If the Beachcomber is not turned into a restaurant, it might be used as a history museum store, or otherwise provide additional space for the type of activities conducted at the History and Cultural Center.

8. Waterfront Park
   There are city festivals in Waterfront Park in the summer months; the venue features films and concerts.

9. The Athenaeum, 201 Prince Street
   The Athenaeum is the home of the Northern Virginia Fine Arts Association. Among many events at the Athenaeum are art shows and dance recitals.

10. Little Theater of Alexandria, 600 Wolfe Street, Alexandria
    Little Theater of Alexandria is a local theater that puts on several plays a year. It has both adult and children's productions.

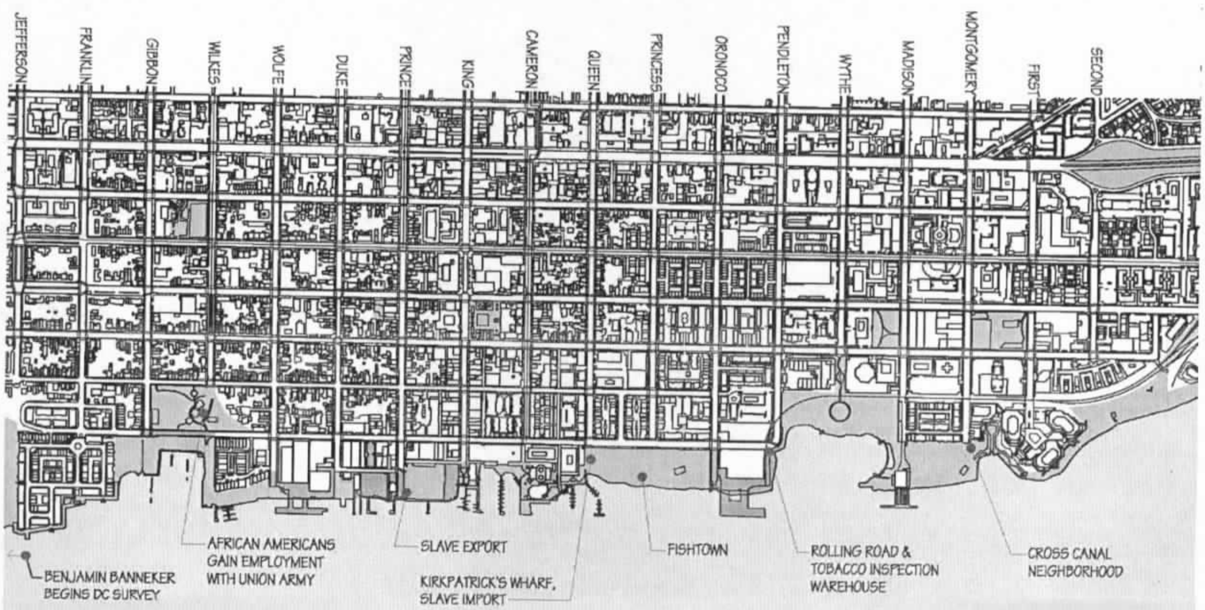
Thematic Walk

African American History – Slavery and Freedom

Some Alexandrians brought African American slaves with them when they moved into their new homes in the new town shortly after the first auction of town lots in July 1749. Before Alexandria was founded, slaves rolled large hogsheads of tobacco down the rolling road that ran from the south and west to the tobacco inspection warehouse at West's Point. It is likely that the first auction of slaves in Alexandria was held in 1750, when Alexandrian John Dalton sold some 25 slaves probably imported from Barbados. Importation points for slaves were at different places along the waterfront at different times, but the first known one was at Kirkpatrick's Wharf at the foot of Queen Street.

At times, slaves and free African Americans worked side-by-side in the city to construct its homes and wharves and perform other skilled and unskilled tasks that contributed to building the town and boosting its economy. In 1830, over half the black population of Alexandria was free. Contraband and freedmen continued to work in various occupations helping the Union Army when Alexandria was occupied by Northern forces during the Civil War, and African Americans continued to be a vital part of the waterfront afterwards.

Visitors particularly interested in African American history along the waterfront could follow the African American History Thematic Walk, which would include the following stops from north to south along the Pedestrian Path:



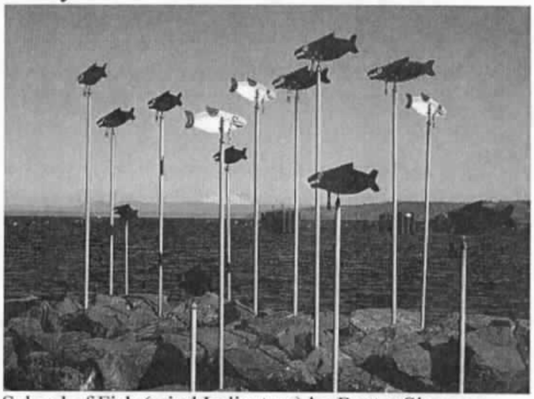
Thematic Walk- African American History- Slavery & Freedom

1. Gateway North
   Cross Canal Neighborhood was an African American neighborhood that existed for many years just across the Alexandria Canal lock at the foot of Montgomery Street. This area is the gateway to the Pedestrian Walk.

2. West's Point
   The rolling road along which African American slaves rolled large hogsheads of tobacco even before Alexandria was founded terminated at the tobacco inspection warehouse on West's Point.

3. Founders Park
   At Kirkpatrick's Wharf at the foot of Queen Street, slaves were imported into Alexandria from Gambia in 1762.
   Fishtown, on the waterfront between Oronoco and Princess Streets, was a shambling collection of smelly shacks where, beginning in the 1830s, free black women and slaves headed and gutted shad and herring brought in from Potomac River fisheries, washed them, and then salted and packed them in wooden casks for sale to fish brokers. The committee recommends a sculpture inspired by Fishtown.

Fishtown workers: Alexandria Library, Special Collections, William Smith Collection

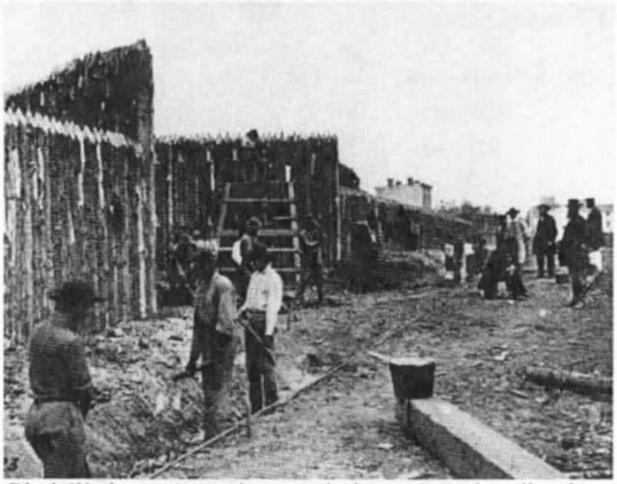


School of Fish (wind Indicators) by Buster Simpson, Edmonds, WA

4. The Strand
   The foot of Prince Street is likely where, particularly during the 1830s-1850s, slaves were loaded onto ships for transportation to New Orleans to be sold. During this period, an African American schooner captain named George Henry, a slave, found himself in the unsettling position of unloading wood on one side of a wharf in Alexandria "when a vessel [was] loading slaves on the other side of the wharf."

   The slaves are credited with grading the bluff and filling in the original crescent bay. They also built roads, wharves and homes in Alexandria. They worked in the potteries, refineries and shipyards.

5. Windmill Hill Park
   Contraband and freedmen worked on the waterfront and on the railroad along the waterfront, helping the Union army during the Civil War.



Black Workers constructing a stockade to protect the railroad during the Civil War: Alexandria Library, Special Collections, William Smith Collection

6. Jones Point

   Benjamin Banneker, the son of a white woman and a black slave, and a largely self-taught surveyor, began surveying the new District of Columbia at this point in 1791.

   There also are African American sites further west of the river: the Black History Museum, the Contraband and Freedmen's Cemetery, the Slave Pen Museum, and the National Cemetery, as well as the statue of the Edmonson Sisters on Duke Street.

Graveshafts at Freedmen's Cemetery: Alexandria Archaeology working at the site

African American woman near the Price, Birch & Company slave pen on Duke Street, Woman beside slave pen: Library of Congress

Thematic Walk

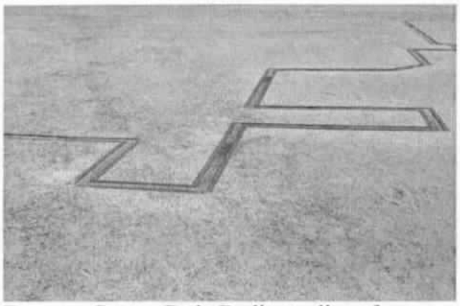
The Old Crescent Bay Shoreline

Where the Torpedo Factory, Starbucks, Ben and Jerry's, and a number of restaurants and other buildings now are located was once underwater in a crescent-shaped bay. Located on a wall in the Alexandria Archaeology Museum (on the third floor of the Torpedo Factory) is an excellent large modern drawing of the waterfront as it looked after Alexandria was founded and before the bay was filled in. This walk retraces the bay's old shoreline pictured on that drawing.

Drawing of Alexandria waterfront: Drawing by Elizabeth Luallen, Alexandria Archaeology

The committee **strongly** suggests that the shoreline of the historic Crescent Bay be marked, where it is possible to do so.

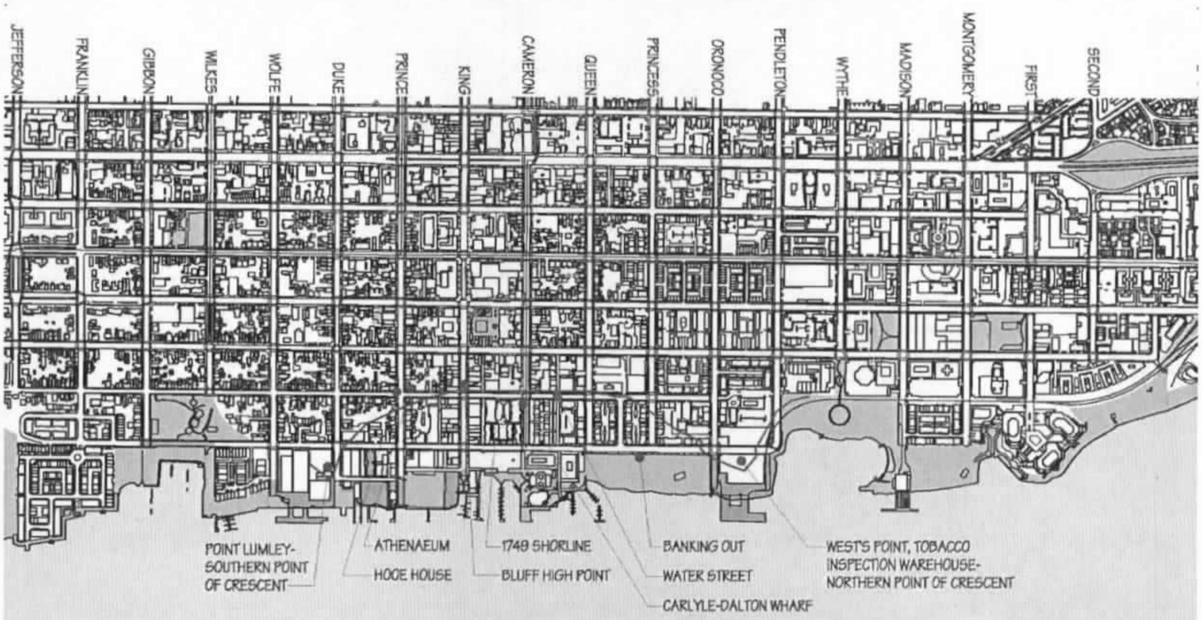
Bernauer Strasse Park, Berlin, the wall is represented by dowels, the former houses by inset steel, and the escape tunnels by flagstones



Bernauer Strasse Park, Berlin, outline of destroyed church

The former Berlin Wall is represented by a double row of ccobblestones

Unlike the other walks, this one is best done from south to north, because the foot of King Street is the best place to appreciate the height of the bluffs that once lined the bay. More research is needed to locate good spots on this walk, but some possibilities are as follows:

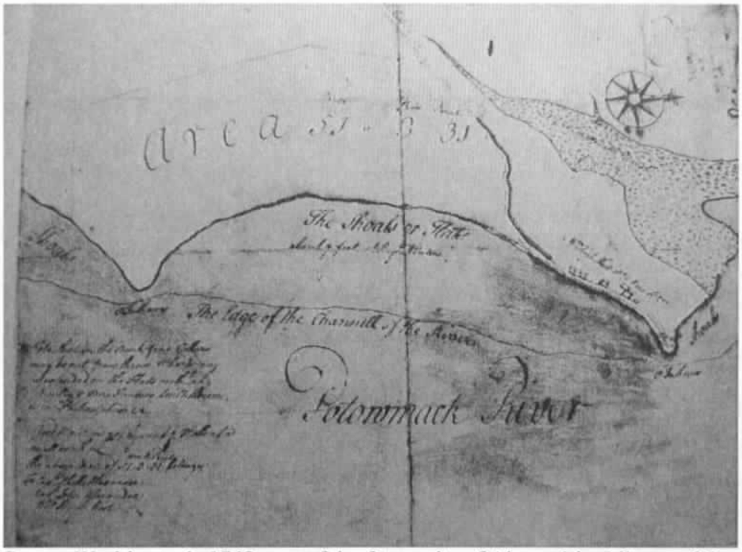


Thematic Walk- The Old Crescent Bay Shorline

1. Robinson Terminal South

   Known earlier as Point Lumley, this location was the southern point of the old crescent bay that curved gradually inland from this point until it reached King Street, where it leveled off for two blocks, and then curved gradually back out toward the river until it reached West's Point at the foot of Oronoco Street. This shallow bay was filled in by two processes. One was known as "banking out," which involved grading dirt from the bluffs that lined the shore into the bay. Someone looking up from this spot to the level of Lee Street would get an idea of the original height of the bluffs that bordered most of the bay and of the gradual grading process that filled it in.

   The other process involved the construction of early wharves that stretched east into the bay. To form the wharves, old boats or large rectangular cribs made of heavy timbers were sunk into the bay and filled with dirt from the bluffs. These early wharves later became part of the new land as Alexandrians filled in the bay to expand the town.



George Washington's 1748 map of the future site of Alexandria: Library of Congress

2. Hooe Home

   Located on the southwest corner of Lee and Prince Streets, it was built after the bay was filled in. In the late 18th and early 19th century, Robert Townshend Hooe, the home's builder, operated a shipping business from Point Lumley, today's Robinson Terminal South. He was one of the justices of the peace whose appointment led to the famous Supreme Court case of *Marbury v. Madison*, in which Chief Justice John Marshall declared for the first time that the Supreme Court could rule that a law was unconstitutional.

3. Athenaeum

   Built in 1852 as a bank, but well preserved since then, it now is the headquarters and gallery of the Northern Virginia Fine Arts Association. There are both art shows and dance recitals at this location.

The Athenaeum was the headquarters of the Alexandria branch of the Union Army's Commissary Dept.: Athenaeum during Civil War: Alexandria Library, Special Collections, William Smith Collection

4. Intersection of King and Lee Streets

This was the center of the bay when the waters of the bay cut Lee Street (then called Water Street) roughly in half.

5. Carlyle House

When it was built in 1752-1753, its back yard was on a high bluff that dropped to a narrow beach beside the bay. The committee strongly recommends that the Carlyle-Dalton Wharf be excavated, allowing the remains of the historic wharf to be seen.

Carlyle House today.

Carlyle House, detail of Drawing of Alexandria waterfront: Drawing by Elizabeth Luallen, Alexandria Archaeology

Carlyle-Dalton Wharf excavation: Alexandria Archaeology

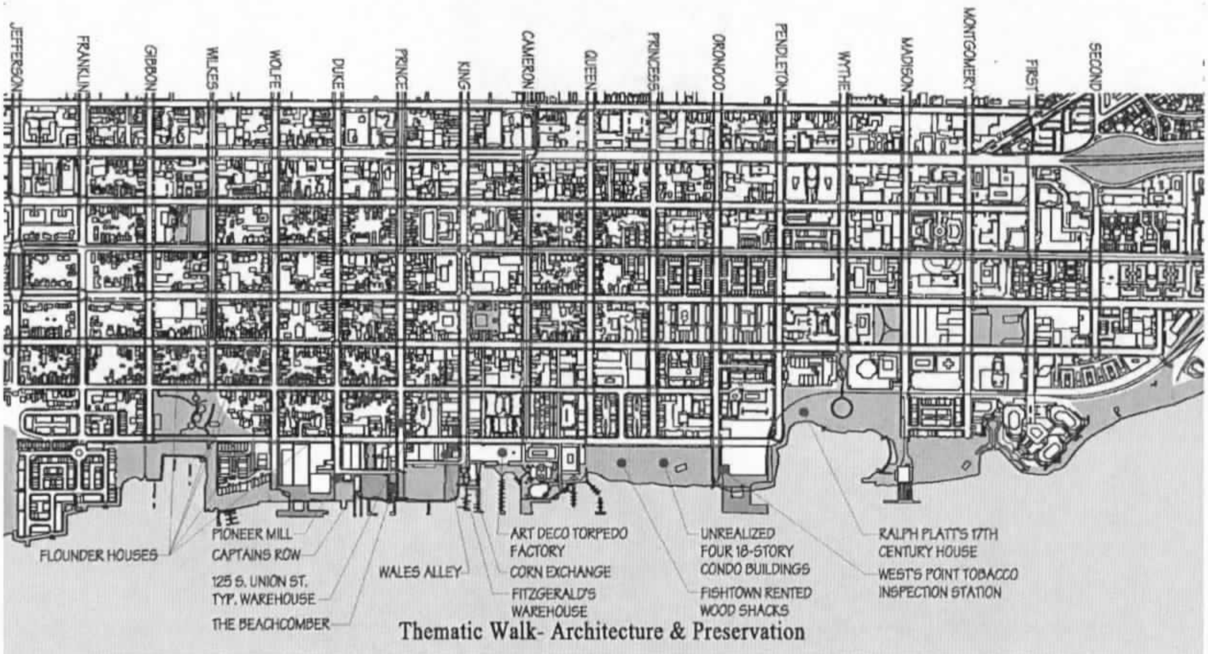
6. Robinson Terminal North

This spot was the northern point of the bay, and the site of the tobacco inspection station that was one of the original structures of what became Alexandria.

Thematic Walk

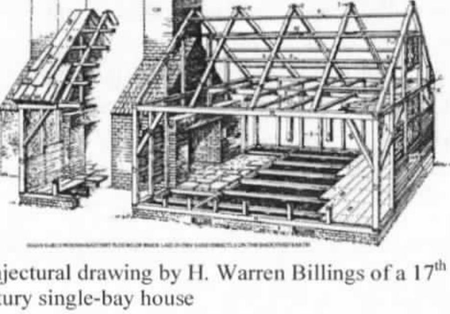
Architecture and Preservation

On the waterfront and close by it are several examples of the different styles of commercial and residential architecture in Alexandria. Also along the waterfront are examples of the preservation of historic structures and places that are characteristic of Alexandria. Visitors interested in these subjects could follow the Architecture and Preservation Thematic Walk, which would include the following stops from north to south along the Pedestrian Path:



Thematic Walk- Architecture & Preservation

1. Oronoco Bay Park
   This is the site of Ralph Platt's 17th century house, an example of a very early colonial residence. The committee's **strong** recommendation for honoring Ralph Platt is to restore the living shoreline at this park, and to re-establish the wetlands that were known as Ralph's Gut.



Conjectural drawing by H. Warren Billings of a 17th century single-bay house

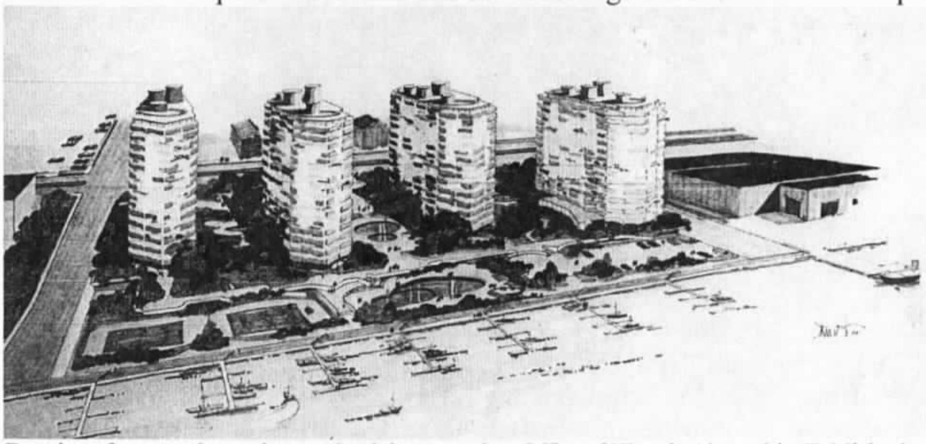
2. West's Point

West's Point is the site of the old tobacco inspection station, a type of structure that was essential to the welfare of the Virginia colony. The committee recommends the creation of a sculpture honoring the building that became the anchor for the development of the city.

Robert Venturi, Franklin Court, Philadelphia, Penn

3. Founders Park

In 1971, a 650-unit condominium complex was proposed for Founders Park. It would have consisted of four 18-story buildings, each set upon 20-foot stilts and rising 178 feet into the air. Alexandria preservationists and the federal government halted this project.



Drawing of proposed towering condominium complex: Office of Historic Alexandria, T. Michael Miller Collection

Fishtown developed in the mid nineteenth century, and occupied what is today Founders Park. As fishing season began each spring, throngs of fishmongers rented wood to build shacks along the wharves, dismantling them at the end of the season and returning the wood. Since 'hired' wood could not be cut, a plank was left out; thus, windows were 15 feet long and a foot tall. These temporary tenements housed a variety of businesses dedicated to salting, packing, selling and eating fish.

4. Torpedo Factory

The Torpedo Factory is an example of an Art Deco building, completed in 1919.

Torpedo Factory Art Center, photo by Steve Ainsworth

5. Fitzgerald Warehouse, 100-104 South Union Street

   The warehouse, built in the late 1790s, is the oldest building still standing on the waterfront.

6. Wales Alley

   Although the name of this alley probably should be Fitzgerald Alley, it is a good example of alleys along the waterfront that were used to move goods from wharves into town.

7. Corn-Exchange Building, 100 King Street, built in 1871

   The large building on the southwest corner of King and Union opposite Fitzgerald Warehouse is of Italianate style. The Exchange Hall on the second floor is 25 feet high, with a beautifully ornamented arched ceiling.

8. Captains Row -- 100 block of Prince Street

   Rebuilt after the 1827 fire, these were the first old houses in Alexandria to be remodeled in the 1920s, which started the revival of residential Old Town.

9. Christmas Attic Building (125 S. Union Street) on the west side of Union Street and former arms-company buildings on the east side of Union Street

   These buildings are typical of the warehouse architecture that dominated the waterfront. The former Norman Fitzhugh Warehouse was built in 1827/28

10. The Strand – Beachcomber, 0 Prince Street

    It once was a restaurant built on stilts over the water, so technically it was not in Virginia, but in the District of Columbia, and could serve alcoholic beverages. When it was built, it won an award from the American Institute of Architects for its "inept" design.

Beachcomber: Alexandria Library, Special Collections, John C. Richards Collection

11. Foot of Duke Street

    This is the location of the Pioneer Mill, a flour mill that once was the highest building on the waterfront. (Pioneer Mill in rear)

Pioneer Mill: Alexandria Library, Special Collections, VF-Civil War Collection

12. Flounder House

A "flounder house" is so called because, like the fish, it has a flat side on the property line that has no "eyes" (windows). Its unusual type of structure is used in Alexandria because of the city's narrow, deep lots. There are several "flounder houses" in Alexandria, representing different time periods and types of architecture. Examples can be found at 220 and 321 South Lee Street, at 412 and 514 South Fairfax Street, at 317 South Saint Asaph Street, and at 511 Queen Street.

13. Historic Plaques on homes

Houses must be 100 years old and must have architectural integrity

Going west from the waterfront, there are several noteworthy buildings: Carlyle House, 121 North Fairfax Street, the Apothecary at 107 South Fairfax Street, a recreation of George Washington's Alexandria "in-town" house, at 508 Cameron Street, and Christ Church, 118 North Washington Street. The different styles of architecture are written about in several books, including:

Alexandria Houses, 1750-1830 by Deering Davis, Stephen P. Dorsey, and Ralph Cole Hall

Historic Alexandria Virginia Street by Street: A Survey of Existing Early Buildings by Ethelyn Cox.

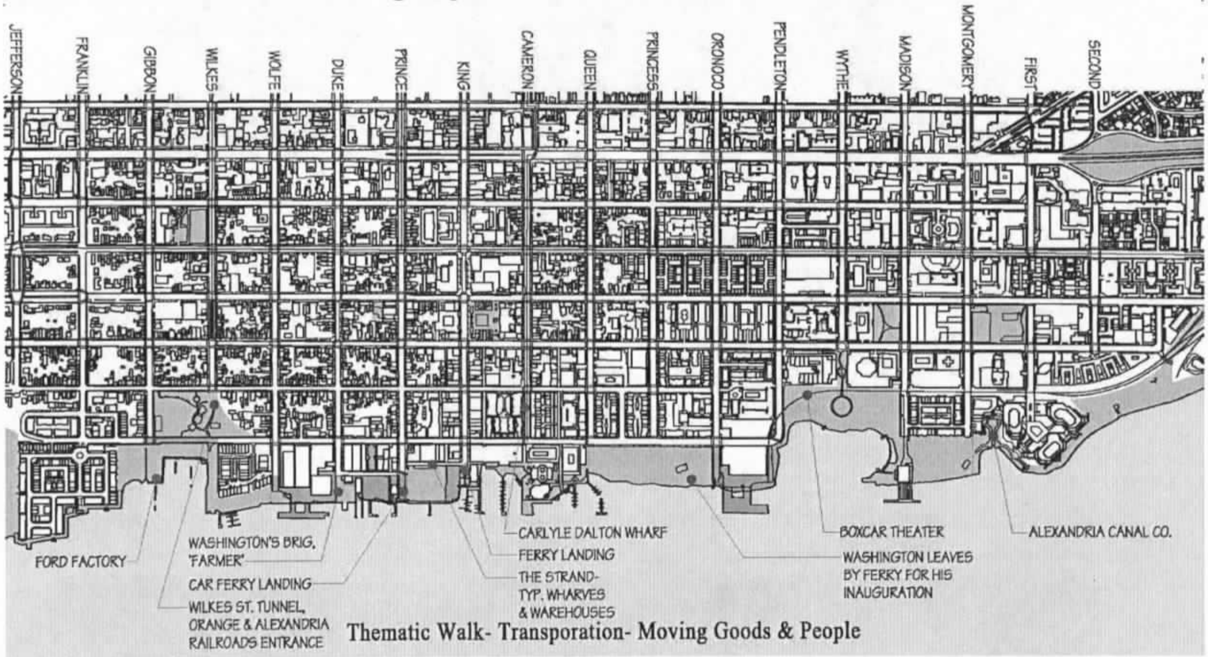
Old Town Alexandria Architecture, 1750-1900 by Penny C. Morrill and John C. Roach

"Architectural Walking Tour of Alexandria, VA" by Denys Peter Myers and T. Michael Miller in the *Alexandria Chronicle*, Spring/Summer 1996—a copy is available through the Alexandria Historical Society's website at:
http://www.alexandriahistorical.org

Thematic Walk

Transportation – Moving Goods & People

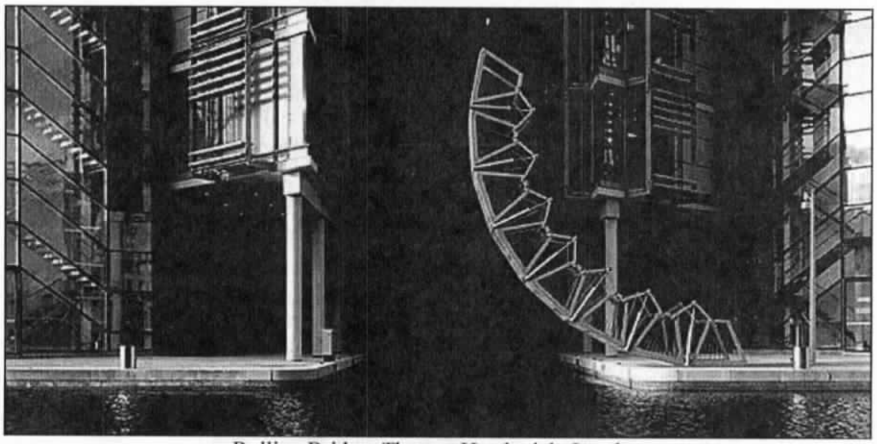
Much of the history of the waterfront has revolved around moving goods and people. Railroad, maritime, canal, and car enthusiasts could follow the Transportation Thematic Walk that would include the following stops:



Thematic Walk- Transporation- Moving Goods & People

1. Tidelock Park and Rivergate Park

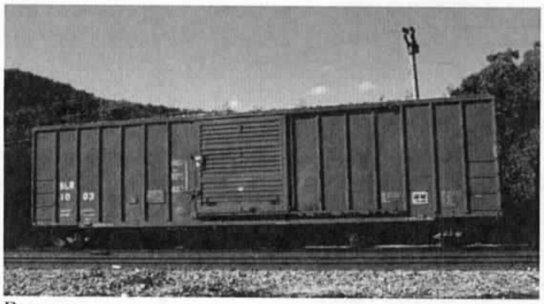
   In 1830, the Alexandria Canal Company was chartered by Congress (Alexandria then was part of the District of Columbia) to build a canal linking the Chesapeake and Ohio Canal with Alexandria. The canal was completed in 1850. It crossed the Potomac at Georgetown by a specially constructed aqueduct located near present-day Key Bridge, and wound its way through today's Potomac Yard to its terminus at the Potomac River at the foot of Montgomery Street, where there is a reproduction of the last lock on the canal. The committee has several recommendations for this area. There should be artwork that commemorates the engineering and physics employed in the building of the canal. A new footbridge over the canal also could be an example of contemporary technology.



Rolling Bridge, Thomas Heathwick, London

2. Oronoco Bay Park

   Railroad tracks once formed a rough rectangle around the heart of Alexandria. The waterfront part of that rectangle ran from Wilkes Street Tunnel north on Union Street to Robinson Terminal North. After proceeding a short distance west on Pendleton Street, it turned north again along the western edge of Oronoco Bay Park, and then along Highway One. These tracks provided a link to the east coast and the interior of the country for goods and people arriving by ship in Alexandria. Part of that rail link is still visible in this area. The committee hopes that the tracks in the park will be the home of the Boxcar Theater. Perhaps the boxcar theatre could be named after its concept creator, Adam Wishnow.



Boxcar

Model for Boxcar Theatre by Matt Harwood

3. West's Point – Robinson Terminal North

   Ships from Scandinavia once brought large rolls of newsprint to the Robinson Terminals North and South for use by the Washington Post. Cruise ships, tall ships, and Navy and Coast Guard vessels occasionally still dock at the terminals.

Sculpture inspired by historic barque sailing the Inland Sea, Naoshima, Japan

4. Founders Park
   George Washington left from a ferry landing in this area to go to New York to become the first president

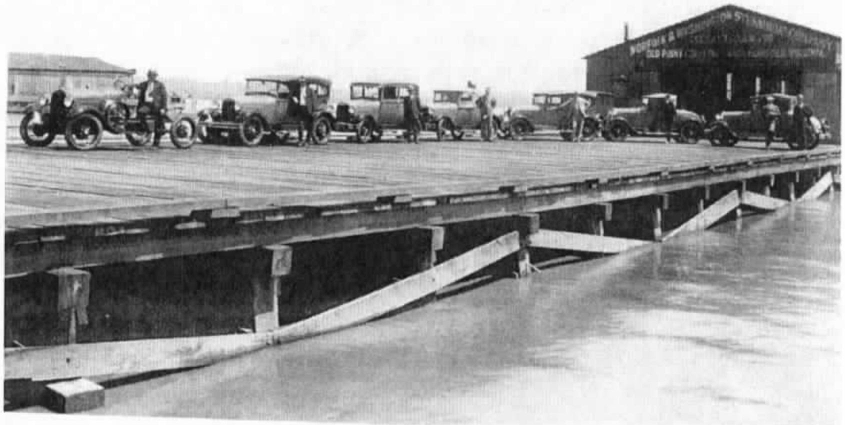
5. Torpedo Factory Complex
   The edge of Cameron Street is the site of Alexandria's earliest private shipping wharf, the Carlyle-Dalton Wharf. The committee recommends that the remains of this wharf be visible through a glass window on Cameron Street. Currently, there is a marina and dock for pleasure and sightseeing boats located at the complex.

6. Foot of King Street
   A ferry from Washington docked at the foot of King Street at the site of the present-day Old Dominion Boat Club for many years until early in the twentieth century. It ran every hour from 8 o'clock in the morning to 7 o'clock at night, bringing goods and people to Alexandria.

Old Town by Moonlight by John M. Barber, the ferry, *City of Alexandria*,is seen behind the building on left of painting

7. Foot of Prince Street

   In the early 20th century, a car ferry ran from the foot of Prince Street.



Cars lined up on the Prince Street wharf waiting to board the car ferry, circa 1929: Alexandria Library, Special Collections, Loeb Collection.

8. The Strand

   The Strand once had many commercial wharves and warehouses used for trade all over the world. All of the surviving 18th and 19th century warehouses are located here.

9. Foot of Duke Street

   This was the location of Thomas Fleming's shipyard, where George Washington once had his brig *Farmer* repaired.

10. Windmill Hill Park

In March and April of 1862, the Quartermaster Department in Alexandria helped transport General McClellan's army and supplies. A British journalist observed "a schooner laden to the water-line with locomotive engines . . .brig shipping artillery horses by a steam derrick, that lifted them bodily from the shore and deposited them in the hold of the vessel."

The Orange and Alexandria Railroad enters the waterfront through Wilkes Street Tunnel

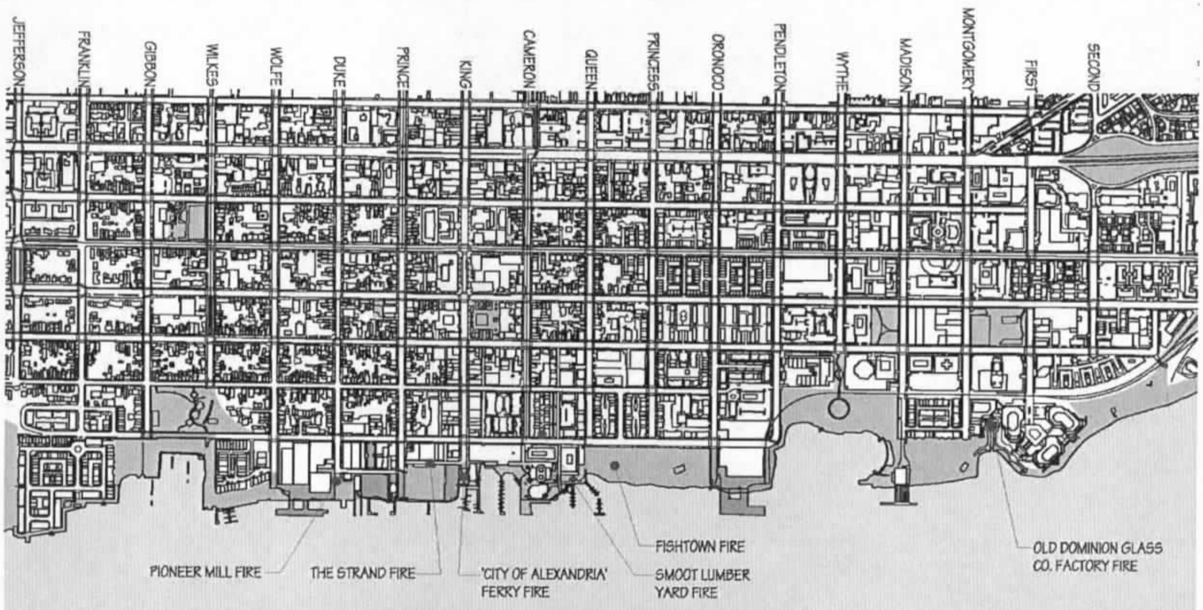
11. Ford's Landing Townhouses

The Ford Motor Company operated a wholesale automobile service and distribution plant here from 1932 to 1942, when it was taken over by the federal government for use as a munitions factory.

Thematic Walk

Fires: The Waterfront in Flames

At a time when many of the city's buildings were made of wood and industrial operations involved dangerous processes, the possibility of fire along the waterfront was an abiding concern. Conflagration buffs and visiting firemen may find this tour of interest.



Thematic Walk- Fires: The Waterfront in Flames

1. Gateway North

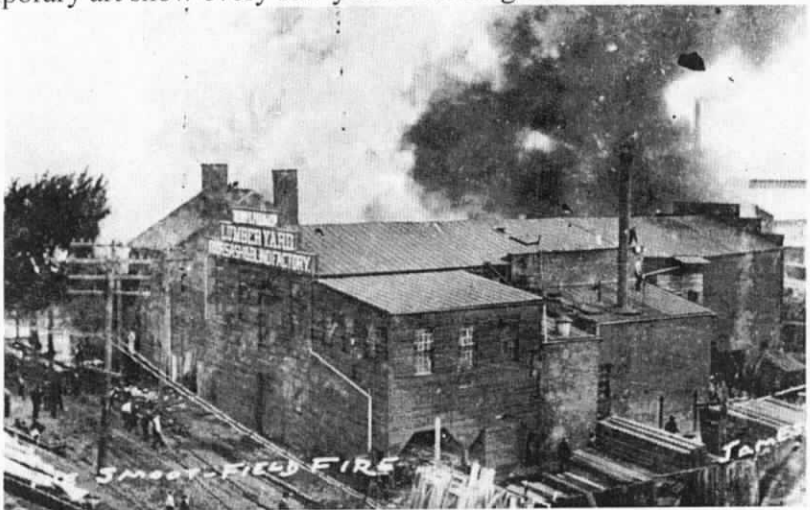
   The Old Dominion Glass Company's factory that was located in this area was ravaged by fire in February 1902, soon after it opened. The *Alexandria Gazette* reported that during that fire, fire engines "after much difficulty in forcing their way through snow and mud reached the scene of the fire, but it was impossible to check the flames and in less than two hours nothing remained but the brick smoke chimney and a heap of ashes." The factory burned again in November 1920. The committee recommends that glass art be added to the canal basin and also to the river to commemorate the glass factories of an earlier era.

2. Founders Park

   On January 16, 1871, a fire broke out in the fish house of George W. Harrison in Fishtown. The flimsy wooden shacks made the fire difficult to contain. As reported in the *Alexandria Gazette*: "the sparks...fell as thick as snowflakes" and set adjacent buildings on fire. Before it was extinguished, the fire had consumed Harrison's fish house, a row of adjoining fish houses, and two restaurants.

3. Torpedo Factory Complex

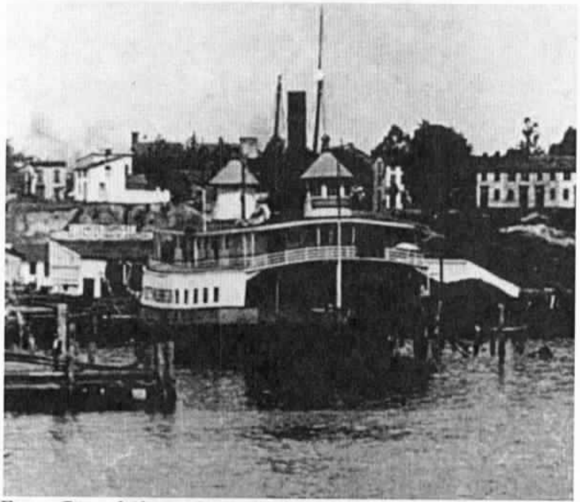
W.A. Smoot and Company's planing mill and lumber yards located on the north and south sides of Cameron Street and the west side of Union Street caught fire in May 1909, and burned for five hours, virtually wiping out the company's property. Smoot Lumber was founded in Alexandria in 1822, and is still in the city having moved several times. A public/private collaborative between Smoot's and the City could sponsor a temporary art show every few years featuring art works made from wood/lumber.



Smoot fire: Alexandria Library, Special Collections, William Smith Collection

4. Foot of King Street

Soon after nine o'clock on October 8, 1892, people standing at the foot of King Street, near where the Alexandria-Washington ferry *City of Alexandria* was docked, saw columns of fire and smoke flash suddenly through the wood of her upper saloon. The people aboard quickly disembarked, all escaping unharmed. The fire, however, could not be contained, and to save the dock and nearby property, two tugs towed the rapidly-burning ferry out into the Potomac and grounded it in shallow water off Maryland, opposite the foot of Duke Street. The *Alexandria Gazette* reported that "a huge bank of light was formed by the crackling fire and oil, paint, canvas, lightwood and other flammable material, which was visible for miles." The next morning, all that remained of the ferry, which had sailed between Alexandria and Washington for 25 years, was "a charred mass of extinct coals, twisted rods and topsy-turvy machinery in a careened hulk."



Ferry *City of Alexandria* docked for repairs near the foot of Franklin Street before the fire, circa 1888: Alexandria Library, Special Collections, Ashby Reardon, Sr. Collection

5. The Strand

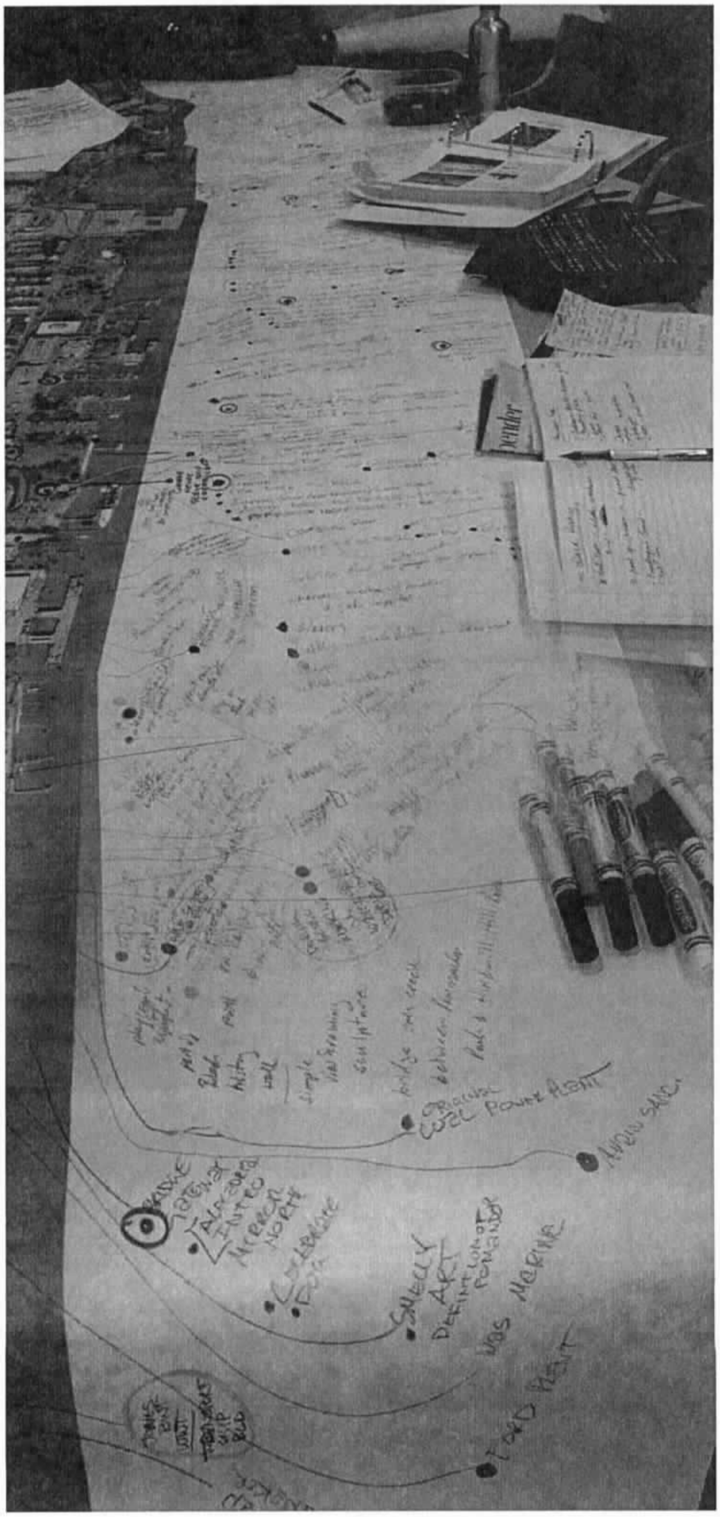
   A fire in 1827 consumed 53 homes and warehouses on Fairfax, Union, Lee (then Water), and Prince Streets. Fire companies from Washington, D.C., circus performers, and even U.S. Congressmen helped fight the fire. The Strand now is a gathering place for many activities. The Committee's recommends this area as the home of a History and Cultural Center: a museum devoted to the Alexandria and its history. The Museum would be a cultural anchor on the southern portion of the Pedestrian Path.

6. Robinson Terminal South

   A fire in June 1897 destroyed Pioneer Mill, which then was located at today's Robinson Terminal South, and several buildings on Union Street and the Strand. Charred marks, probably from that fire, are still visible in the attic of the Robinson Terminal headquarters building, and on the walls of Chadwick's Restaurant.

7. Friendship Fire Company (museum), 107 South Alfred Street

   There are plaques on several houses in Alexandria; the plaques tell the firefighters that a house is insured and which fire company is to respond.



Waterfront Map
Art and History Waterfront Plans Implementation Committee
2013

Sec. 6-300 - Floodplain district.

6-301 - Purpose and intent.

(A) This ordinance is adopted pursuant to the authority granted to all localities by Va. Code § 15.2-2280, as well as the authority specifically granted to the city in its Charter. The purpose of these provisions is to prevent: the loss of life and property, the creation of health and safety hazards, the disruption of commerce and governmental services, the extraordinary and unnecessary expenditure of public funds for flood protection and relief, and the impairment of the tax base by:

(1) Regulating uses, activities, and development which, alone or in combination with other existing or future uses, activities, and development, will cause unacceptable increases in flood heights, velocities, and frequencies;

(2) Restricting or prohibiting certain uses, activities, and development from locating within districts subject to flooding;

(3) Requiring all those uses, activities, and developments that do occur in flood-prone districts to be protected and/or flood-proofed against flooding and flood damage; and,

(4) Protecting individuals from buying land and structures which are unsuited for intended purposes because of flood hazards.

6-302 - Applicability.

(A) These provisions shall apply to all privately and publicly owned lands within the jurisdiction of the City of Alexandria and identified as being in a floodplain as designated in the flood insurance study and as shown on the flood insurance rate maps prepared by the Federal Emergency Management Agency (FEMA) dated June 16, 2011.

(B) The floodplain district regulations in section 6-300 are adopted in compliance with floodplain management criteria set forth in regulations promulgated by FEMA.

(C) This section shall be applicable to all applicants for building permits in the floodplain area.

(D) All buildings for which a building permit shall have been duly and regularly issued by the director of building and mechanical inspections on or before May 24, 1977, which permit has not expired, may be completed without the necessity of complying with the floodplain district regulations in section 6-300, but after completion, any such building or structure and the land on which it is situated shall be subject to all the provisions of said section.

(E) All preliminary site plans which have been duly and regularly approved on or before May 24, 1977, and which have not expired, may be completed without the necessity of complying with the floodplain district regulations in section 6-300, but after completion, any building or structure on said site plan together with the land included in said site plan shall be subject to all the provisions of said section

(F) All final site plans which have been duly and regularly approved and released on or before May 24, 1977, and which have not expired may be completed without the necessity of complying with the floodplain district regulations in section 6-300, but after completion, any building or structure on said site plan together with the land included in said site plan shall be subject to all the provisions of said section.

(G) Any building or structure which is in existence on or before June 15, 2011, or for which a preliminary or combination site plan, building permit or subdivision approved on or before June 15, 2011, continues in force and effect shall not be deemed a nonconforming use provided, that any such building or structure which, following June 15, 2011, is the subject of substantial improvement shall comply with the floodplain regulations in effect at the time of such improvement.

6-303 - Definitions.

For the purposes of this section 6-300 the following terms and phrases shall have the meaning ascribed as follows below. Should any uncertainty occur with respect to the definition of any word, term or phrase used in this section, the applicable definitions set out in 44 CFR 59.1, as amended, shall apply.

(A) *A Zone.* An area of the one hundred (100)-year flood as shown on the Flood Insurance Rate Map. This zone is also referred to as the Approximated Floodplain District.

(B) *AE Zone.* An area shown of the 100-year flood on the flood insurance rate map for which corresponding base flood elevations have been provided. This zone is also referred to as the Special Floodplain District.

(C) *Base flood.* The flood having a one percent chance of being equaled or exceeded in any given year. May also be referred to as the 100-year flood.

(D) *Base flood elevation (BFE).* The FEMA designated 100-year water surface elevation as shown on the flood insurance rate map that corresponds to the base flood.

(E) *Basement.* Any area of a building (including parking) having its floor subgrade (below ground level) on all sides.

(F) *Development.* Any man-made change to improved or unimproved real estate, including, but not limited to, the construction of buildings or other structures, the placement of manufactured homes, the construction of streets, the installation of utilities and other activities or operations involving paving, filling, grading, excavating, mining, dredging or drilling, the storage of equipment or materials.

(G) *Existing manufactured home park or subdivision.* A manufactured home park or subdivision for which the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including, at a minimum, the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads) is completed before the effective date of the floodplain management regulations adopted by a community.

(H) *Flood/flooding.*

(1) A general and temporary condition of partial or complete inundation of normally dry land areas from:

(a) The overflow of inland or tidal waters;

(b) The unusual and rapid accumulation or runoff of surface waters from any source; or,

(c) Mudflows which are proximately caused by flooding as defined in paragraph (1)(b) of this definition and are akin to a river of liquid and flowing mud on the surfaces of normally dry land areas, as when earth is carried by a current of water and deposited along the path of the current.

(2) The collapse or subsistence of land along the shore of a lake or other body of water as a result of erosion or undermining caused by waves or currents of water exceeding anticipated cyclical levels or suddenly caused by an unusually high water level in a natural body of water, accompanied by a severe storm, or by an unanticipated force of nature such as flash flood or an abnormal tidal surge, or by some similarly unusual and unforeseeable event which results in flooding as defined in paragraph (1)(a) of this definition.

(I) *Flood insurance rate map (FIRM).* An official map of a community, on which the FEMA Federal Insurance Administrator has delineated both the special flood hazard areas and the risk premium zones applicable to the community. A flood insurance rate map that has been made available digitally is called a digital flood insurance rate map (DFIRM). The official Flood Insurance Rate Map for the City of Alexandria shall be the in the digital format prepared by FEMA, Federal Insurance Administration, dated June 16, 2011, as amended.

(J) *Flood insurance study (FIS).* An examination, evaluation and determination of flood hazards and, if appropriate, corresponding water surface elevations, or an examination, evaluation and determination of mudflow and/or flood-related erosion hazards. The official Flood Insurance Study for the City of Alexandria shall be the flood insurance study prepared by FEMA, Federal Insurance Administration, dated June 16, 2011, as amended.

(K) *Floodplain.* A relatively flat or low land area adjoining a river, stream or other watercourse which is subject to partial or complete inundation by water from such watercourse, or a land area which is subject to the unusual and rapid accumulation or runoff of surface waters from any source.

(L) *Floodplain district.* The areas encompassed by the 100-year floodplain as shown on the flood insurance rate map.

(M) *Flood-prone area.* Any land area susceptible to being inundated by water from any source more often than once in a 100-year period.

(N) *Floodproofing.* Any combination of structural and non-structural additions, changes, or adjustments to structures which reduce or eliminate flood damage to real estate or improved real property, water and sanitary facilities, structures and their contents.

(O) *Floodway.* The designated area of a floodplain required to carry and discharge flood waters of a given magnitude. For purposes of this section 6-300, a floodway must be capable of accommodating a flood of the 100-year magnitude.

(P) *Freeboard.* A factor of safety usually expressed in feet above a specified flood level for purposes of floodplain management. "Freeboard" tends to compensate for the many unknown factors that could contribute to flood heights greater than the height calculated for a selected size flood and floodway conditions, such as wave action, bridge openings, and the hydrological effect of urbanization in the watershed.

(Q) *Highest adjacent grade.* The highest natural elevation of the ground surface prior to construction next to the proposed walls of a structure.

(R) *Historic structure.* Any structure that is:

(1) Listed individually in the National Register of Historic Places (a listing maintained by the Department of Interior) or preliminarily determined by the Secretary of the Interior as meeting the requirements for individual listing on the National Register;

(2) Certified or preliminarily determined by the Secretary of the Interior as contributing to the historical significance of a registered historic district or a district preliminarily determined by the Secretary to qualify as a registered historic district;

(3) Individually listed on a state inventory of historic places in states with historic preservation programs which have been approved by the Secretary of the Interior; or,

(4) Individually listed on a local inventory of historic places in communities with historic preservation programs that have been certified either by an approved state program as determined by the Secretary of the Interior or directly by the Secretary of the Interior in states without approved programs.

(S) *Lowest floor.* The lowest floor of the lowest enclosed area (including basement). A parking structure that is below grade on all sides is considered a basement and therefore the lowest floor. An unfinished or flood resistant enclosure, usable solely for parking of vehicles, building access or storage, in an area other than a basement area (the enclosure is not below grade on all sides) is not considered a building's lowest floor; provided, that such enclosure is not built so as to render the structure in violation of the applicable floodproofing non-elevation design requirements of this section 6-300.

(T) *Manufactured home.* A structure, transportable in one or more sections, which is built on a permanent chassis and is designed to be used as a single-family dwelling, with or without permanent foundation, when connected to the required facilities, and which includes the plumbing, heating, air conditioning and electrical systems contained in the structure. A manufactured home shall include park trailers and other similar vehicles when placed on a site for greater than 180 days.

(U) *Mixed-use building.* Any building or structure that is used or intended for use for a mixture of nonresidential and residential uses in the same building or structure. For floodplain management purposes, a mixed-use building is subject to the same rules and conditions as a residential building unless all of the provisions set forth more specifically herein are met.

(V) *New construction.* Buildings and structures as to which the start of construction occurred on or after May 24, 1977, including any subsequent improvements to such buildings or structures. For floodplain management purposes, new construction means structures for which the start of construction commenced on or after the effective date of a floodplain management regulation adopted by a community and includes any subsequent improvements to such structures.

(W) *Nonresidential building.* Any building or structure which is not a residential building or a mixed-use building.

(X) *Recreational vehicle.* A vehicle which is:

(1) Built on a single chassis;

(2) Four hundred square feet or less when measured at the largest horizontal projection;

(3) Designed to be self-propelled or permanently towable by a light duty truck; and,

(4) Designed primarily not for use as a permanent dwelling but as temporary living quarters for recreational camping, travel, or seasonal use.

(Y) *Residential building.* Any single-family dwelling, two-family dwelling, row or townhouse dwelling, or multi-family dwelling, and any accessory building or structure.

(Z) *Shallow flooding area.* A special flood hazard area with base flood depths from one to three feet where a clearly defined channel does not exist, where the path of flooding is unpredictable and indeterminate, and where velocity flow may be evident. Such flooding is characterized by ponding or sheet flow.

(AA) *Special flood hazard area (SFHA).* The land in the floodplain subject to a one percent or greater chance of being flooded in any given year as designated on the official Flood Insurance Rate Map for the City of Alexandria.

(BB) *Start of construction.* The date a building permit is issued, provided that the actual start of construction begins within 180 days of the permit issuance date. For new construction, the actual start of construction means the initial placement of permanent construction of a structure on the site, such as the pouring of footings or a slab, the installation of piles, the construction of columns or any work beyond the state of excavation, or the placement of a manufactured home on a foundation. Permanent construction does not include land preparation, such as clearing, grading and filling, or the installation of streets or walkways, or excavation for a basement or for footings, piers or foundations, or the erection of temporary forms, or the installation of accessory buildings, such as garages or sheds not occupied as dwelling units and not part of the main structure. For substantial improvements, the actual start of construction means the first alteration of any wall, ceiling, floor or other structural part of a building, whether or not the alteration affects the external dimensions of the buildings.

(CC) *Structure.* For flood plain management purposes, a walled and roofed building, including a gas or liquid storage tank, that is principally above ground, as well as a manufactured home. "Structure" for insurance coverage purposes, means:

(1) A building with two or more outside rigid walls and a fully secured roof, that is affixed to a permanent site;

(2) A manufactured home (also known as a mobile home), is a structure: built on a permanent chassis, transported to its site in one or more sections, and affixed to a permanent foundation; or

(3) A travel trailer without wheels, built on a chassis and affixed to a permanent foundation, that is regulated under the community's floodplain management and building ordinances or laws.

For the latter purpose, "structure" does not mean a recreational vehicle or a park trailer or other similar vehicle, except as described in paragraph (3) of this definition, or a gas or liquid storage tank.

(DD) *Substantial damage.* Damage of any origin sustained by a building or structure whereby the cost of restoring the building or structure to its before damaged condition would equal or exceed 50 percent of the market value of the building or structure before the damage occurred.

(EE) *Substantial improvement.* Any repair, reconstruction, rehabilitation, addition or other improvement of a building or structure, the cost of which equals or exceeds 50 percent of the market value of the building or structure immediately before construction of the improvement is commenced, or any restoration of a building or structure which has incurred substantial damage; provided, that the term does not include:

(1) Any improvement of a building or structure that is necessary to correct existing violations of state or local health, sanitary or safety code specifications which have been identified by appropriate officials of the state or city and which are the minimum necessary to assure safe living conditions; or

(2) Any improvement of a "historic structure," as defined in this section, so long as the improvement does not preclude the structure's continued designation as a "historic structure."

(FF) *Violation.* The failure of a structure or other development to be fully compliant with the City of Alexandria's floodplain management regulations. A structure or other development without the elevation certificate, other certifications, or other evidence of compliance required in 44 CFR 60.3(b)(5), (c)(4), (c)(10), (d)(3), (e)(2), (e)(4), or (e)(5) is presumed to be in violation until such time as that documentation is provided.

6-304 - Description of floodplain districts.

(A) The various floodplain districts shall include the special flood hazard areas described below. The basis for the delineation of these districts shall be the flood insurance study and the flood insurance rate maps for the City of Alexandria prepared by FEMA, Federal Insurance Administration, dated June 16, 2011, and any subsequent revisions and amendments thereto.

(1) The special floodplain district shall include those areas identified as an AE zone on the flood insurance rate map for which 100-year base flood elevations have been provided.

(2) The approximated floodplain district shall include those areas identified as an A zone on the flood insurance rate map. In these zones, no detailed flood profiles or elevations are provided, but the 100-year floodplain boundary has been approximated. For these areas, the 100-year flood elevations and floodway information from federal, state, and other acceptable sources shall be used, when available. Where the specific 100-year flood elevation cannot be determined for this area using other sources of data, such as the U.S. Army Corps of Engineers Flood Plain Information Reports, U.S. Geological Survey Flood-prone Quadrangles, etc., then the applicant for the proposed use, development and/or activity shall determine this elevation in accordance with FEMA-approved hydrologic and hydraulic engineering techniques. Hydrologic and hydraulic analyses shall be undertaken only by professional engineers or others of demonstrated qualifications, who shall certify that the technical methods used correctly reflect currently-accepted technical concepts. Studies, analyses, computations, etc., shall be submitted in sufficient detail to allow a thorough review by the director of transportation and environmental services.

(B) The delineation of any of the floodplain districts may be revised by the City of Alexandria where natural or man-made changes have occurred and/or where more detailed studies have been conducted or undertaken by the U.S. Army Corps of Engineers or other qualified agency, or an individual documents the need for such change. Updates to the delineation of the floodplain districts require approval from both the City of Alexandria and the FEMA Federal Insurance Administration.

(C) Any uncertainty on the floodplain district map, or flood insurance rate map, with respect to the boundary of any floodplain district, either A or AE zone, shall be determined by the director of transportation and environmental services by scaling and computation from the map or by land survey information.

6-305 - Administration.

(A) The director of transportation and environmental services shall be responsible for the administration of the floodplain management regulations set forth in this section 6-300. He or she shall be responsible for the review of all proposed uses and development to determine whether the land on which the proposed use or development is located is in a floodplain, and that the site is reasonably safe from flooding.

(B) An applicant must apply for a permit and issuance of the permit is required prior to the start of any development within the special flood hazard area.

(C) No site plan, subdivision plat or building permit application which proposes to construct or make substantial improvements within any floodplain district shall be approved by any agency of the City of Alexandria without certification by the director of transportation and environmental services that the plan, plat or permit application meets the requirements of this section 6-300. The director of transportation and environmental services shall insure that all other required permits related to development in the floodplain from state or federal governmental agencies have been obtained.

(D) All applications for new construction or substantial improvement within any floodplain district, and all building permits issued for the floodplain shall incorporate the following information:

(1) The base flood elevation at the site;

(2) The elevation of the lowest floor (including basement);

(3) For structures to be floodproofed (nonresidential only), the elevation to which the structure will be floodproofed; and,

(4) Topographic information showing existing and proposed ground elevations.

(E) The director of transportation and environmental services may require information from the applicant, including, but not limited to, an engineering study of the floodplain. Upon a determination that the land on which the proposed use or development is located in a floodplain, the director of transportation and environmental services shall determine whether such use or development may be permitted in accordance with the provisions of section 6-306 through 6-308 or requires the approval of a variance as set forth in section 6-311.

(F) The director of transportation and environmental services shall be responsible for the collection and maintenance of records necessary for the city's participation in the National Flood Insurance Program. Base flood elevations may increase or decrease resulting from physical changes affecting flooding conditions. As soon as practicable, but not later than six months after the date such information becomes available, the director of transportation and environmental services shall notify or require the applicant to notify the FEMA Federal Insurance Administrator of any change in base flood elevation or the boundaries of any special flood hazard area depicted on the city's flood insurance rate map by submitting technical and scientific data to FEMA for a letter of map revision.

6-306 - Special regulations.

Within the boundaries of any A or AE zones in any floodplain district as shown on the flood insurance rate map, buildings or structures and their extensions and accessory buildings or structures maybe be constructed or substantially improved only in accordance with the following requirements of this section 6-300 and all other applicable provisions of law.

(A) The elevation of the lowest floor, including the basement, for any new residential building or any extension to a residential building shall be at least one foot above the base flood elevation.

(B) The elevation of the lowest floor, including the basement for any new nonresidential building or structure and any extension or accessory to a nonresidential building shall be at least one foot above the base flood elevation. Nonresidential buildings located in all A or AE zones may be floodproofed in lieu of being elevated provided that all areas of the building components below the elevation corresponding to the base flood elevation plus one foot are watertight with walls substantially impermeable to the passage of water, and use structural components having the capability of resisting hydrostatic and hydrodynamic loads and the effect of buoyancy. In no event shall any floor below at least one foot above the base flood elevation be used for human or animal habitation, food storage or food preparation.

(C) All new and replacement public utilities, water mains and sanitary sewers shall be designed to minimize or eliminate infiltration and exfiltration and to insure their structural integrity under flood conditions to the satisfaction of the director of transportation and environmental services.

(D) Water heaters, furnaces, electrical distribution panels and other critical mechanical or electrical installations shall not be installed below the base flood elevation. Separate electrical circuits shall serve areas below the base flood elevation and shall be dropped from above.

(E) Any proposed use of land, development and any new construction or substantial improvement of a building or structure within an A or AE zone, in conjunction with all other uses, existing or possessing a valid permit for construction, shall not increase the water-surface elevation of the 100-year flood by more than 0.5 foot. Any party proposing a land use or development or such construction or improvement within an A or AE zone shall furnish specific engineering data and information as to the effect of the proposed action on future flood heights and obtain approval from the director of transportation and environmental services prior to undertaking the action.

(F) No building permit shall be issued for the construction or substantial improvement of a building or structure unless the applicant submits to the department of code administration a certification from a duly registered architect or engineer that the proposed construction (including prefabricated homes) or improvement meets the following requirements:

(1) The construction shall be protected against flood damage;

(2) The construction shall be designed (or modified) and anchored to prevent flotation, collapse or lateral movement of the building and structure;

(3) The construction shall be built using materials and utility equipment that are resistant to flood damage; and,

(4) The construction shall be built using methods and practices that will minimize flood damage. The certification required be section 6-306(F)(1) and (2) shall be based on the 100-year flood level as noted

on the flood insurance rate map.

(G) No building permit for the substantial improvement of an existing nonresidential building shall be issued unless the building, together with attendant utility and sanitary facilities, has the lowest floor (including the basement) elevated at least one foot above the base flood elevation. Should this not be feasible, no such permit shall be issued unless the existing structure is watertight floodproofed as described in section 6-306 in all areas below the base flood elevation to the classification designated by the director of transportation and environmental services.

(H) No building permit for the substantial improvement of an existing residential building shall be issued unless the building has the lowest floor (including the basement) elevated at least one foot above the base flood elevation.

(I) Wherever floodproofing is utilized within the scope of this section 6-300, such floodproofing shall be done by approved methods. A registered professional engineer or architect shall certify the adequacy of the floodproofing design to withstand the stresses of the base flood and such plan shall cite the elevation to which the structure is floodproofed. Such certification shall be provided on Federal Emergency Management Agency, National Flood Insurance Program, elevation certificate and/or floodproofing certificate as applicable. Designs meeting the requirements of the W-1 and W-2 without human intervention technique as outlined in floodproofing regulations of the Office of the Chief of Engineers, U.S. Army, December 15, 1995, shall be deemed to comply with this requirement. The building or code official shall maintain a file of such certifications, including the elevation of the lowest floor for structures that are elevated in lieu of watertight floodproofing.

(J) For all new construction or substantially improved structures, fully enclosed areas below the lowest floor (other than a basement) which are below the base flood elevation shall:

- (1) Only be used for the parking of vehicles, building access, or limited storage of maintenance equipment used in connection with the premises and shall not be designed or used for human habitation. Access to the enclosed area shall be the minimum necessary to allow for parking of vehicles (garage door) or limited storage of maintenance equipment (standard exterior door), or the entry to the living area (stairway or elevator);
- (2) Be constructed entirely of flood resistant materials below the base flood elevation; and,
- (3) Include, in A and AE zones, measures to automatically equalize hydrostatic flood forces on walls by allowing for the entry and exit of floodwaters. To meet this requirement, the openings must be certified by a professional engineer or architect or meet the minimum design criteria:
  - (a) Provide a minimum of two openings on different sides of each enclosed area subject to flooding;
  - (b) The total net area of all openings must be at least one square inch for each square foot of enclosed area subject to flooding;
  - (c) If a building has more than one enclosed area, each area must have openings to allow floodwaters to automatically enter and exit;
  - (d) The bottom of all required openings shall be no higher than one foot above the adjacent grade;
  - (e) Openings may be equipped with screens, louvers, or other opening coverings or devices, provided they permit the automatic flow of floodwaters in both directions; and,
  - (f) Foundation enclosures made of flexible skirting are not considered enclosures for regulatory purposes, and, therefore, do not require openings. Masonry or wood underpinning, regardless of structural status, is considered an enclosure and requires openings as outlined above.

(K) Any mixed-use building may be considered a nonresidential building for purposes of this section 6-306 if all of the following conditions are met; otherwise, the building shall be considered a residential building:

- (1) No more than 20 percent of the development site is within the boundaries of any A or AE zones in any floodplain district as shown on the flood insurance rate map;
- (2) At least 20,000 square feet of finished floor area of the proposed mixed-use building is devoted to nonresidential use;
- (3) Basement areas (including below grade parking) must be located outside the boundaries of any A or AE

zones in any floodplain district; and,

(4) All floodproofing requirements specified in this section 6-300 and as specified in FEMA Technical Bulletin 3-93 Non-Residential Floodproofing - Requirements and Certification must be met.

6-307 - Other conditions.

(A) No filling of any kind shall be allowed within the boundaries of any A or AE zone except where such filling, when considered in conjunction with all other uses, existing and proposed, will not increase the base flood elevation more than 0.5 foot. Persons proposing such filling shall furnish specific engineering data and information as to the effect of their proposed action on future flood heights and shall obtain approval from the director of transportation and environmental services prior to any filling.

(B) All uses, activities and development occurring within any floodplain district shall only be undertaken in strict compliance with the Virginia Uniform Statewide Building Code (VA USBC).

(C) No wall, fence or other outdoor obstruction shall be constructed in any floodplain district unless such structure is approved by the director of transportation and environmental services; provided that open mesh wire fences of not less than No. 9 wire, with mesh openings of not less than six inches times six inches, whose supports shall be securely anchored in concrete and whose wire shall be securely fastened to the supports, may be erected without any review by or approval of the director of transportation and environmental services under this section 6-300.

(D) The provisions of this section 6-300 shall not be construed to prevent the remodeling (not amounting to substantial improvement), maintenance or floodproofing of buildings and structures now existing, or prevent the surfacing or resurfacing of existing streets or parking lots within two inches of the existing grade.

6-308 - Subdivision requirements.

(A) Subdivision proposals which are located in A or AE zones must comply with the provisions of section 6-300 and shall:

(1) Be consistent with the need to minimize flood damage;

(2) Have public utilities and facilities such as sewer, gas, electrical and water systems located and constructed to minimize flood damage;

(3) Have adequate drainage provided to reduce exposure to flood hazards; and,

(4) Include base flood elevation data.

6-309 - Trailer camps, manufactured homes, mobile homes, recreational vehicles and septic tank systems.

(A) Trailer camps, manufactured homes and mobile homes are not permitted in any floodplain district.

(B) All recreational vehicles in the floodplain must be on the site for fewer than 180 consecutive days and be fully licensed and ready for highway use.

(C) Installation of septic tank systems in any floodplain district is prohibited.

6-310 - Flood prevention projects.

Nothing in section 6-304 through section 6-308 shall be construed to prohibit the City of Alexandria or any person from undertaking lawful filling, draining, construction, realignment or relocation of stream channels or any other improvement that is intended to eliminate or reduce the danger of flooding, provided:

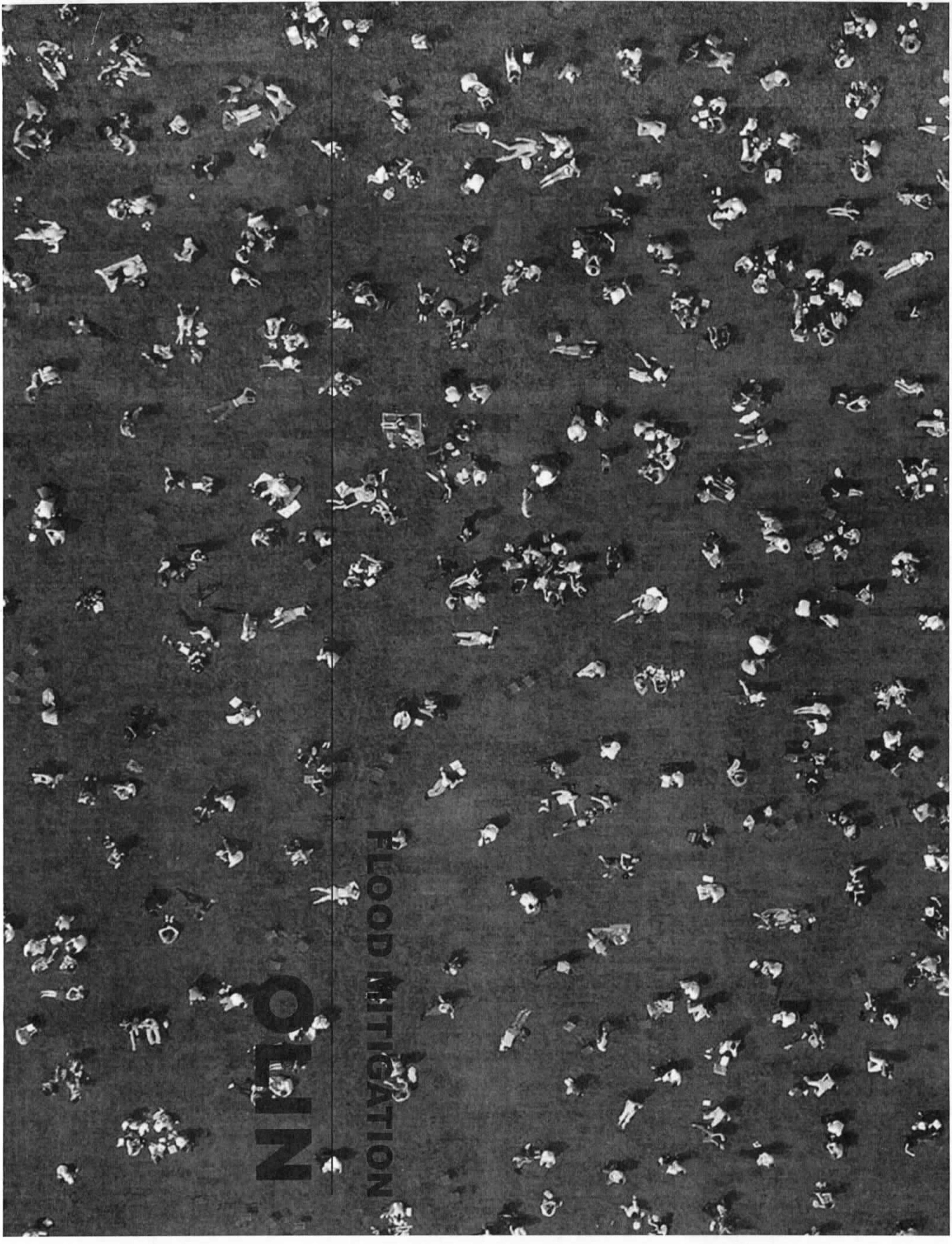
(A) The improvement is in accord with the City of Alexandria's flood improvement plan for the floodplain district involved and the director of transportation and environmental services has issued a certificate to that effect;

(B) The improvement is under the general supervision of the director of transportation and environmental services;

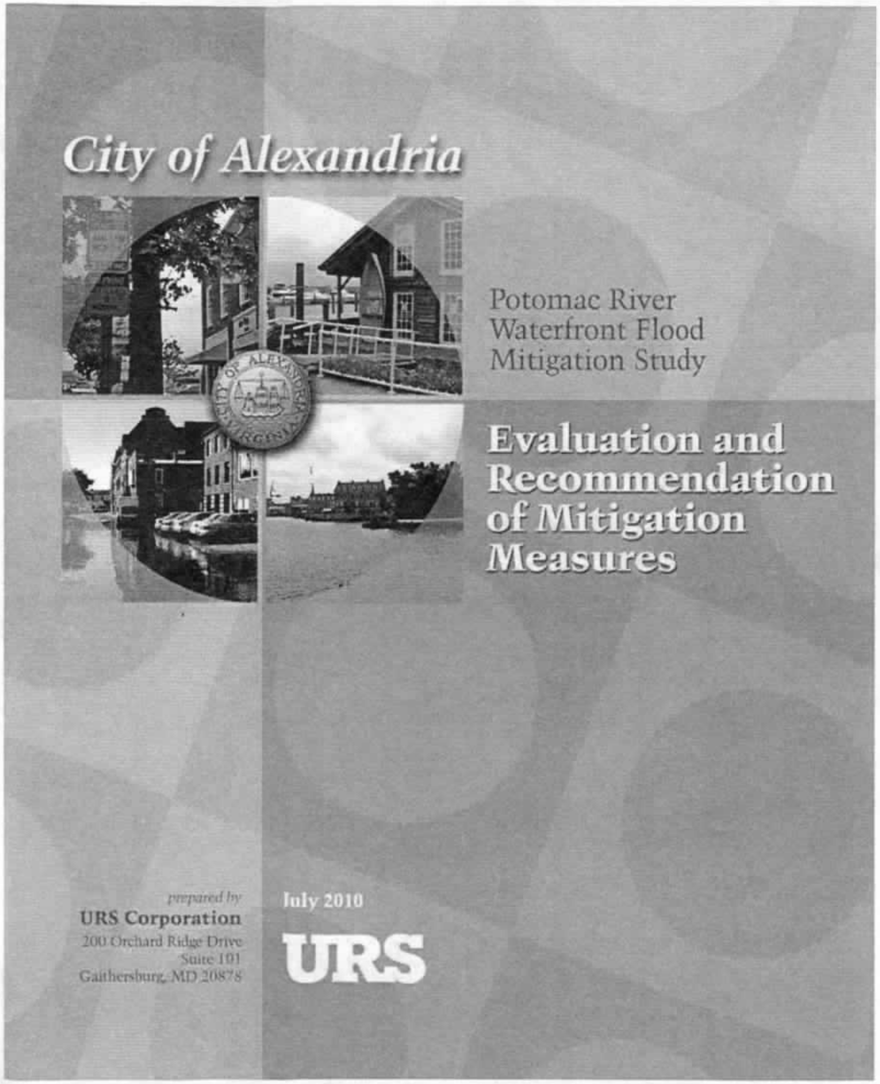
(C) The realignment or relocation of any stream channel is designed and constructed so that there will be no reduction in the natural valley storage capacity of the area with respect to the 100-year flood, unless such relocation or realignment is designed to contain the 100-year flood within the banks of the channel;

(D) Notification, in riverine situations, is provided to adjacent communities, Virginia Department of Conservation and Recreation, FEMA, and other required agencies prior to any alteration or relocation of a watercourse; and,

(E) The requirements of section 6-306(E) and section 6-307(A) must be met.


OLIN
FLOOD MITIGATION

Flood Mitigation Study

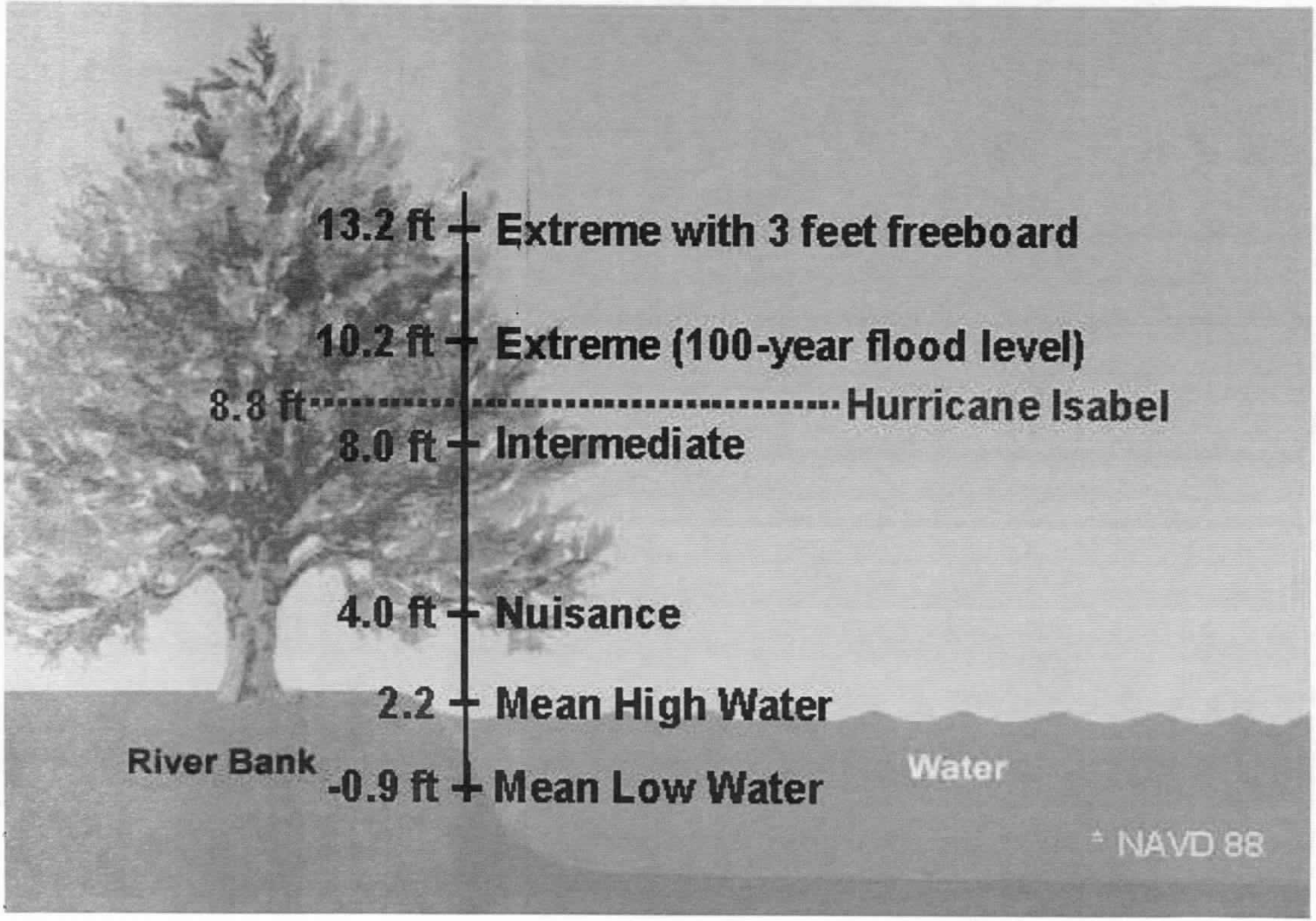


www.alexandriava.gov/waterfront

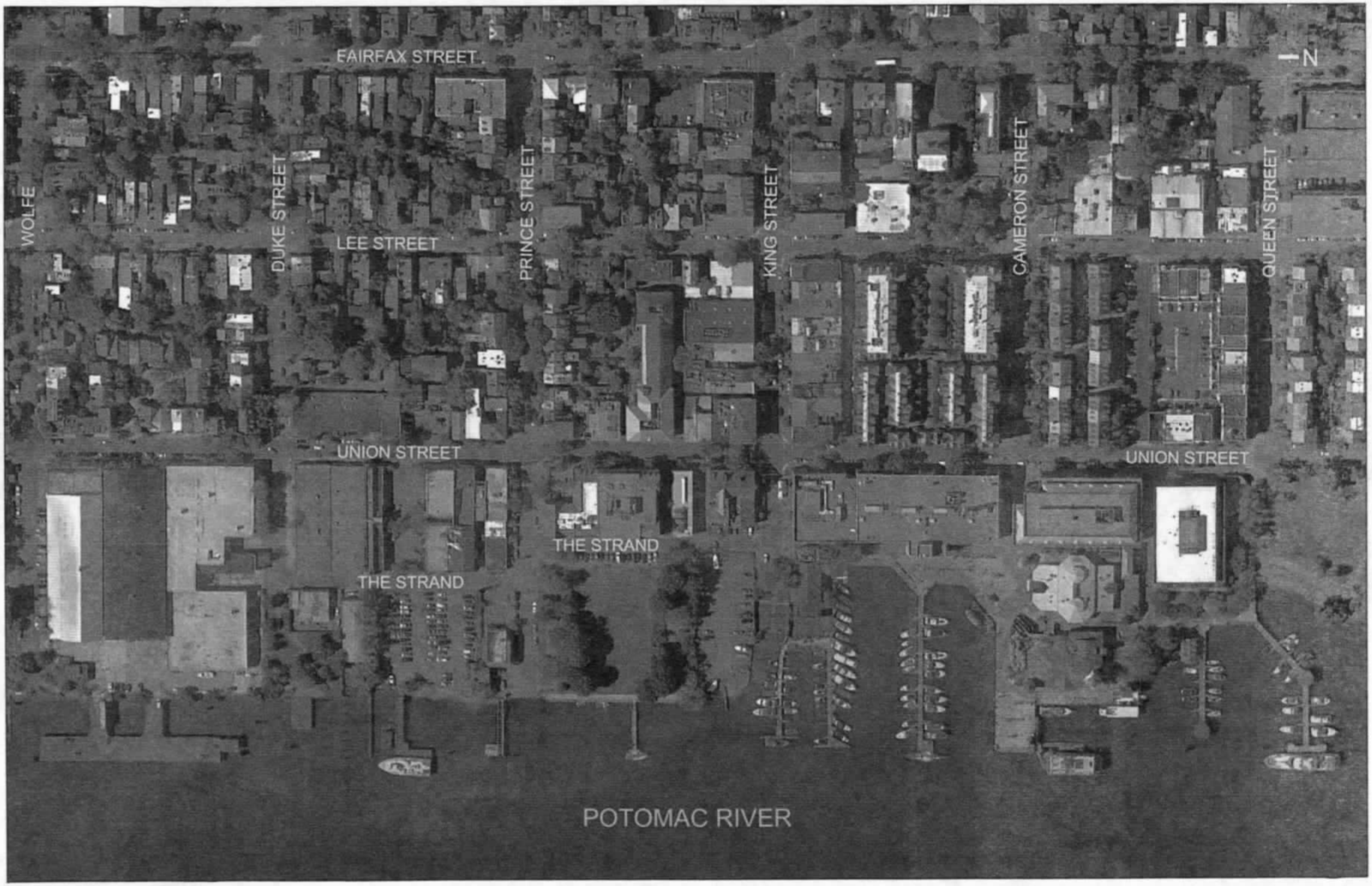
- July 2010
- Comprehensive evaluation of flood levels and mitigation
- Protect to Elevation 6.0'
- Elevated walkway concept
- Balances flood mitigation, cost and maintaining views

Flood Levels

Figure 2-2: Flood Levels Studied



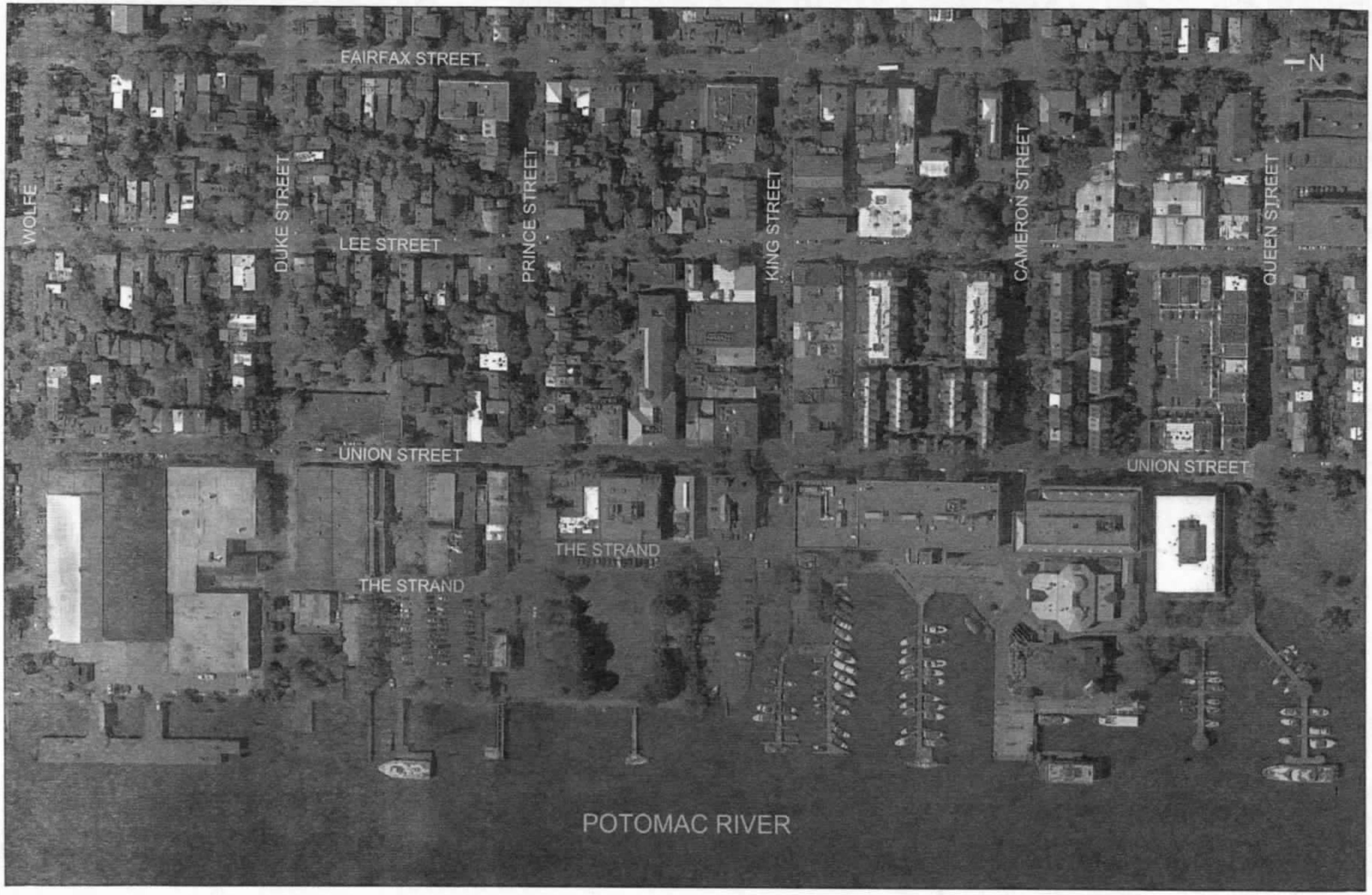
EXISTING CONDITIONS
RIVER ELEVATION = 2.0 FT



EXISTING CONDITIONS
RIVER ELEVATION = 3.0 FT

EXISTING CONDITIONS
RIVER ELEVATION = 4.0 FT

EXISTING CONDITIONS
RIVER ELEVATION = 5.0 FT



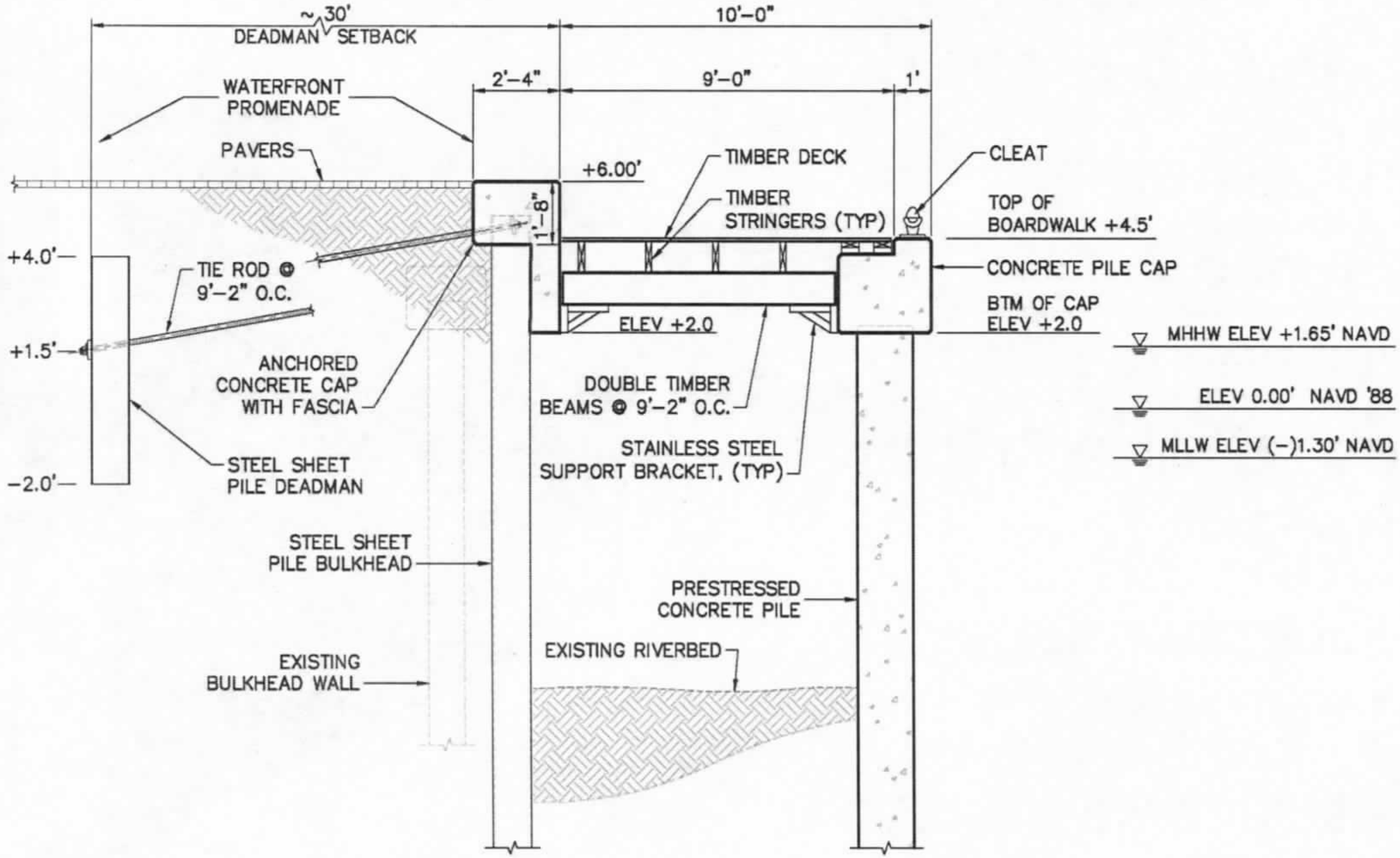
EXISTING CONDITIONS
RIVER ELEVATION = 6.0 FT

Recent Flooding

Flood Mitigation

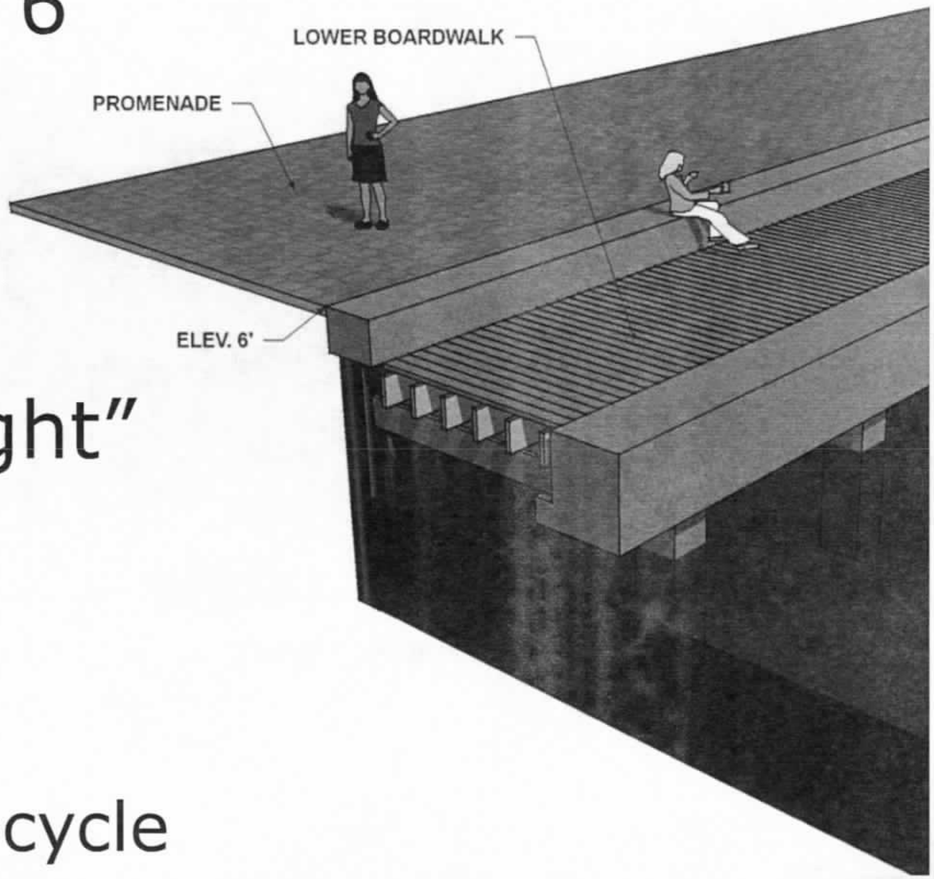
- URS Corporation
- Build upon 2010 study
- Incorporate into Olin Landscape Design
- 15% Design for the core area
- Drainage and infrastructure analyses
- 3 main components
  - Raised bulkhead
  - Pump stations (2)
  - Isolated storm sewer system

Bulkhead Detail

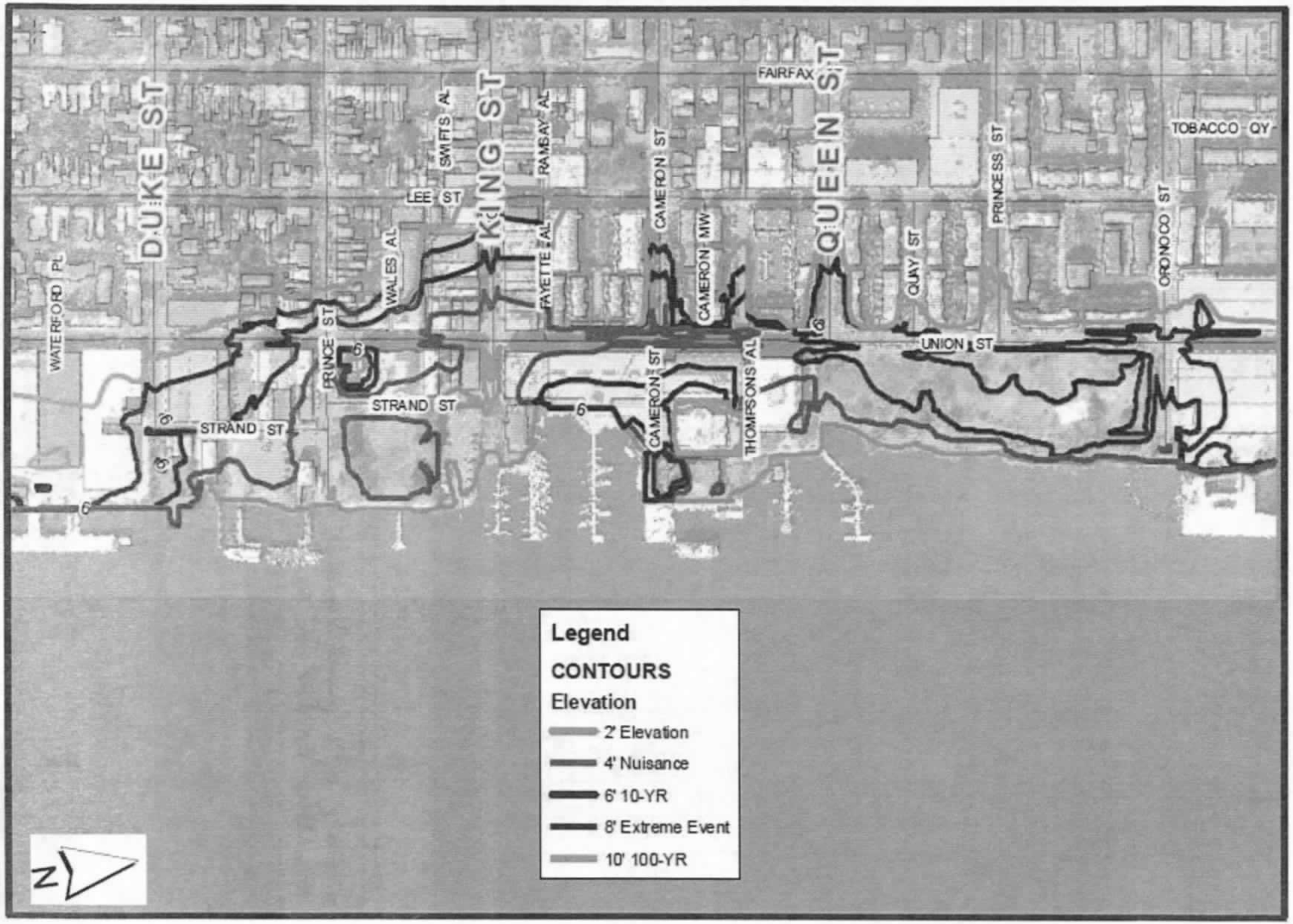


Bulkhead/Promenade

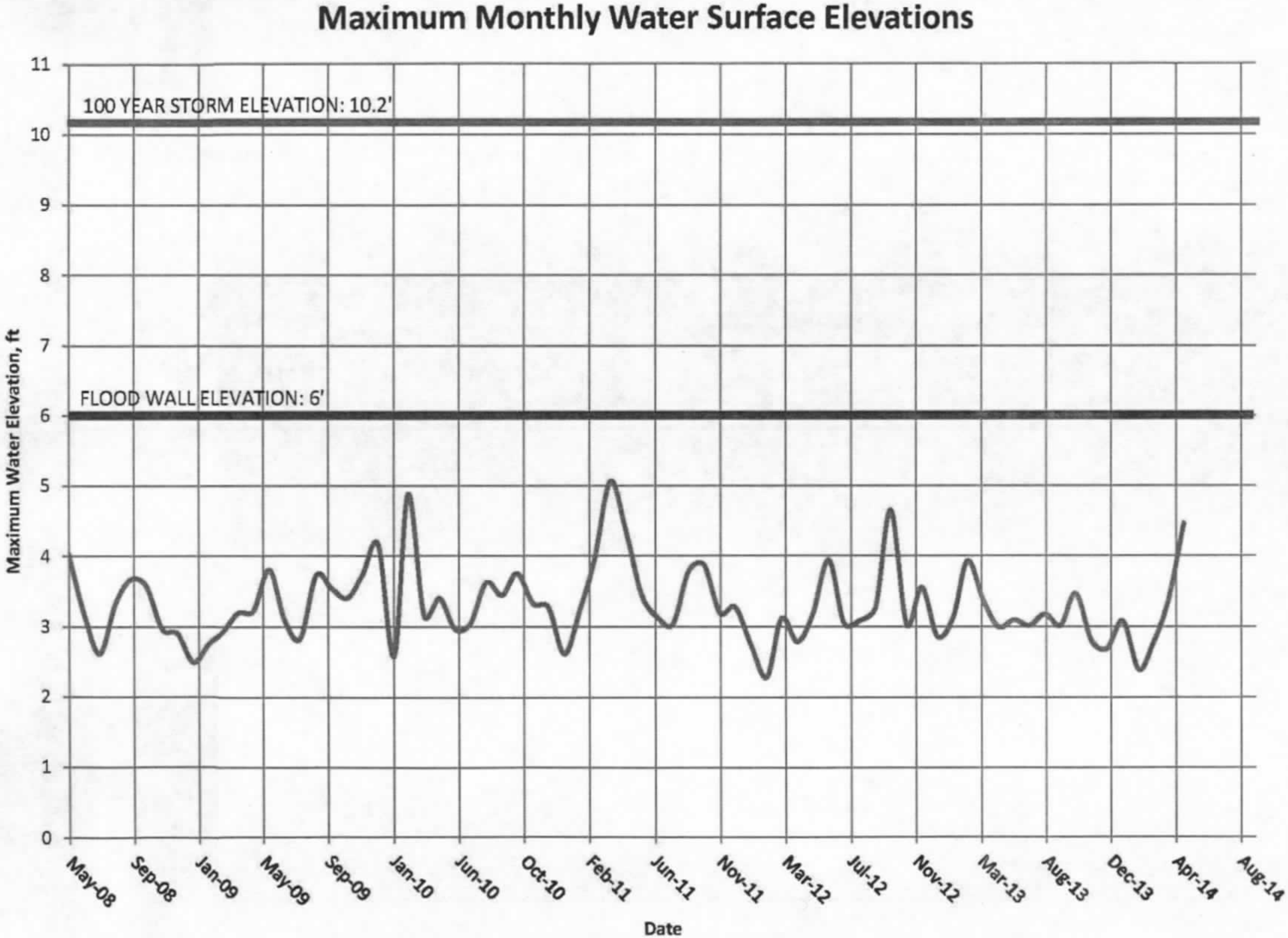
- Flood mitigation bulkhead to Elev. 6′
- Enhancements
  - Promenade
  - Lower boardwalk
- Is Elev. 6′ the "right" number?
  - Climate change
  - Cost/benefit
  - Infrastructure life-cycle



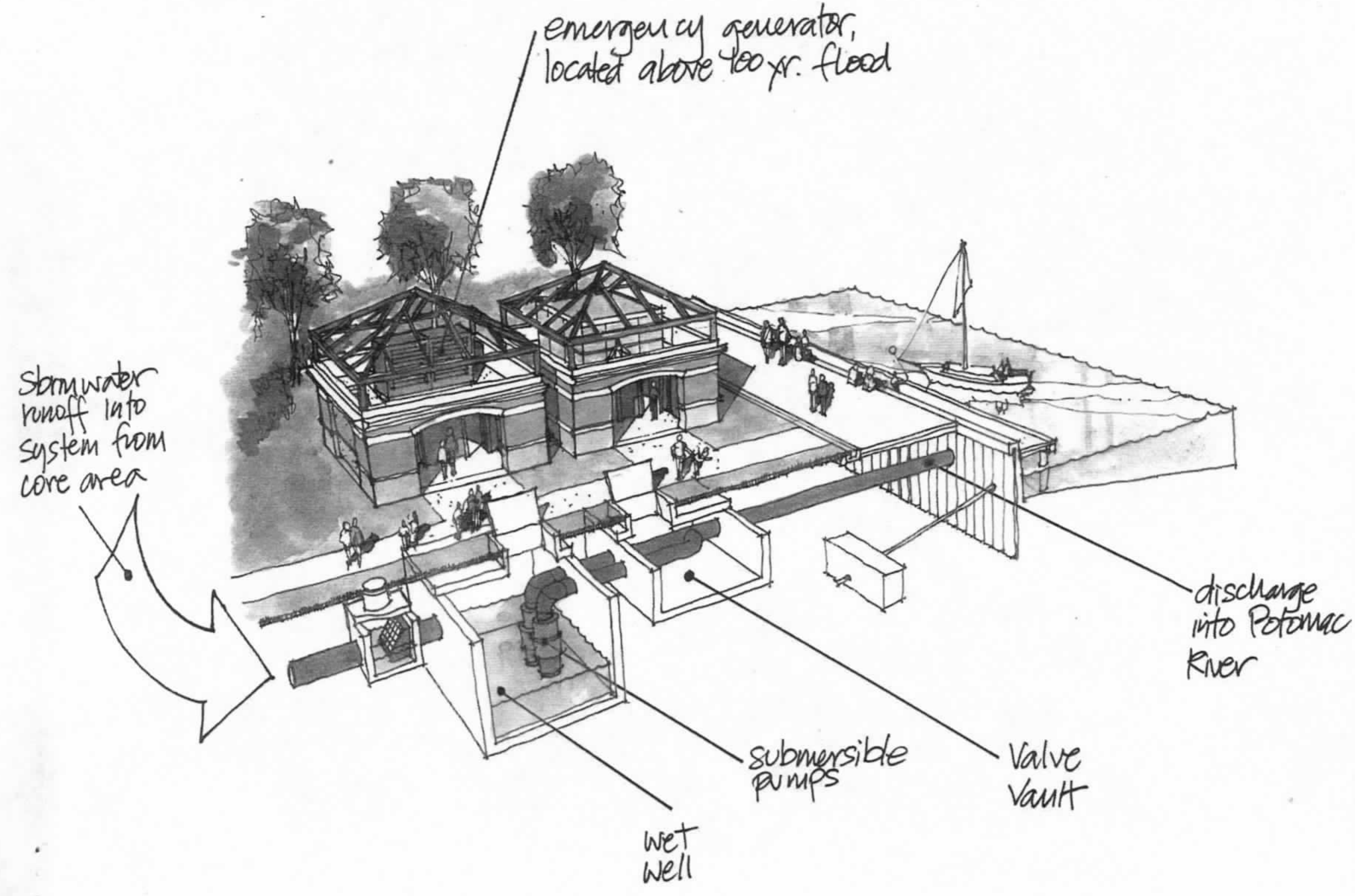
Flood Extents



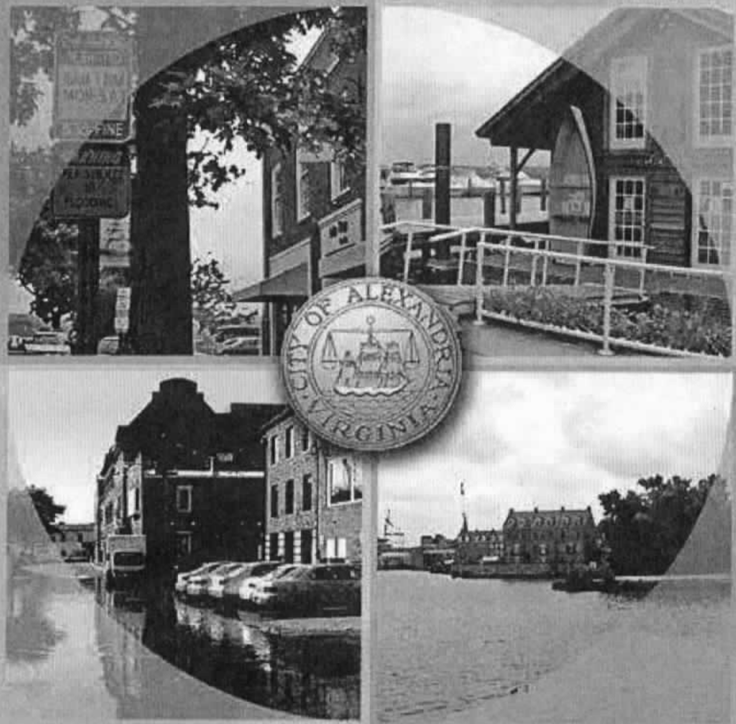
USGS – Recent River Data



Pump Stations Schematic



City of Alexandria



Potomac River
Waterfront Flood
Mitigation Study

Evaluation and Recommendation of Mitigation Measures

prepared by
URS Corporation
200 Orchard Ridge Drive
Suite 101
Gaithersburg, MD 20878

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

URS Corporation
200 Orchard Ridge Drive, Suite 101
Gaithersburg, MD 20878
Project Number: 15298592

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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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N

0 100 200 400 Feet

TITLE Focus Areas

URS
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.

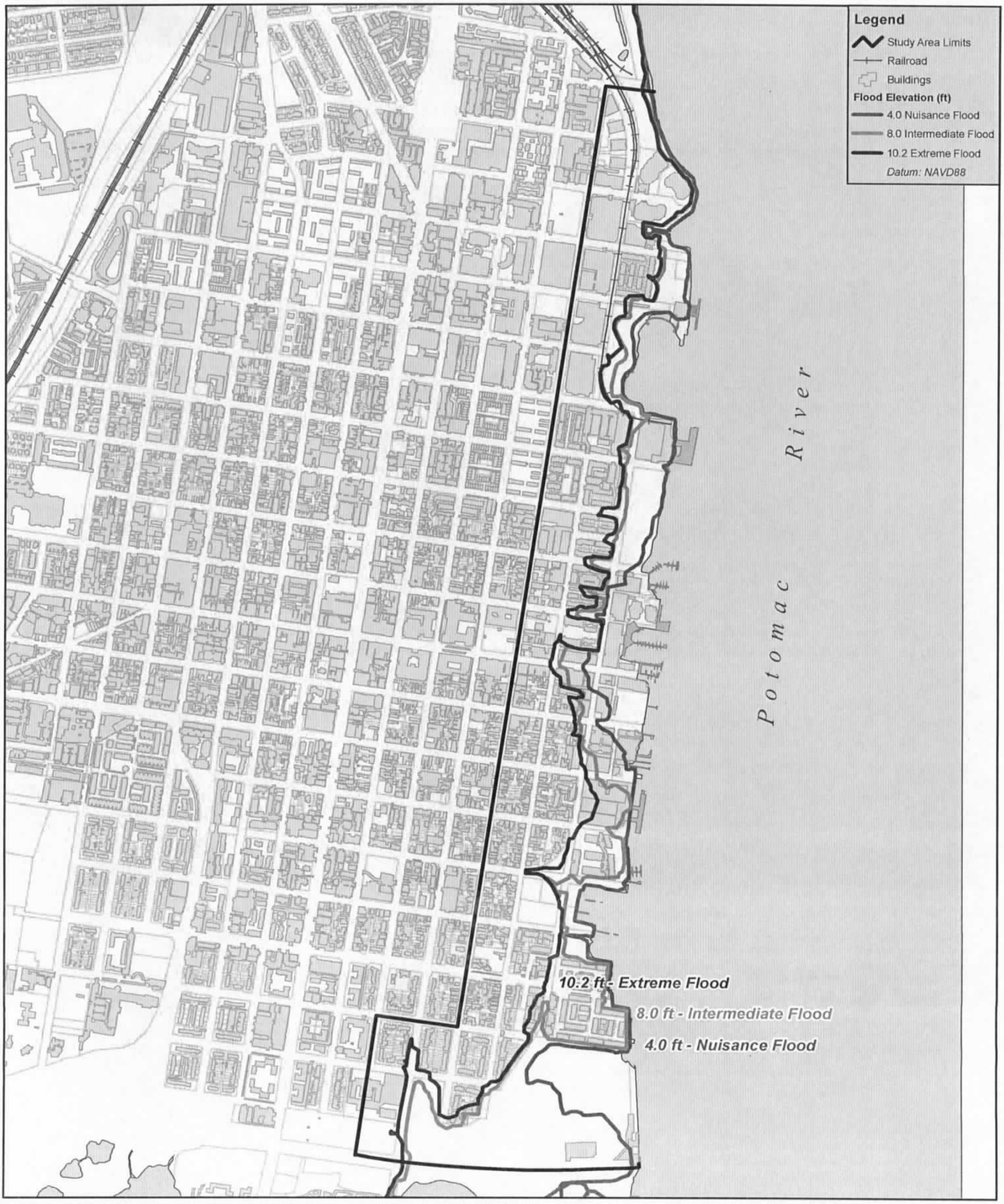
The project considers three discrete flood events: nuisance flooding (elevation 4.0 feet North American Vertical Datum [NAVD]); intermediate flooding (elevation 8.0 feet NAVD); and extreme flooding (elevation 10.2 feet NAVD). The three flood events have return periods associated with them. A return period 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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N

0 250 500

Feet

TITLE Inundation Areas for Selected Flood Level Categories

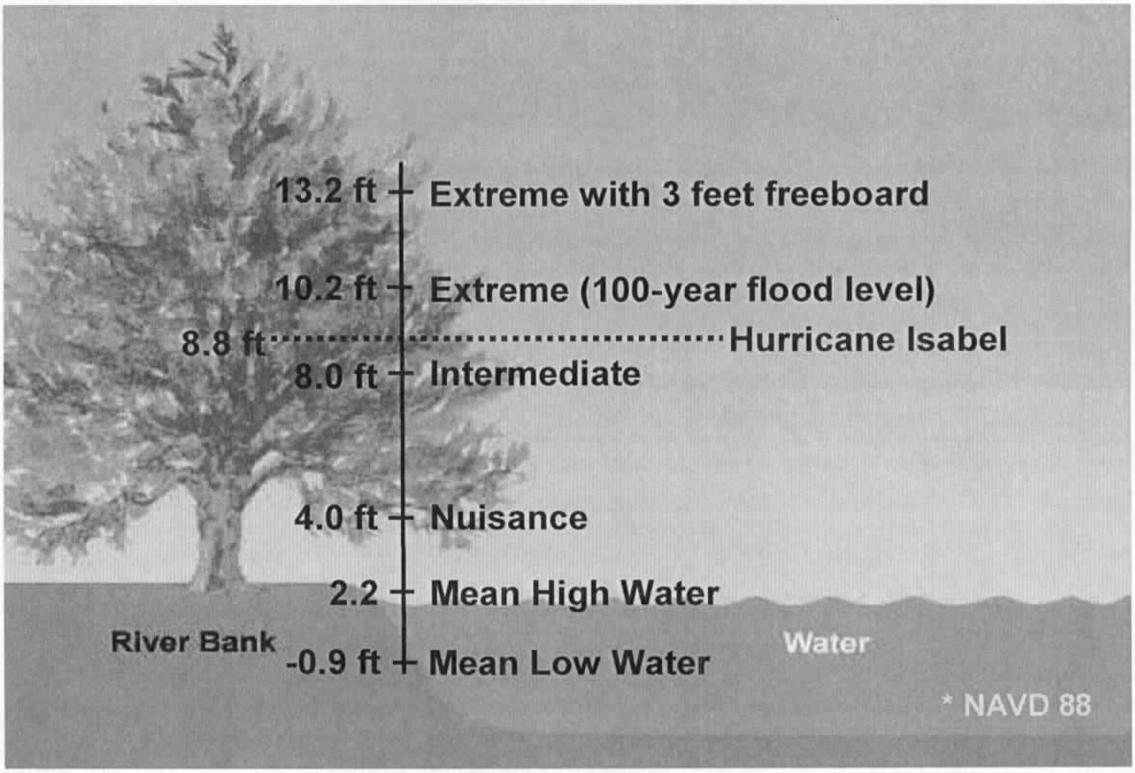
URS

200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO 15298592

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).

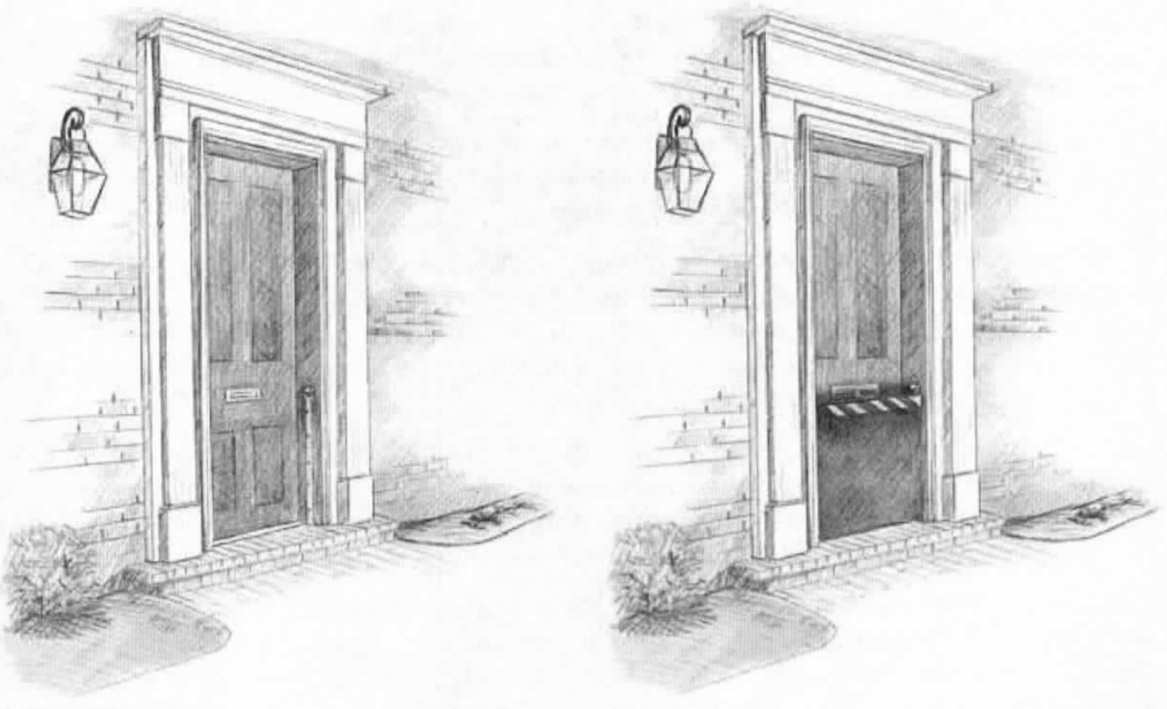


Figure 3-1: Floodgate

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).

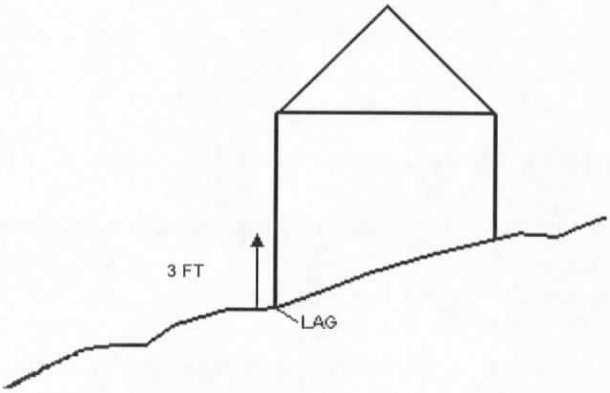


Figure 3-2: Three-Foot Dry Floodproofing Limitation

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).

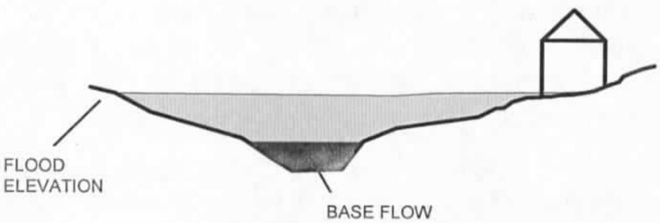


Figure 3-3: Flooded Building

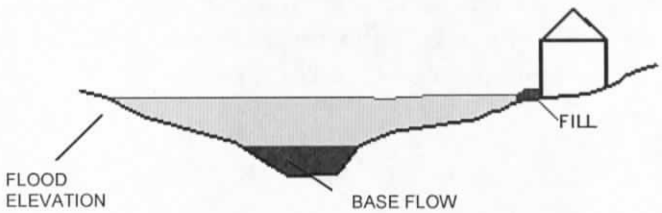


Figure 3-4: LAG Elevated to Protect Building from Flooding

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.

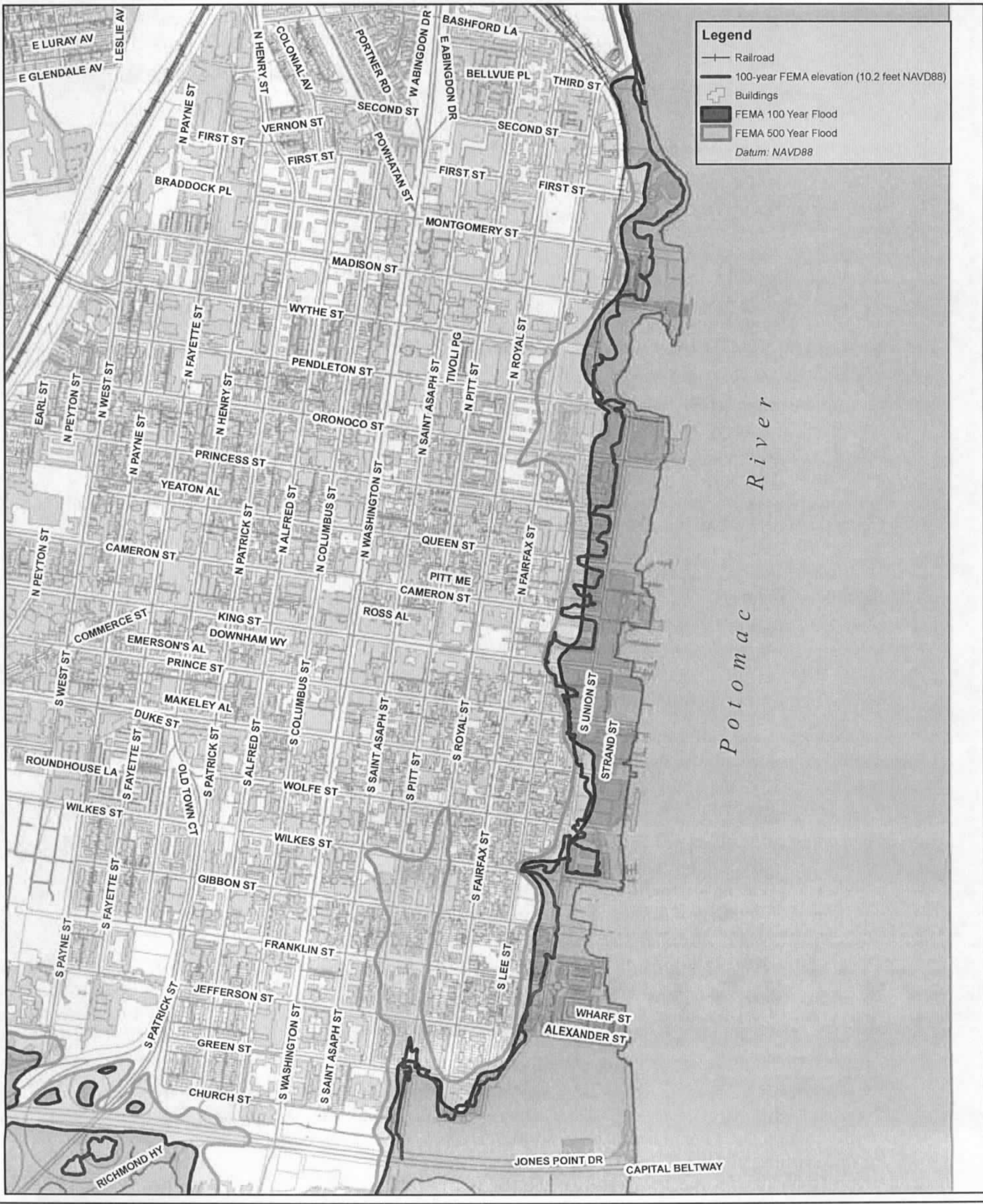
The 100-year regulatory floodplain boundary from the City's FIRM is also provided in the City's GIS. The regulatory FIRM boundaries are the actual boundaries as shown on the FIRM, without regard to recent topographic data. Therefore, the regulatory floodplain does not necessarily match the topographic 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

N

0 250 500
Feet

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.

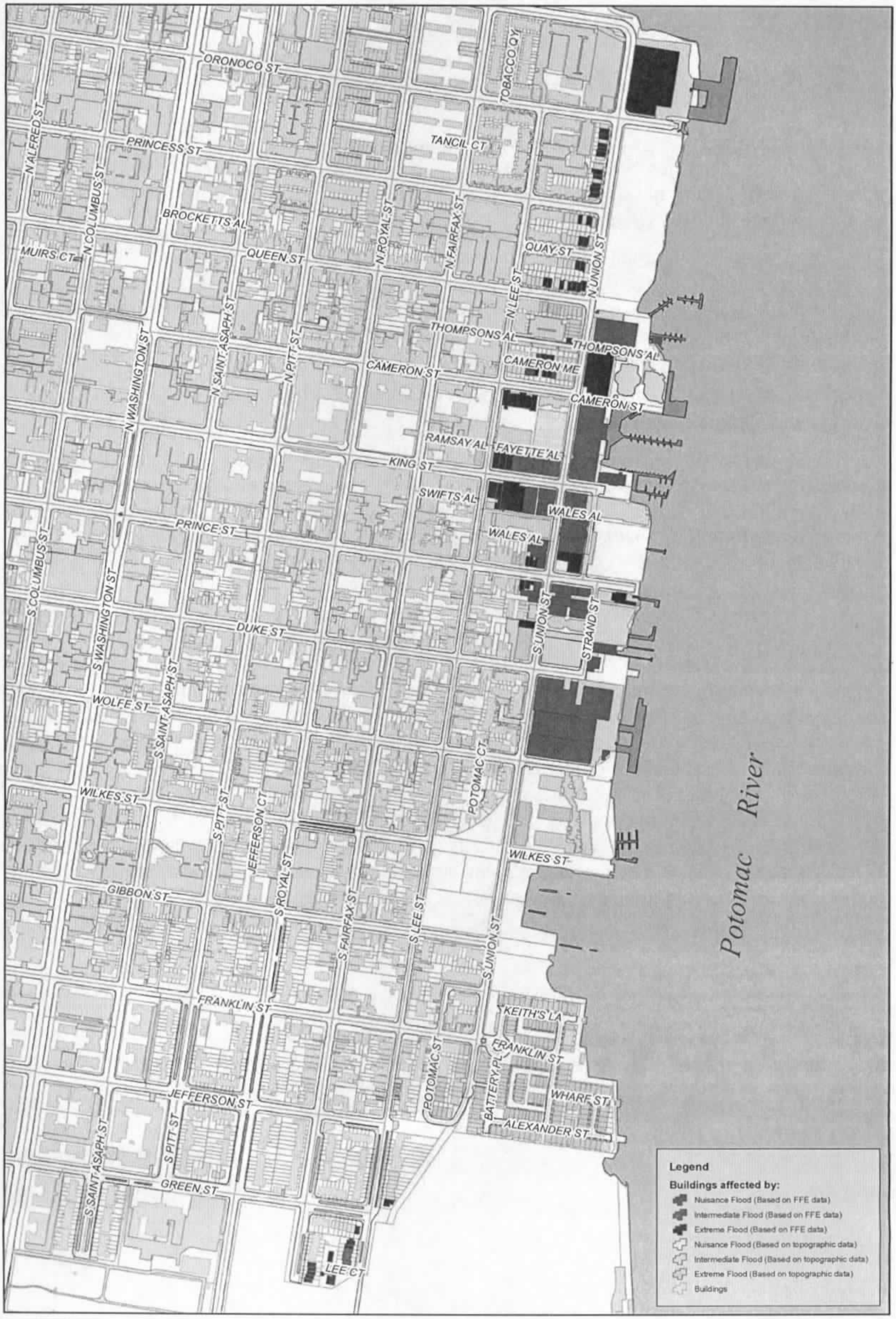
FFE survey data were not obtained for all structures located within floodprone areas. If FFE data were not available for a structure, the FFE was estimated using available topographic data. Figure 4-2 illustrates structures affected by the nuisance, intermediate, and extreme flood events based on FFE 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			
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
W:\City of Alexandria\15298470 - Lower King St\Task 3 Report\Final Figures\MXDs\F4-2 Structure Flooding.mxd		CHK BY	MER	10/04/09

TITLE
Structures Predicted to be Flooded for Each Event

URS
200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO 15298592

FIGURE 4-2

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° 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

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
		CHK BY	MER	10/04/09

0 50 100 200 feet

N

TITLE Proposed Floodwall Layout

URS
200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO 15298582

FIGURE 6-1

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

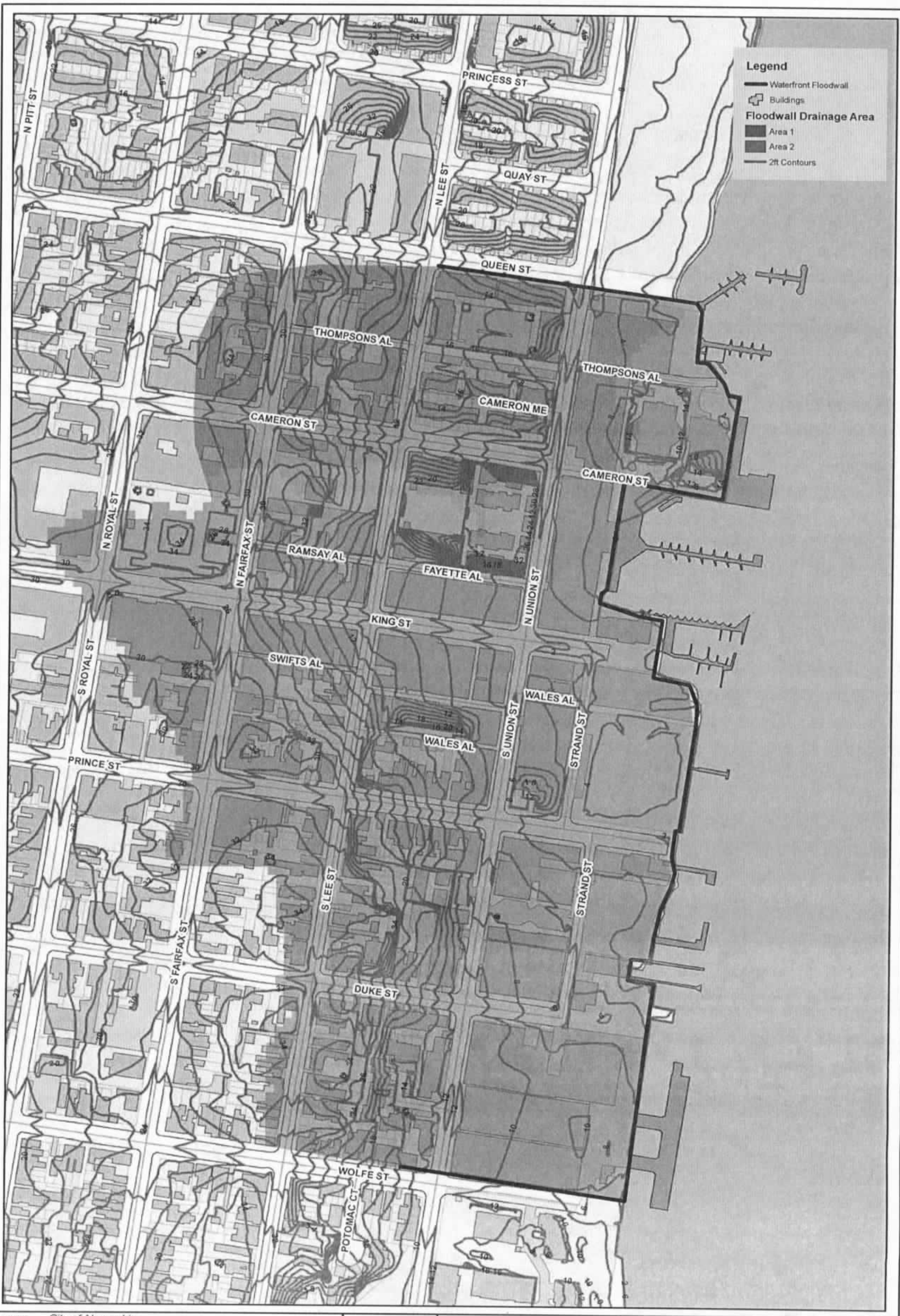
cfs = cubic foot/feet per second

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			
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
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

TITLE Interior Drainage Area of Proposed Floodwall

URS 200 Orchard Ridge Drive Gaithersburg, MD 20878

PROJ NO	15298592
FIGURE	6-2

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.

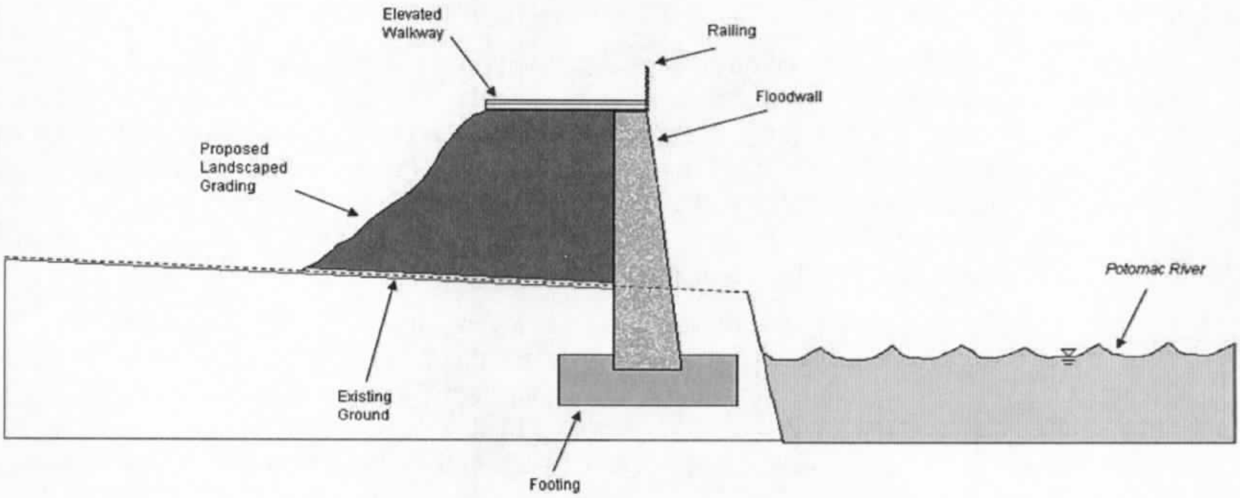


Figure 6-3: Proposed Elevated Walkway Example Cross-Section

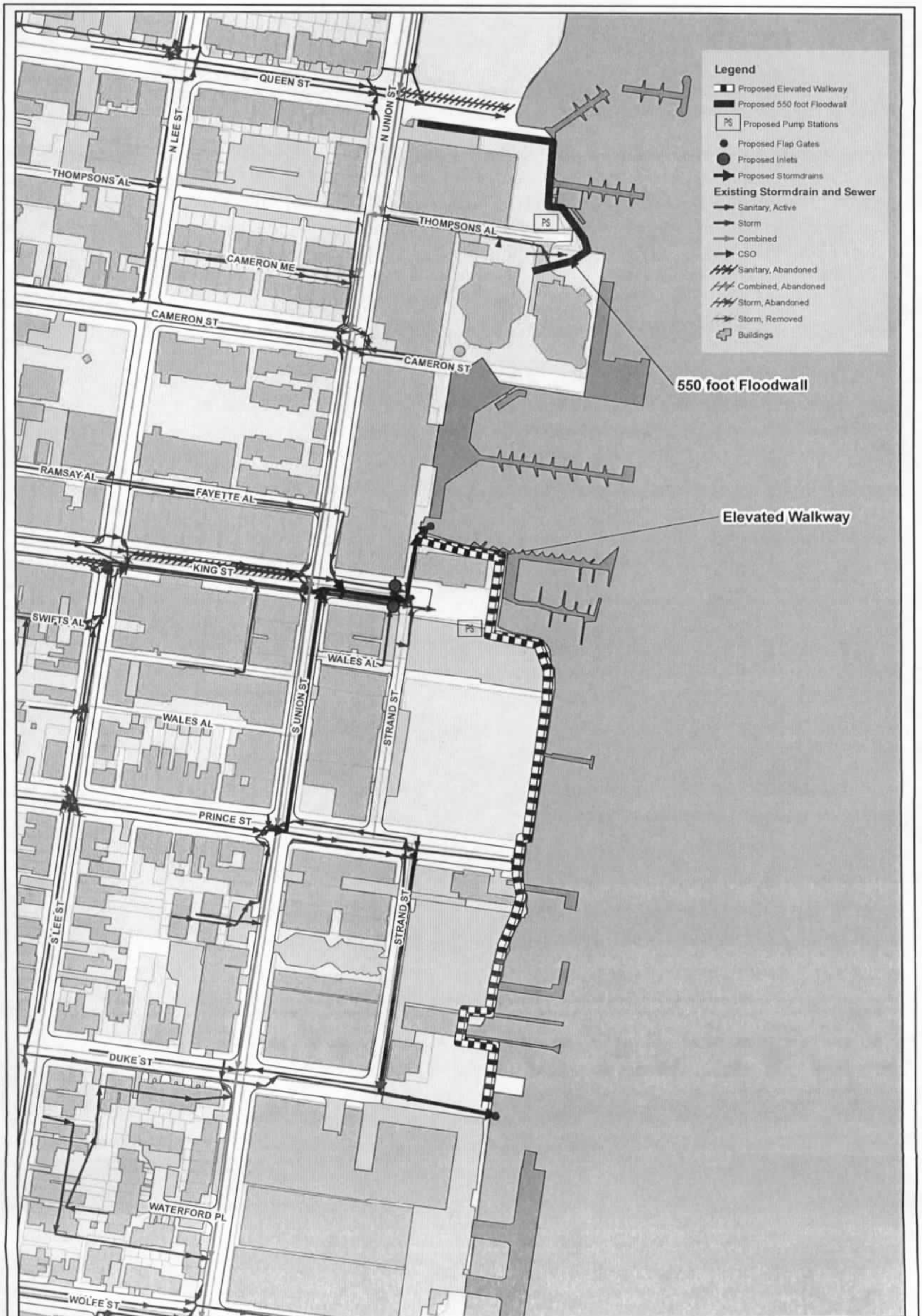
This alternative provides protection from frequent flooding while maintaining a scenic walkway along the Potomac River. The elevated walkway is proposed to have the following dimensions:

- 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					TITLE Proposed Elevated Walkway 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 = 150 feet	DR BY	CJL	09/24/09	FIGURE 6-4
W:\City of Alexandria\15298470 - Lower King St\Task 3 Report Final Figures\MXD\Fig 6-4 Walkway Overall Layout.mxd		CHK BY	MER	10/04/09	

0 37.5 75 150 feet

N

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
W:\City of Alexandria\15298470 - Lower King St\Task 3 Report\Final Figures\MXDs\F6-5 Walkway Interior Drainage.mxd		CHK BY	MER	10/04/09

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**

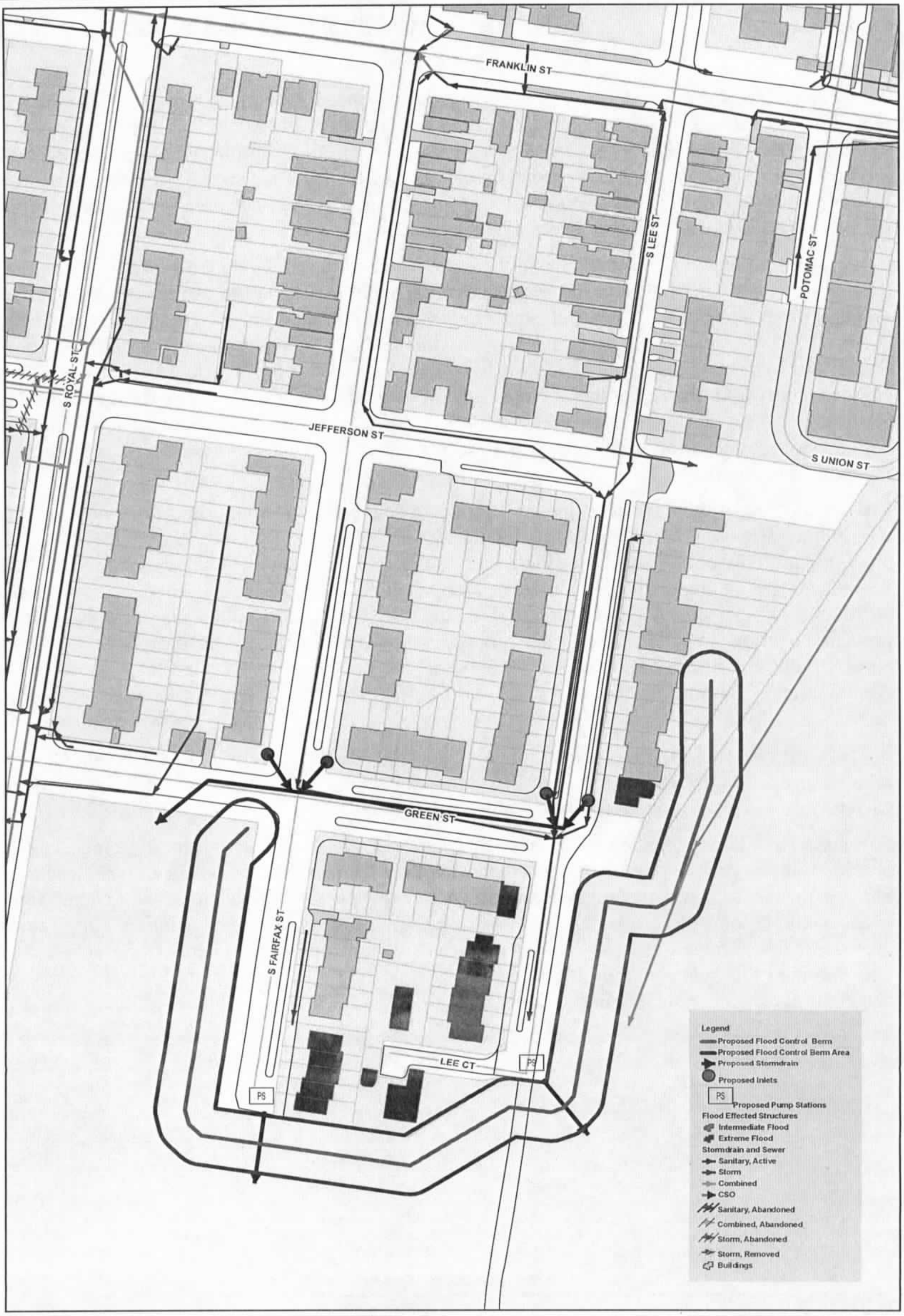
6.3 JONES POINT BERM

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				TITLE Proposed Jones Point Berm Layout
PROJ	Potomac River Waterfront Flood Mitigation Study				
REVISION NO	0	DES BY	CJL	09/11/09	PROJ NO 15298592
SCALE	1 inch = 100 feet	DR BY	CJL	09/24/09	URS 200 Orchard Ridge Drive Gaithersburg, MD 20878
		CHK BY	MER	10/04/09	FIGURE 6-6

N

0 25 50 100 feet

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

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

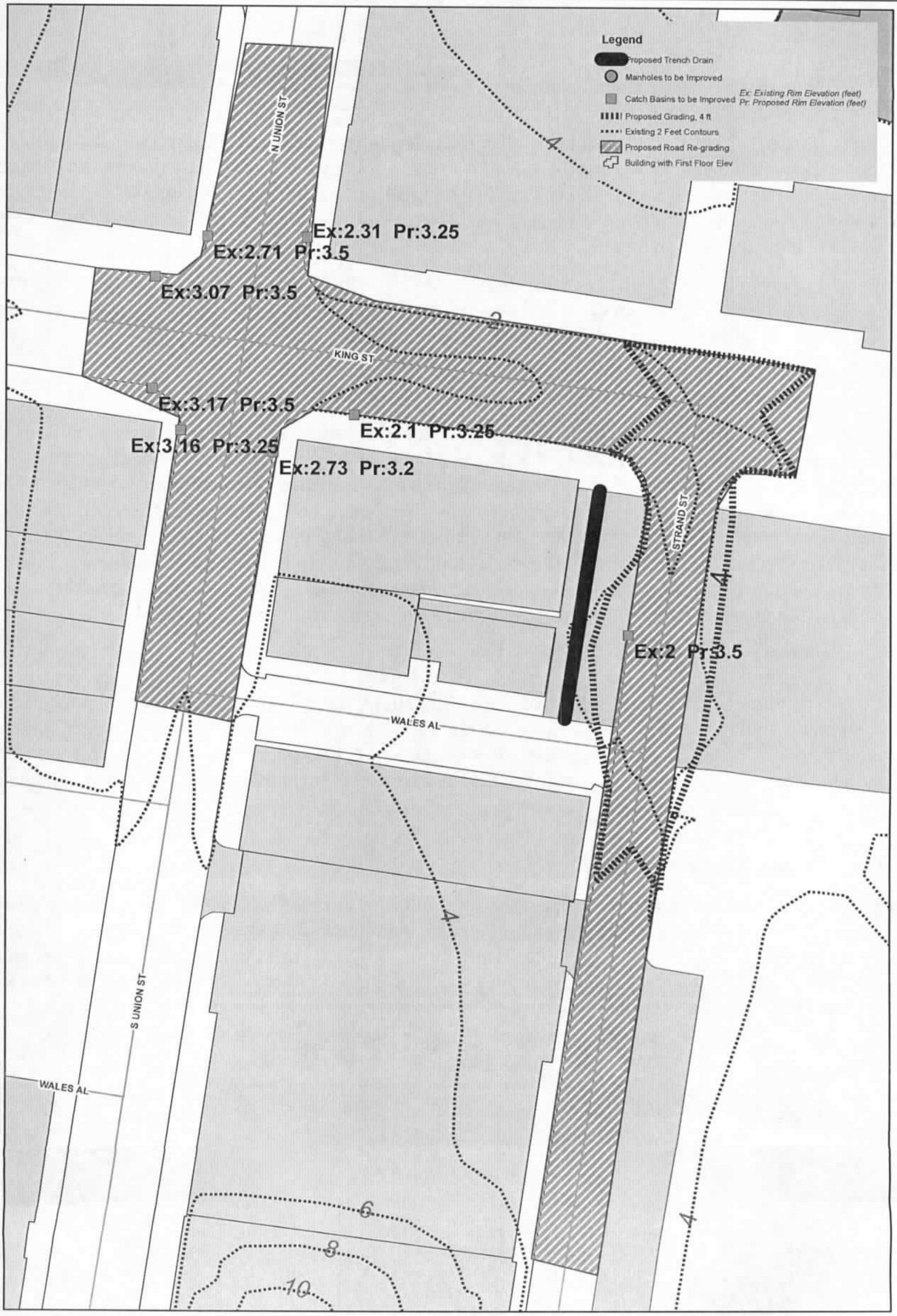
Several factors limit how much the road and inlets can be elevated. Three commercial buildings adjacent to the proposed road and inlet improvements have FFEs below an elevation of 4 feet. The grading for this alternative considered the assumed curb height of 6 inches (although from site visits and photographs, 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	URS 200 Orchard Ridge Drive Gaithersburg, MD 20878 — PROJ NO 15298592
SCALE	1 inch = 30 feet	DR BY	CJL	09/25/09	FIGURE 6-8
W:\City of Alexandria\15298470 - Lower King St\Task 3\Report Final\Figures\MXDs\F6-8 Road Improvements.mxd		CHK BY	MER	10/04/09	

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.