Year Build [Year_Built]
7. Construction Quality [Constr_Quality]
8. Story [Story]
9. Ext. Wall Construction[Ext_Wall]
10. Above Grade Living Area (Does not include basement area) [BLDGSF]
11. Total Basement Area [Bsm_A_sqf]

Data was collected for 55 commercial and 395 Residential units. Most of these properties were within the 100-year floodplain; however, data collection also included additional buildings just outside the floodplain that were connected to a row house or part of the same complex that were within the floodplain. This was important to increase the accuracy. Some of the row townhouses were studied as one unit.

Method for calculating the RATIO.

RATIO = Average(Sale Price/Assessed Value at time of sale)

The ratio that was used for the FMV was based on available sales data since 2000. Usually the last 12 months sales data is used when using the Market Data Method. However because of the limitation on the available sales prices and an extreme market situation, an average ratio was used which is a more conservative estimate than the past twelve month ratio.

Method for Calculating the FMV

FMV = (Property OR Building Value)*RATIO

NOTE: For acquisition the price for the land and building (property) was used, while for DDV only the building price was used.

Appendix K

Floodproofing

Exhibit 1. Floodproofing Cost Estimates

Flood Gate

Price quotes from DoorDam's website, http://www.doordam.com/, show floodgates priced from $500-$700 dollars. Therefore, the average price for a floodgate was estimated to be $600.

Floodproof Doors

Price quotes from FloodGuard UK's website, http://www.floodguarduk.co.uk/en-us/front.html, showed floodproof doors to cost approximately 4,500 pounds or about $7,000.

Raising the Lowest Adjacent Grade (LAG)

RSMeans 2009 was used to estimate the cost for raising the LAG. This price included cost and labor for fill placement and rebuilding a surface if necessary (i.e. patio or driveway). The fill costs were based on the estimate of 300 cubic yards of clay soil, which would be about $1,100. The rebuild price was estimated to be about $4,200. Therefore the total cost for raising the LAG was estimated to be about $5,300.

Internal Elevation

Price quotes from Access Floor System's website, http://www.accessfloorsystems.com/, were used to estimate the cost for internal elevation. The website has a tool that provides a price estimate based on the square footage, height of elevation, and materials used. Two focus areas, King Street and Waterfront, have structures that were considered for internal elevation. Separate price estimates were generated for each of the focus areas, using the average square footage from the GIS data provided by the City. The structures where internal elevation is considered in the King Street focus area have an average area of about 3,600 square feet. This resulted in a price estimate of approximately $69,700 per structure for internal elevation in the King Street focus area. The structures where internal elevation is considered in the Waterfront focus area have an average area of about 24,500 square feet. This resulted in a price estimate of approximately $430,500 per structure for internal elevation in the Waterfront focus area.

Cost Benefit Ratio

In an effort to make sure the costs for floodproofing are not underestimated in the BCR calculations, the price estimates were all increased by 50 percent to account for shipping, installation, and any other unforeseen costs. The price estimates used are shown in Table 1 below.

Table 1: Price Estimates for Floodproofing Measures

Method	Cost per Unit
Flood Gate	$900.00
Flodproof Door	$10,000.00
Raise Patio / Fill	$8,000.00
Internal Elevation (King Street)	$104,580.00
Internal Elevation (Waterfront)	$645,688.50

Exhibit 2. Window Replacement Costs

Cost estimates were derived for window replacements in historic Alexandria from the Fairfax Glass Company of Falls Church, Virginia and the American Housing Contractor of Fairfax, Virginia. Both estimates were based on the type of material used (wood or aluminum) and whether or not a true replication of the existing window is required. Considering that windows should meet historic district criteria, the conservative cost estimate of window replacement received was approximately $100 per square foot. To calculate the estimated price of window replacements, average window size, sales tax and any contingencies during installation were considered.

For residential properties, colonial windows with dimensions of 6 feet x 4 feet at $100 per square foot for a 24 square foot window, the cost of one colonial window is $2,400. With a five percent sales tax and accounting for 20 percent for contingencies, the total cost is approximately $3,000 per residential window.

Because commercial windows are larger and may be more difficult to replace, commercial windows were assumed to be twice as expensive as residential. Therefore, window replacement for commercial properties in the historic district is approximately $6,000 per window.

Another option besides replacing historic windows would be to modify existing windows using secondary glazing and caulking. This method is designed to stop water penetration. It meets the historical requirements in Alexandria and does not affect the window appearance. The cost of secondary glazing for windows is between $300 and $400, depending on window size.

Window replacement is suggested instead of window shields to preserve the aesthetics of the historic district. Window replacement prices will vary based on size and specifications. Windows should be appropriate to the historic period and architectural style of the building. Specific information on acceptable window types can be found in the City of Alexandria's *Design Guidelines for the Old and Historic Alexandria District and the Parker-Gray District*.

References:

Buck Schuckman from Fairfax Glass Company. Falls Church, VA. 703-560-1140
Danny Kim from American Housing Contractor (Marvin Windows). Fairfax, VA. 703-293-6393
Nick Kalivretenos. The Window Man. 703-932-7220. 3000 Jefferson Davis Hwy. Alexandria, Virginia 22305

Design Guidelines for the Old and Historic Alexandria District and the Parker-Gray District, City of Alexandria, Virginia, Department of Planning and Community Development.

Mon-Ray Inc, Storm Window Search, Accessed September 2009
http://www.monray.com/mr500.htm

Exhibit 3. FEMA guidance on floodproofing utility systems.

You Can Floodproof Your Utility Systems Before Disaster Strikes

Release Date: October 23, 2006
Release Number: 1661-010

GLEN ALLEN, VA -- If you aren't located in a flood zone, you may think you don't have to worry about protecting your home or business against flood damage. But, Mother Nature would tell you otherwise. Nearly a quarter of National Flood Insurance (NFIP) claims come from areas that aren't considered at high risk for flooding.

The Federal Emergency Management Agency (FEMA) has information for both home and business property owners on how to floodproof electrical, plumbing and heating systems.

"Before they begin, property owners must call their local planning commission to get the base flood-elevation levels for their location," said Gracia Szczech, FEMA's federal coordinating officer for recovery operations. "Specific rules apply based on your community's risk for floods."

Advice for property owners is available on FEMA's web site, www.floodsmart.gov, that will save you money and, in the long run, help keep your home or business safe.

"The first and most important thing a property owner should do is elevate electrical and heating systems 12 inches above the height water would reach during a 100-year flood event or the highest known flood levels for the area," said Michael Cline, the state coordinating officer. "That information is available from your local planning commission office, and making use of it could save you a lot of money and inconvenience in the future."

Below are other important safety measures to take before the next flood:

Electrical and Heating Systems

- Elevate all outlets, switches, light sockets and junction boxes, as well as the main breaker or fuse box and electric motors. Junctions should be located in approved junction boxes with the 100-year rule in mind.
- Run wires overhead. If they have to be in areas where they could get wet, use a wire rated for underground use.
- Elevate electric baseboard heater systems. For the wall area below the baseboard units, use waterproof wall construction materials and techniques.

- Elevate or relocate the electric panel with the 100-year rule in mind. The maximum panel height is regulated by the code. Check with your local county commission office for the maximum height that applies to your community.
- Elevate or relocate the heating unit. Consider installing utilities on the second floor or in the attic. If you are replacing your furnace, ask the supplier for information about a downdraft system.
- You can also consider suspending the heating system, making sure it is 12 inches above the highest flood levels.
- Elevate your air conditioner or heat pump on masonry, concrete or pressure-treated lumber base at least 12 inches above the highest flood levels.
- Anchor your fuel tank. Unanchored fuel tanks can tip over or float, and escaping fuel may result in spills or fires. Use non-corrosive metal structural supports and fasteners. Check with the fuel tank manufacturer for recommendations since the type of anchorage, including slab dimensions, varies depending on tank size. Keep the tank topped off to reduce its tendency to float.

Appliances

- Elevate a basement-level washer and dryer on a masonry or pressure treated lumber base to at least 12 inches above the highest flood levels.
- Relocate the washer and dryer to a higher floor in the home.
- Elevate or relocate the water heater to at least 12 inches above the highest flood levels.

When making repairs or putting up a building, you should always check with the local planning commission, local building official or floodplain administrator to make sure you are following local zoning regulations and state and local building codes. Damaged properties should be checked before any work, since repairs to very badly damaged buildings are not permitted.

Be sure you have all the necessary permits before any work begins. Electrical wiring has to be done by a licensed electrician and approved by the building department.

For more information on how to protect your home, call FEMA publications at 1-800-480-2520 and ask for booklet F-0206, Coping With a Flood; Before, During and After.

FEMA manages federal response and recovery efforts following any national incident, initiates mitigation activities and manages the National Flood Insurance Program. FEMA works closely with state and local emergency managers, law enforcement personnel, firefighters and other first responders. FEMA became part of the U.S. Department of Homeland Security on March 1, 2003.

Source: http://www.fema.gov/news/newsrelease.fema?id=30984

Appendix L

Potential Federal Funding Options

Potential Federal Funding Options

Overview

A number of the flood mitigation activities recommended in the Potomac River Waterfront Flood Mitigation Study carry significant capital improvement costs and operation and maintenance expenditures. Available funding sources include:

- Government Grants
- Revenue Bonds
- Enterprise Funds
- Special Purpose Local Option Sales Taxes
- State Revolving Fund Loans
- Impact Fees
- Special Assessments

There are several Federal grants that may be appropriate with the mitigation measures recommended in this Potomac River Waterfront Flood Mitigation Study. Information regarding these grants can be accessed in a variety of ways.

As part of the Federal government's E-Grants Initiative the Grants.gov Web site: http://www.grants.gov/ is a central repository and clearinghouse for over 1,000 grants with over $500 billion in awards per year. Through Grants.gov over 300,000 applications were submitted in fiscal year 2009. Grants.gov provides a grants search engine with several search categories including agency name or funding activities. The most appropriate grants for flood mitigation are those administered by FEMA's Hazard Mitigation Assistance (HMA) grant programs.

FEMA has detailed descriptions of each of its HMA grant programs on its Web site http://www.fema.gov/government/grant/hma/index.shtm. However, since applications for these programs are submitted through individual State governments, it is required that the City of Alexandria coordinate with the Virginia Department of Emergency Management (VDEM) when preparing HMA grant applications. It is important to note that, in addition to FEMA deadlines, VDEM has its own internal deadlines for the acceptance of grant applications. VDEM provides information on grant opportunities on its Web site, including an E-mail alert service to receive Grant Alerts http://www.vaemergency.com/grants/index.cfm.

While there are numerous grant options, eligibility requirements can restrict the types of funding mechanisms available to the City. Some common eligibility restrictions include:

- Grants by invitation only (e.g., Economic Development Initiative—Special Project)
- Open only to rural communities or disadvantaged populations
- Participation in the National Flood Insurance Program (NFIP)
- Inclusion in a recent Presidential major disaster declaration that is still open

Hazard Mitigation Assistance (HMA) Grant Programs

Under the Department of Homeland Security (DHS), FEMA oversees HMA grant programs. The five different HMA programs are listed below with the associated Catalog of Federal Domestic Assistance (CFDA) numbers.

- Hazard Mitigation Grant Program (HMGP) – CFDA 97.039
- Pre-disaster Mitigation (PDM) – CFDA 97.047
- Flood Mitigation Assistance (FMA) – CFDA 97.029
- Repetitive Flood Claims (RFC) – CFDA 97.092
- Severe Repetitive Loss (SRL) – CFDA 97.110

The FEMA brochure included in this appendix provides an overview of each program including cost share requirements, subapplicant eligibility, available funding, eligible activities, management costs, and general requirements.

The PDM, FMA, RFC, and SRL programs are subject to the availability of appropriation funding. The HMA Unified Guidance for Fiscal Year 2011 (FY11) was released on June 1, 2010. The application period for PDM, FMA, RFC and SRL is June 1, 2010, to December 3, 2010. FEMA intends to report projects identified for further review in March 2011. During that time the City of Alexandria must work with VDEM to submit grant applications to FEMA through eGrants. It is important to note that VDEM has its own internal deadlines for the acceptance of grant applications.

HMGP grants can only be sought after a major disaster declaration within the Commonwealth of Virginia. FEMA posts disaster declarations at http://www.fema.gov/news/disasters.fema. The amount of funding available to the applicant depends on the funding allocated by FEMA for disaster recovery under the major disaster declaration. Typically a major disaster declaration is active for 12 months. As with the other HMA grant programs, the City of Alexandria is required to coordinate with VDEM to submit an HMGP grant application to FEMA. VDEM has its own internal deadlines for the acceptance of grant applications. As of July 2010, the VDEM deadlines have passed for the three active major disaster declarations. However, major disaster declarations happen relatively frequently, and the type of mitigation measure for which HMGP funding is sought does not necessarily have to mitigate the effects of the hazard that led to the disaster declaration.

Applicability for the Potomac River Waterfront Flood Mitigation Study

The mitigation measures recommended for the City of Alexandria that may be available for funding through the HMA programs include the following:

- Elevated pedestrian walkway
- Dry floodproofing
- Inlet and road elevation improvement

Table 1 summarizes the mitigation measure activities allowed for funding through the above-mentioned programs.

Table 1. HMA Funding Options by Project Type

Flood Mitigation Project Type	HMGP	PDM	FMA	RFC	SRL
Dry Floodproofing					
Historic residential	x	x	x	x	x
Non-residential	x	x	x	x	
Elevated Pedestrian Walkway	x	x	x		
Inlet and Road Elevation Improvements	x	x			

In general, HMA funds may be used to pay up to 75 percent of the eligible activity costs. The remaining 25 percent of eligible activity costs are derived from non-Federal sources. More information about each program can be found on the FEMA HMA Web site: www.fema.gov/government/grant/hma/index.shtm.

Dry Floodproofing

Funding for dry floodproofing is available under most HMA grant programs. Floodproofing is typically only allowed for non-residential structures. Historic residential structures may be considered for dry floodproofing when other techniques that would mitigate to the BFE would cause the structure to lose its status. Structures that remain in the Special Flood Hazard Area (SFHA) after the implementation of the mitigation project, must maintain flood insurance for the life of the structure.

Elevated Walkway

Localized minor flood reduction projects are fundable under the HMGP, PDM and FMA grant programs. These projects may include the installation or modification of culverts and floodgates, minor floodwall systems that generally protect an individual structure or facility, stormwater management activities such as creating retention and detention basins, and the upgrade of culverts to bridges. Whereas, major flood control projects related to the construction of a floodwall or seawall are not eligible projects.

The elevated walkway is considered a floodwall. As of July 2010, FEMA does not have a definitive description of a large flood control system. However, the elevated walkway proposed in this study is not a typical mitigation measure. It is a site specific flood barrier and does not greatly alter the grounds of the floodplain or impound water; therefore, there is a chance that it will be considered a localized minor flood reduction project.

Inlet and Road Elevation Improvements

Raising the road elevations and inlet openings for catch basins would be considered an infrastructure retrofit project, which is eligible for both HMGP and PDM grants. PDM grants can be pursued through the VDEM application schedule. For an HMGP grant, the City could prepare to apply, but would need to wait for a disaster declaration before it could submit an application to VDEM and FEMA.

Grant Application Elements

The PDM, FMA, RFC, and SRL applications must be submitted through the eGrants system by the applicant, generally VDEM, by December 3, 2010, at 3 PM Eastern Time. Prior to the submission, applicants and subapplicants such as the City of Alexandria are encouraged to work with their regional FEMA office to ensure that the application is complete, clear, and appropriate for the grant program. The application must be cost-effective, technically feasible, effective at mitigating risk, and able to meet HMA Unified Guidance program requirements including Environmental Planning and Historic Preservation requirements.

The application should describe the process that the City undertook and make a case for the City's chosen flood mitigation project. A detailed scope of work (SOW) provides a clear and concise means of describing the proposed conceptual design and means of implementation of the project; it also clearly identifies the risks to be mitigated and the intended project accomplishments. Future residual risks to the project should also be described. Necessary documents supporting a SOW include credible sources for the following: assessment of past damages, preliminary design drawings/sketches, FIRMs, and photos. In addition, a work schedule that identifies all of the tasks outlined in the SOW must be included.

Caution must be taken with the application's cost estimate. It must accurately reflect the SOW and must include costs associated with mitigating environmental impacts or impacts to historic properties, appraisal costs, construction demolition, survey, and material disposal costs. The cost estimate cannot have a line item for contingencies.

A Benefit Cost Analysis (BCA) must be submitted with the application. As the name implies, the BCA compares the project benefits to the project costs. Project costs include those that are explained above as well as an estimate for annual maintenance costs. Annual maintenance costs are not funded by HMA, so they should only be included in the BCA submittal and not in the application's cost estimate. Benefits are calculated as avoided damages and losses. The benefit cost ratio (BCR) is simply the benefit divided by cost and must be equal to or greater than 1.0 to be eligible for HMA program funds. The BCA must be performed using the FEMA approved software as noted in the most recent HMA Unified Guidance document.

FEMA

Program Information **Mitigation**

HAZARD MITIGATION ASSISTANCE HMA GRANT PROGRAMS

Hazard Mitigation Assistance

The Department of Homeland Security (DHS) Federal Emergency Management Agency (FEMA) Hazard Mitigation Assistance (HMA) programs present a critical opportunity to reduce the risk to individuals and property from natural hazards while simultaneously reducing reliance on Federal disaster funds.

A COMMON GOAL

While the statutory origins of the programs differ, all share the common goal of reducing the risk of loss of life and property due to natural hazards.

FUNDING DISASTER RECOVERY EFFORTS

The Hazard Mitigation Grant Program (HMGP) may provide funds to States, Territories, Indian Tribal governments, local governments, and eligible private non-profits following a Presidential major disaster declaration .

The Unified Hazard Mitigation Assistance Grant Programs

Authorities and Purpose

The Hazard Mitigation Grant Program (**HMGP**) is authorized by Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended (the Stafford Act), Title 42, United States Code (U.S.C.) 5170c. The key purpose of HMGP is to ensure that the opportunity to take critical mitigation measures to reduce the risk of loss of life and property from future disasters is not lost during the reconstruction process following a disaster. HMGP is available, when authorized under the Presidential major disaster declaration, in the areas of the State requested by the Governor. The amount of HMGP funding available to the Applicant is based upon the total Federal assistance to be provided by FEMA for disaster recovery under the major disaster declaration.

HMGP HAZARD MITIGATION GRANT PROGRAM

The Pre-Disaster Mitigation (**PDM**) program is authorized by Section 203 of the Stafford Act, 42 U.S.C. 5133. The PDM program is designed to assist States, Territories, Indian Tribal governments, and local communities to implement a sustained pre-disaster natural hazard mitigation program to reduce overall risk to the population and structures from future hazard events, while also reducing reliance on Federal funding from future major disaster declarations.

The Flood Mitigation Assistance (**FMA**) program is authorized by Section 1366 of the National Flood Insurance Act of 1968, as amended (NFIA), 42 U.S.C. 4104c, with the goal of reducing or eliminating claims under the National Flood Insurance Program (NFIP).

The Repetitive Flood Claims (**RFC**) program is authorized by Section 1323 of the NFIA, 42 U.S.C. 4030, with the goal of reducing flood damages to individual properties for which one or more claim payments for losses have been made under flood insurance coverage and that will result in the greatest savings to the National Flood Insurance Fund (NFIF) in the shortest period of time.

The Severe Repetitive Loss (**SRL**) program is authorized by Section 1361A of the NFIA, 42 U.S.C. 4102A, with the goal of reducing flood damages to residential properties that have experienced severe repetitive losses under flood insurance coverage and that will result in the greatest amount of savings to the NFIF in the shortest period of time.

PDM PRE-DISASTER MITIGATION | FMA FLOOD MITIGATION ASSISTANCE | RFC REPETITIVE FLOOD CLAIMS | SRL SEVERE REPETITIVE LOSS

Additional HMA resources, including the HMA Unified Guidance may be accessed at www.fema.gov/government/grant/hma/index.shtm

program comparisons

COST SHARE

In general, HMA funds may be used to pay up to 75 percent of the eligible activity costs. The remaining 25 percent of eligible costs are derived from non-Federal sources.

The table to the right outlines exceptions to the 75 percent Federal and 25 percent non-Federal share.

Cost Share Requirements

Programs	Mitigation Activity Grant (Percent of Federal/Non-Federal Share)
HMGP	75/25
PDM	75/25
PDM—subgrantee is small impoverished community	90/10
PDM—Tribal grantee is small impoverished community	90/10
FMA	75/25
FMA—severe repetitive loss property with Repetitive Loss Strategy	90/10
RFC	100/0
SRL	75/25
SRL—with Repetitive Loss Strategy	90/10

ELIGIBLE APPLICANTS AND SUBAPPLICANTS

States, Territories, and Indian Tribal governments are eligible HMA Applicants. Each State, Territory, and Indian Tribal government shall designate one agency to serve as the Applicant for each HMA program.

All interested subapplicants must apply to the Applicant. The table to the left identifies, in general, eligible subapplicants. For specific details regarding eligible subapplicants, refer to 44 CFR Part 206.434(a) for HMGP and 44 CFR Part 79.6(a) for FMA and SRL. For HMGP and PDM see 44 CFR Part 206.2(16) for a definition of local governments.

Eligible Subapplicants

✓ Subapplicant is eligible for program funding

	HMGP	PDM	FMA	RFC	SRL
State agencies	✓	✓	✓	✓	✓
Tribal governments	✓	✓	✓	✓	✓
Local governments/communities	✓	✓	✓	✓	✓
Private non-profit organizations (PNPs)	✓				

Individuals and businesses are not eligible to apply for HMA funds, however, an eligible subapplicant may apply for funding to mitigate private structures. RFC funds are only available to subapplicants who cannot meet the cost share requirements of the FMA program.

Available Funding

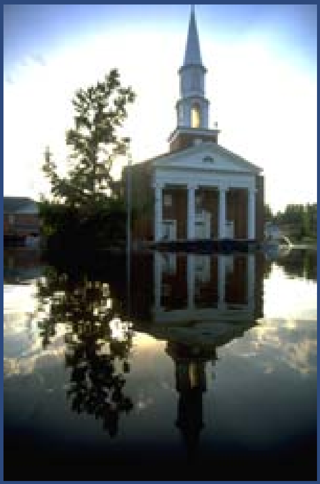
HMA programs are subject to the availability of appropriation funding or funding based on disaster recovery expenditures, as well as any directive or restriction made with respect to such funds.

HMGP funding depends on federal assistance provided for disaster recovery, while PDM, FMA, RFC, and SRL funding is appropriated annually by Congress.

program comparisons (continued)

ELIGIBLE ACTIVITIES

The table to the right summarizes eligible activities that may be funded by HMA programs. Detailed descriptions of these activities are found in the HMA Unified Guidance.



Eligible Activities

Eligible Activities	HMGP	PDM	FMA	RFC	SRL
1. Mitigation Projects	✓	✓	✓	✓	✓
Property Acquisition and Structure Demolition or Relocation	✓	✓	✓	✓	✓
Structure Elevation	✓	✓	✓	✓	✓
Mitigation Reconstruction					✓
Dry Floodproofing of Historic Residential Structures	✓	✓	✓	✓	✓
Dry Floodproofing of Non-residential Structures	✓	✓	✓	✓	
Minor Localized Flood Reduction Projects	✓	✓	✓	✓	✓
Structural Retrofitting of Existing Buildings	✓	✓			
Non-structural Retrofitting of Existing Buildings and Facilities	✓	✓			
Safe Room Construction	✓	✓			
Infrastructure Retrofit	✓	✓			
Soil Stabilization	✓	✓			
Wildfire Mitigation	✓	✓			
Post-disaster Code Enforcement	✓				
5% Initiative Projects	✓				
2. Hazard Mitigation Planning	✓	✓	✓		
3. Management Costs	✓	✓	✓	✓	✓

✓ Mitigation activity is eligible for program funding

Management Costs

For HMGP only: The Grantee may request 4.89 percent of HMGP allocation for management costs. The Grantee is responsible for determining the amount, if any, of funds that will be passed through to the subgrantee(s) for their management costs.

Applicants for PDM, FMA, RFC, or SRL may apply for a maximum of 10 percent of the total funds requested in their grant application budget (Federal and non-Federal shares) for management costs to support the project and planning subapplications included as part of their grant application.

Subapplicants for PDM, FMA, RFC, or SRL may apply for a maximum of 5 percent of the total funds requested in a subapplication for management costs.

General Requirements

All mitigation projects must be cost-effective, be both engineering and technically feasible, and meet Environmental Planning and Historic Preservation requirements in accordance with HMA Unified Guidance. In addition, all mitigation activities must adhere to all relevant statutes, regulations, and requirements including other applicable Federal, State, Indian Tribal, and local laws, implementing regulations, and Executive Orders.

program information

National Flood Insurance Program (NFIP) Participation

NFIP Participation Requirement

There are a number of ways that HMA eligibility is related to the NFIP.

- **Subapplicant eligibility**: All subapplicants for FMA, RFC, or SRL must currently be participating in the NFIP, and not withdrawn or suspended, to be eligible to apply for grant funds. Certain non-participating political subdivisions (i.e., regional flood control districts or county governments) may apply and act as subgrantee on behalf of the NFIP-participating community in areas where the political subdivision provides zoning and building code enforcement or planning and community development professional services for that community.
- **Project eligibility**: HMGP and PDM mitigation project subapplications for projects sited within a Special Flood Hazard Area (SFHA) are eligible only if the jurisdiction in which the project is located is participating in the NFIP. There is no NFIP participation requirement for HMGP and PDM planning subapplications or project subapplications located outside of the SFHA.
- **Property eligibility:** Properties included in a project subapplication for FMA, RFC, and SRL funding must be NFIP-insured at the time of the application submittal. Flood insurance must be maintained at least through completion of the mitigation activity.

Mitigation Plan Requirement

All Applicants and subapplicants must have hazard mitigation plans meeting the requirements of 44 CFR Part 201.

Application Process

Applications for HMGP are processed through the National Emergency Management Information System (NEMIS). Applicants use the Application Development Module of NEMIS, which enables each Applicant to create project applications and submit them to the appropriate FEMA Region in digital format for the relevant disaster.

Applications for PDM, FMA, RFC, and SRL are processed through the Electronic Grants (*e*Grants) system. The *e*Grants system encompasses the entire grant application process and provides the means to electronically create, review, and submit a grant application to FEMA via the Internet. Applicants and subapplicants can access *e*Grants at https://portal.fema.gov.

NFIP INFORMATION

In 1968, Congress created the National Flood Insurance Program (NFIP) to help provide a means for property owners to financially protect themselves. The NFIP offers flood insurance to homeowners, renters, and business owners if their community participates in the NFIP. Participating communities agree to adopt and enforce ordinances that meet or exceed FEMA requirements to reduce the risk of flooding.

Find out more about the NFIP and how it can help you protect yourself.

http://www.floodsmart.gov

MITIGATION ELECTRONIC GRANTS SYSTEM

For PDM, FMA, RFC, and SRL, FEMA has developed a web-based, Electronic Grants (eGrants) management system to allow States, Federally-recognized Indian Tribal governments, territories, and local governments to apply for and manage their mitigation grant application processes electronically.

program information

GovDelivery Notifications

Stay up to date on the HMA Grant Programs by subscribing to GovDelivery notifications.

Have email updates delivered to an email address or mobile device.

To learn more visit www.fema.gov or just click the icon below.

Email Updates

Application Deadline

The PDM, FMA, RFC, and SRL application period is anticipated to be from June 1, 2010, through December 3, 2010. Applicants must submit an FY11 grant application to FEMA through the *e*Grants system by December 3, 2010, at 3:00:00 p.m. Eastern Time.

The HMGP application deadline is 12 months after the date of the disaster declaration date and is not part of the annual application period.

Details can be found in the HMA Unified Guidance.

FEMA Review and Selection

All subapplications will be reviewed for eligibility and completeness, cost-effectiveness, engineering feasibility and effectiveness, and for Environmental Planning and Historical Preservation compliance. Subapplications that do not pass these reviews will not be considered for funding.

FEMA will notify Applicants of the status of their subapplications and will work with Applicants on subapplications identified for further review.

Contact Information

HMA Helpline: (866) 222-3580
hmagrantshelpline@dhs.gov

Contact information for FEMA Regional Offices is provided at:
http://www.fema.gov/about/contact/regions.shtm

Contact information for each State Hazard Mitigation Officer (SHMO) is provided at:
http://www.fema.gov/about/contact/shmo.shtm

Mitigation Works