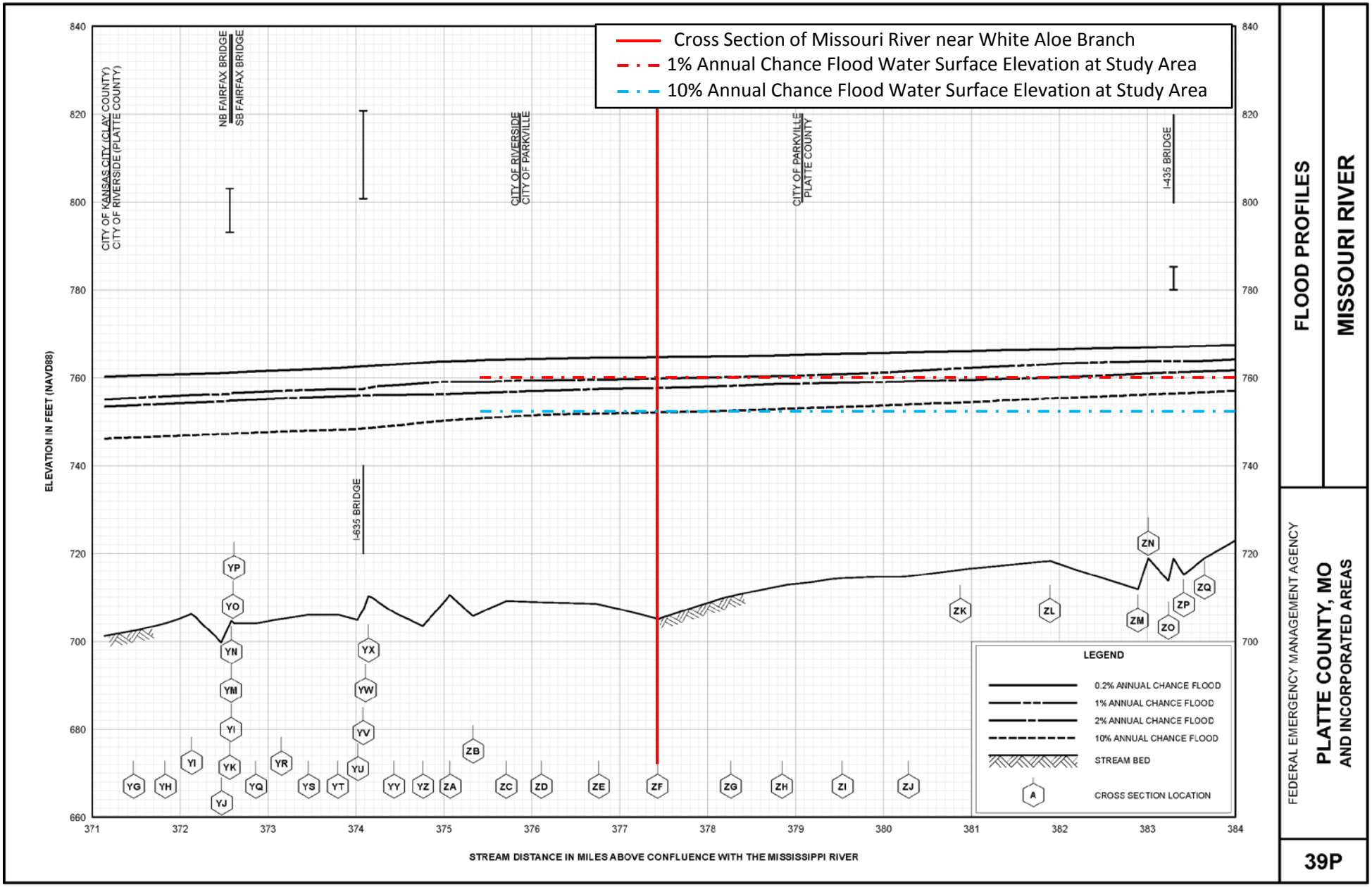

Figure 3-2 Preliminary Flood Profile for Missouri River (SEMA, March 2012)

The review for this study utilized some of the USACE Test Report's evaluation, such as the possibility of puncture and leakage, and constructability.

The FEMA design standards include a freeboard requirement for base flood protection. The height of FEMA flood design flood protection is based on the base flood elevation and the permanent flood levee protection regulations as found in 44 CFR 65.10 (b) (1) *Freeboard* (Table 3-1).

Table 3-1 FEMA Freeboard Requirements [1]

Type	Description
Minimum freeboard [2]	Three feet above base flood elevation
Freeboard either side of structure (such as bridge)	An additional one foot for a distance of 100 feet on either side of structure
Upstream end of levee	An additional one-half foot starting at upstream end of levee system tapering to minimum at the downstream end

[1] Source 44 CFR 65.10 (b) (1)
[2] Exceptions may be approved after appropriate and approved engineering analysis, however freeboard less than 2 feet is unacceptable per 44 CFR 65.10 (b) (1) (ii).

3.2.3 Interview Comments

USACE flood fighters and flood protection vendors provided their comments on the practical use of each technology. These comments provide a real-world perspective on the use of these flood protection technologies. Some of their comments included:

- Stop logs (metal panel flood protection) have some seepage.
- Most fabric membrane (including dams and water-inflated options) does not last as long as advertised due to weakened spots from exposure to elements and along fold lines from storage.
- Storing of the temporary fabric technology is more labor intensive. It requires thorough cleaning and proper folding to prevent rot and weakening of fabric.
- Wind effects fabric technology during set-up and prior to flood waters holding the fabric in place.
- It is important to practice installing temporary technologies. The installation process can be difficult to implement during an emergency due to panic, stress, etc. that can affect human reactions.
- Technologies with multiple pieces can suffer from loss/misplace of system pieces.

3.2.4 Internet Research Results

Material retrieved from the Internet included vendor contact information, product specifications, photos, and installation locations. This information is provided in Appendix A.

3.3 Evaluation of Technologies

This section evaluates each flood protection technology using the parameters defined in Sub-Section 3.2. The following tables present advantages and disadvantages related to these parameters, more specifically to the installation, maintenance, and cost for each respective flood protection technology.

3.3.1 Concrete Walls

The use of concrete walls is a permanent flood protection technology as shown on Figure 3-3. Table 3-2 lists the advantages and disadvantages of using a concrete wall for flood protection.

Figure 3-3 Concrete Floodwall (Photo Source: CDM Smith)

Table 3-2 Concrete Floodwalls Advantages and Disadvantages

Parameter	Advantages	Disadvantages
Maintenance	▪ Reduces long-term maintenance (annual inspection may be required)	▪ Limits dry side drainage ▪ Potential for graffiti
Installation	▪ Requires minimal base width ▪ Reduces time needed for flood fighting effort versus temporary efforts ▪ Can be built in any configuration ▪ Permanent protection (possibly lead to LOMR)[1]	▪ Requires adequate space for construction
Cost	▪ Reduces long-term maintenance cost ▪ No storage costs ▪ No repeated installation costs	▪ Initial installation more expensive

[1] For a fee, a Letter of Map Revision (LOMR) is a procedure offered by FEMA that changes the Special Flood Hazard Area (SFHA) based on revised hydrology and hydraulics.

3.3.2 Fabric Membrane Dams

The use of fabric membrane dams is a temporary flood protection technology as shown on Figure 3-4. Table 3-3 lists the advantages and disadvantages of using fabric membrane dams for flood protection. The City utilized this temporary flood protection technology for the Downtown study area in 2011.

Figure 3-4 Fabric Membrane Dam Flood Protection (Photo Source: Portadam)

Table 3-3 Fabric Membrane Dam Advantages and Disadvantages

Parameter	Advantages	Disadvantages
Maintenance	▪ City personnel familiar with maintenance process from 2011 experience	▪ Can be punctured ▪ Must be continually inspected during operation ▪ Must be thoroughly cleaned prior to storage after each use
Installation	▪ City personnel familiar with installation process ▪ 1/10th the weight of standard sandbags ▪ Does not require permanent foundation ▪ Does not require prepared surface ▪ Can be installed in any configuration	▪ Requires sandbag supplementation ▪ Wind effects (until weight of floodwater stabilizes) ▪ Equipment required to move pallets of material to installation spots
Cost	N/A	▪ Most expensive of the fabric flood protection technologies (material cost)

3.3.3 Metal Panels

The use of metal panels is a temporary flood protection technology with a permanent footer as shown on Figure 3-5. Metal panels are also usable as a mixed technology with the use of a permanent stem-wall. Table 3-4 lists the advantages and disadvantages of using metal panels for flood protection.

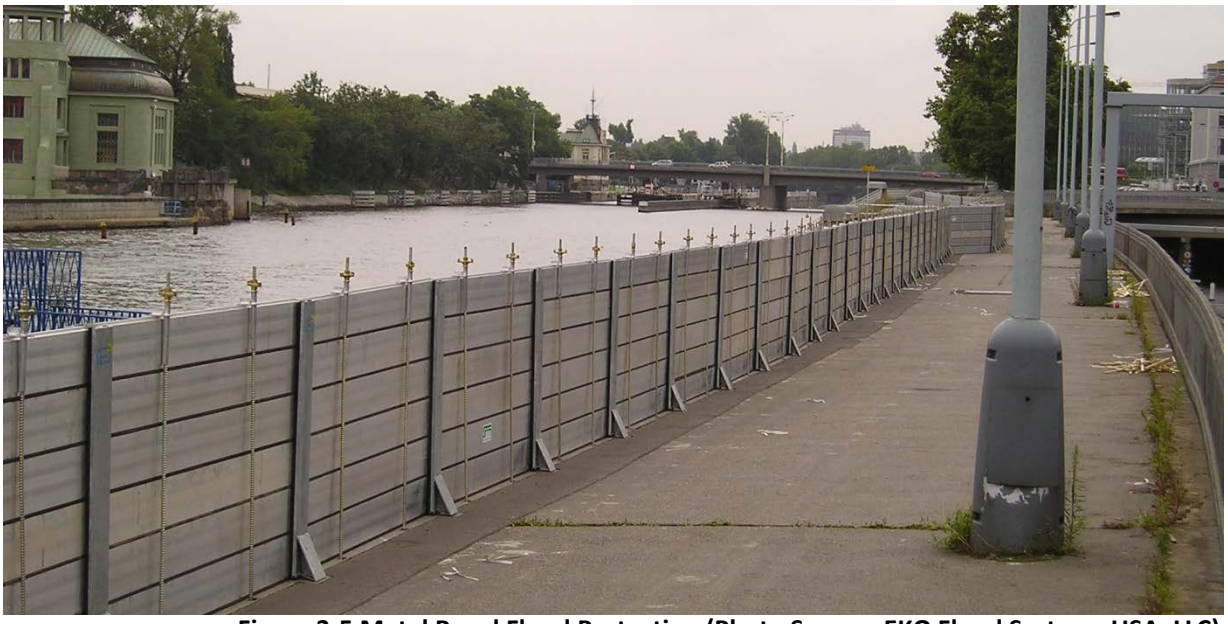

Figure 3-5 Metal Panel Flood Protection (Photo Source: EKO Flood Systems USA, LLC)

Table 3-4 Metal Panel Advantages and Disadvantages

Parameter	Advantages	Disadvantages
Maintenance	▪ Minimal maintenance – Easily stored (stackable)	▪ Must be cleaned with pressure washer after each use
Installation	▪ Quick Installation (Example: 1 person can install 1,000 square feet in 5 hours) ▪ Multiple configuration options (footer and stemwall) ▪ Greater height does not require a greater above surface base width ▪ Can be used with permanent stem wall (reduces time needed for installation of flood protection)	▪ Seepage occurs ▪ Equipment required to move pallets of material to installation spots ▪ Requires permanent footer – Size of footer dependent upon soil structure and wall height – Requires adequate space for initial construction of footer
Cost	▪ Additional panels can be purchased in future to increase height of flood protection	▪ Most expensive of temporary applications

3.3.4 Water-Inflated Tubes

The use of water-inflated tubes is a temporary flood protection technology as shown on Figure 3-6. Table 3-5 lists the advantages and disadvantages of using water-inflated tubes for flood protection.

Figure 3-6 Water-Inflated Tubes at Testing Grounds (Photo Source: US Flood Control Corporation)

Table 3-5 Water-Inflated Tubes Advantages and Disadvantages

Parameter	Advantages	Disadvantages
Maintenance	▪ Can withstand up to 2,680 pounds of lateral pressure (depending on anchor diameter)[1] ▪ Punctures do not necessarily result in loss of flood protection	▪ Must be thoroughly cleaned prior to storage after each use ▪ Can be punctured ▪ Must be continually inspected during operation
Installation	▪ Quick installation ▪ Stackable (to achieve greater height) ▪ Can be installed in many configurations ▪ Does not require permanent foundation	▪ Greater height requires a wider base (approximate 1V:1H due to interlocking of tubes as shown in Figure 3-7) ▪ Equipment required to move pallets of material to installation spots ▪ Limited turning radius
Cost	▪ Least expensive of reviewed flood protection	N/A

[1] Wenck Associates, Inc. Review of the Tiger Dam System Technical Memorandum dated March 22, 2010.

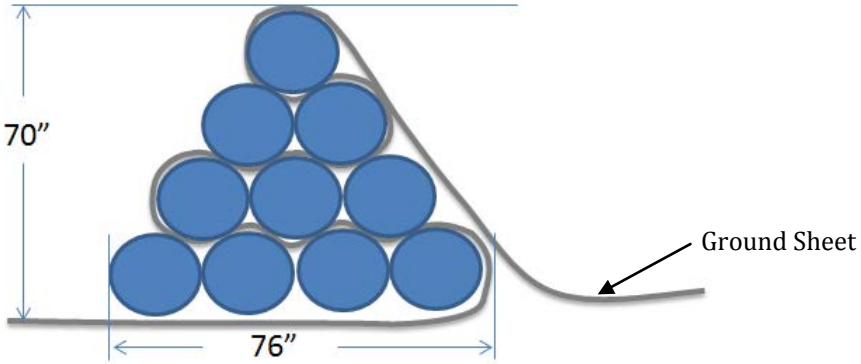

Figure 3-7 Water-Inflated Tubes Dimension Cross Section

3.3.5 Water-Inflated Baffled Bladders

The use of water-inflated baffled bladders is a temporary flood protection technology as shown on Figure 3-8. Table 3-6 lists the advantages and disadvantages of using water-inflated baffled bladders for flood protection.

Figure 3-8 Water-Inflated Baffled Bladder (Photo Source: Hydrological Solutions, Inc.)

Table 3-6 Water-Inflated Baffled Bladders Advantages and Disadvantages

Parameter	Advantages	Disadvantages
Maintenance	▪ Limited maintenance during installation	▪ Can be punctured ▪ Must be continually inspected during operation ▪ Must be thoroughly cleaned prior to storage after each use
Installation	▪ Quick installation ▪ Stable (will not roll) ▪ Does not require permanent foundation	▪ Greater height requires a wider base (1V:2.25H) ▪ Limited height (protects up to 6-foot WSE) ▪ Limited configuration (Does not bend like water-inflated tubes) ▪ Not stackable ▪ Equipment required to move pallets of material to installation spots
Cost	N/A	N/A

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Section 4

Flood Protection Plan and Cost Estimate for Downtown Parkville

The level of flood protection for Downtown Parkville is the maximum achievable within the constraints of the desirable and maximum allowable height of barrier (aesthetics and flood protection technology constraints), available project base width for installation, desired alignment, affordability by the City, compliance with FEMA floodplain regulations, interior stormwater drainage, and other utilities considerations. As such, the level of protection evaluated for Downtown was the base flood elevation (commonly referred to as the 100-Year flood or 1-Percent Annual Chance Flood).

4.1 Downtown Parkville Flood Protection Alignment

During the October 5, 2012 project progress meeting, the City stated that they have evaluated flood protection access to the businesses located south of the BNSF tracks. Therefore, this area was not considered in the recommendation for the Downtown study area. Figure 4-1 shows the City's preferred flood protection alignment for the Downtown. The flood protection alignment runs along the west side of White Aloe Creek to the north side of the BNSF tracks, then westerly along the tracks. This alignment was used to determine physical parameters for flood protection, such as ground surface elevation and available space for installation.

According to the elevation contours and the November 2012 survey provided by the City the ground surface elevation varies between 754 feet and 756 feet along the preferred flood protection alignment.

Data provided by the City indicates that the proposed flood protection alignment for the Downtown has at least three areas that cross over sanitary sewer lines and at least three areas that cross over stormwater lines as shown in Figure 4-1.

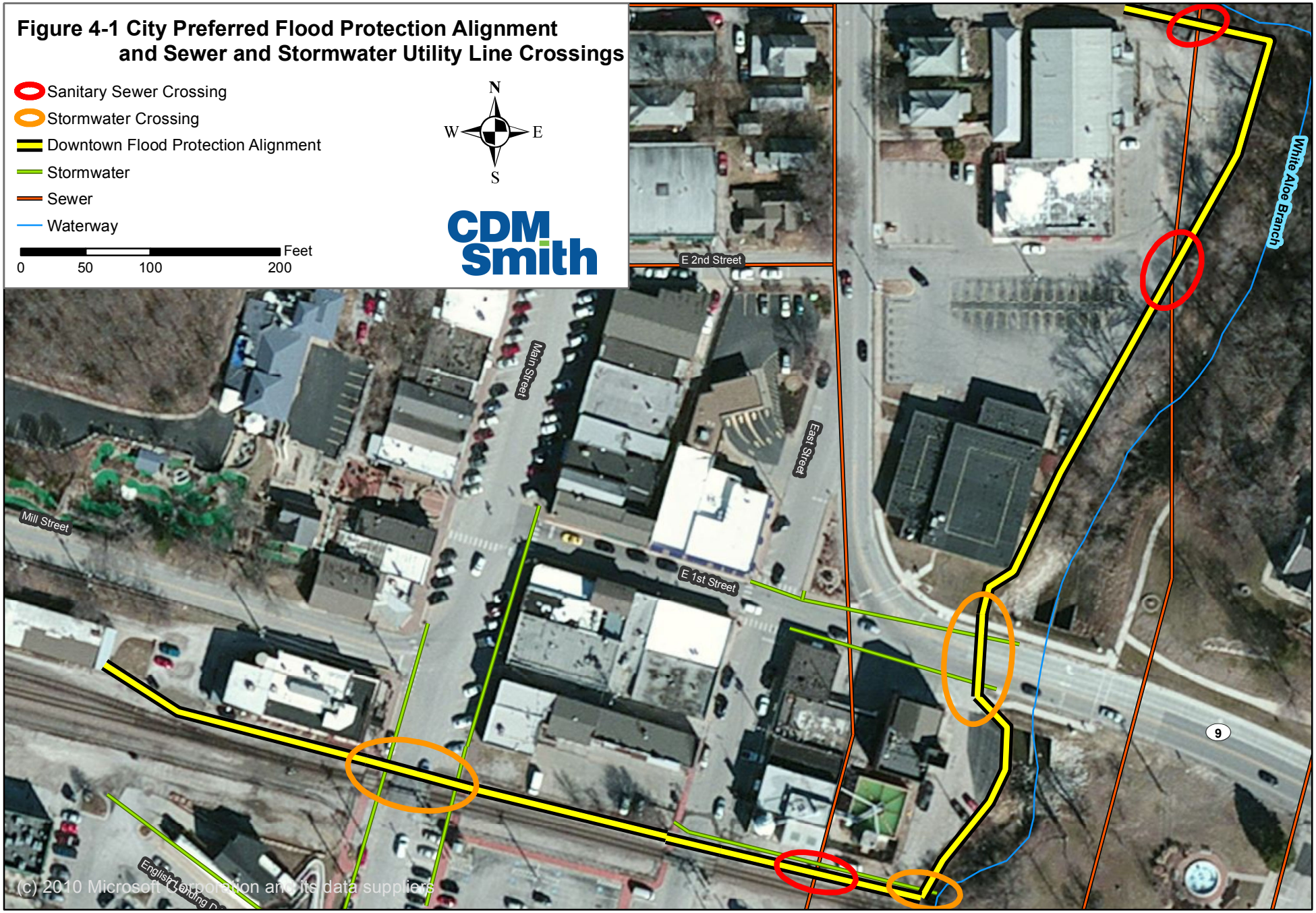
4.2 Determination of Recommended Downtown Flood Protection Technology

The recommended flood protection technology for the Downtown area was based on an evaluation of three parameters: maintenance, installation, and cost.

4.2.1 Flood Protection Technology Maintenance

In order to determine the recommended flood protection technology, the types of maintenance requirements associated with the different flood protection technologies was researched and compared. The concrete floodwall had the least long-term maintenance concerns, as cleaning requirements are related to aesthetics, versus specific cleaning requirement that are required post-flood for all of the temporary technologies. The fabric membrane technologies and the metal panel system require frequent inspection to identify possible puncturing of the fabric or seepage in a metal panel system. To reduce chances of rotting and cracking fabric membranes, water-inflated tubes, and water-inflated baffled bladders require more thorough cleaning of the flood protection material and specific folding requirements for long-term storages.

Figure 4-1 City Preferred Flood Protection Alignment and Sewer and Stormwater Utility Line Crossings



4.2.2 Flood Protection Technology Installation

Installation criteria were based on both the flood protection height and associated required width for installation along the preferred flood protection alignment. In order to establish the flood protection height needed to provide protection from the base flood elevation, the height of flood protection was estimated. The estimated flood protection height was based on the preliminary base flood elevation, the current ground surface elevation of the proposed flood protection alignment, and the permanent flood levee protection regulations as found in 44 CFR 65.10 (b) (1) *Freeboard* and described in Table 3-1.

The height of the flood protection vary along the preferred alignment due to the varying ground surface elevation and FEMA freeboard regulations (Table 3-1). Figure 4-2 shows sections of the alignment based on this varying ground surface. Table 4-1 relates the approximate required height of the flood protection in each of these sections.

Table 4-1 Downtown Flood Protection Heights including Freeboard Requirements

Flood Protection	Approximate Height (ft) [1]	Approximate Length (ft)	FEMA Freeboard Requirements [2]
Section 1	7.5	218	Upstream end of levee, minimum freeboard
Section 2	7	157	Minimum freeboard
Section 3	7	238	Minimum freeboard
Section 4	8	106	Freeboard either side of structure (such as bridge), minimum freeboard
Section 5	10	100	Freeboard either side of structure (such as bridge), minimum freeboard
Section 6	9	516	Minimum freeboard
Road Crossing 1	7	83	Minimum freeboard
Road Crossing 2	7	43	Minimum freeboard
Road Crossing 3	10	64	Freeboard either side of structure (such as bridge), Minimum freeboard

[1] Approximate height based on estimated ground elevation along preferred flood protection alignment and the preliminary base flood elevation of 760 feet

[2] As described in Table 3-1

Specific benefits were found related to installation of each technology and also in meeting the FEMA freeboard criteria. Since the width of the flood protection is determined by the desired height of the flood protection, the narrower base requirement for both the metal panel and concrete wall technologies is an important factor. A benefit of the height of the flood protection meeting the FEMA design criteria is that this estimated height varies between one-half and one and a half feet below the 1993 flood WSE of 764.5 (based on HDR 1999 report), and therefore could provide increased protection.

Fabric membrane, water-inflated tubes, and water-inflated baffled bladders all require more labor and time for installation when compared to the concrete floodwall or metal panel systems. These systems also cannot meet the height requirements through the entire alignment due to the required base width for installation.

4.2.3 Flood Protection Technology Cost

Flood protection technology cost estimates obtained from vendors were used to perform a cost comparison of the technologies on a cost per linear foot basis. This is shown graphically in Figure 4-3. The green line representing the baffled bladder indicates the maximum flood protection height of 6 feet specific to this technology. The purple line representing the fabric dam represents the maximum flood protection height of 10 feet specific to this technology.

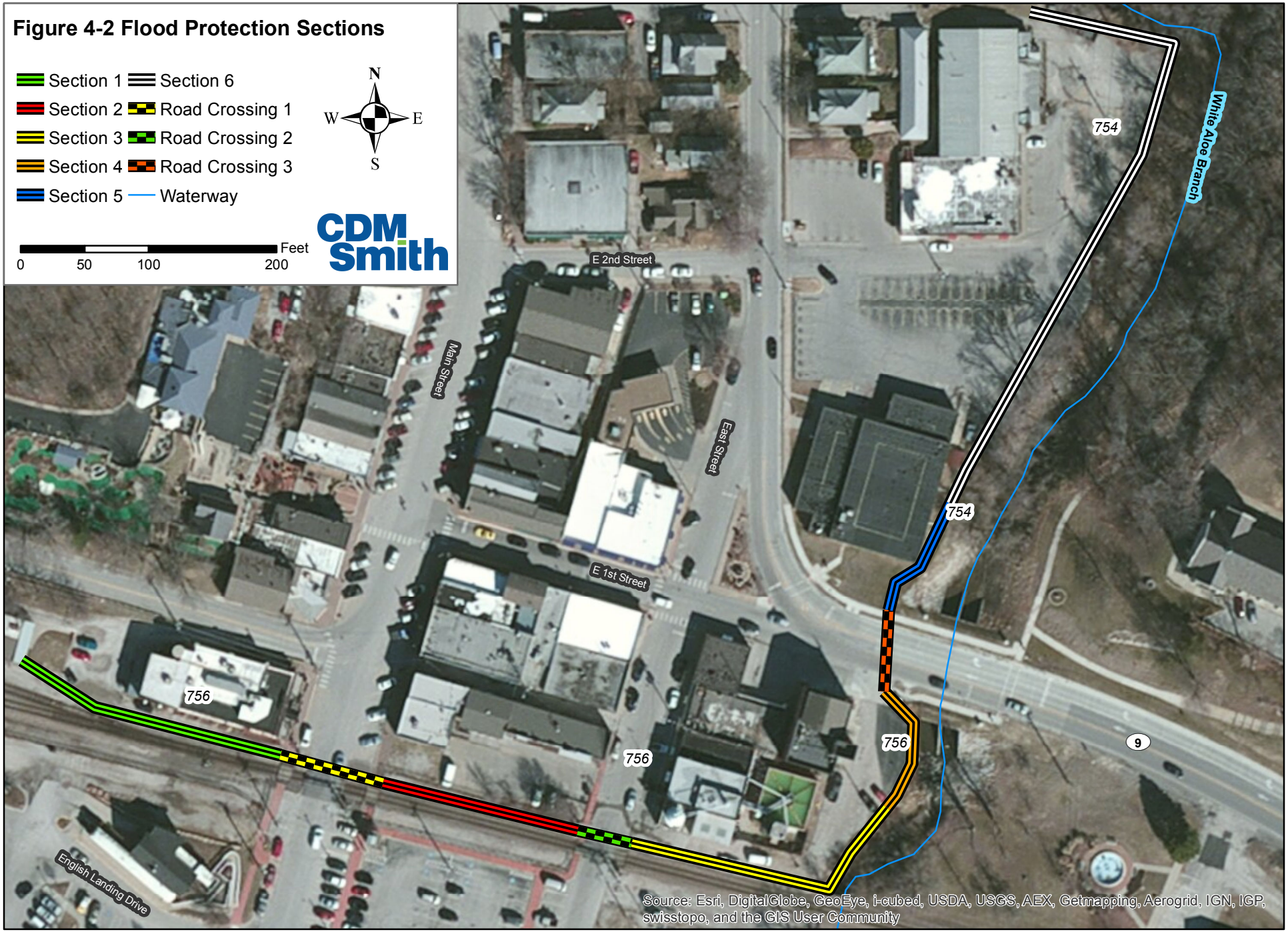


Figure 4-2 Flood Protection Sections
Section 1
Section 2
Section 3
Section 4
Section 5
Section 6
Road Crossing 1
Road Crossing 2
Road Crossing 3
Waterway
N
W
E
S
0
50
100
200
Feet
CDM Smith
E 2nd Street
Main Street
East Street
E 1st Street
English Landing Drive
White Aloe Branch
754
754
756
756
756
9
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

The blue box on Figure 4-3 highlights the approximate flood protection heights from Table 4-1 along with their corresponding costs per linear foot. Of note, four of the technologies are within $200 per linear foot when installed at the flood protection height of 8 feet. It is important to note that the unit cost for the temporary technologies only include material costs and do not include the costs associated with installation, maintenance, and storage.

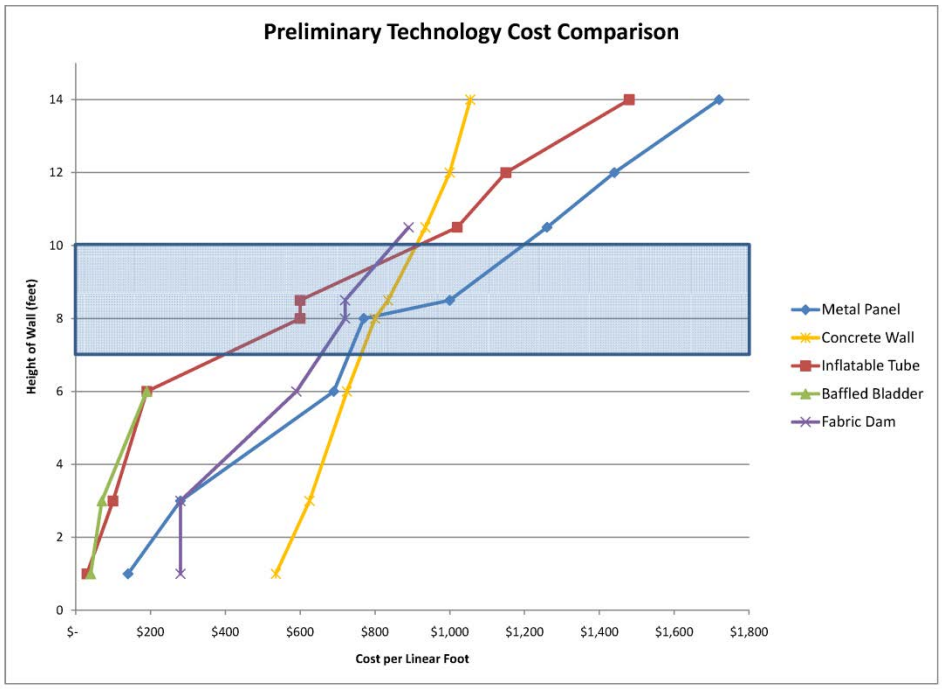


Figure 4-3 Flood Protection Material Cost Curve

Table 4-2 uses interpolated unit costs from Figure 4-3 in conjunction with the heights and lengths listed on Table 4-1 to estimate a total material cost for the installation of a single flood protection technology on the preferred alignment. The water-inflated baffled bladder flood protection technology is not included in Table 4-2 due to its installation height not meeting the requirements for the Downtown study area.

Table 4-2 Flood Protection Technology Cost Comparison

Description	Concrete Floodwall with Footer [2]	Fabric Dam[1]	Water-Inflated Tubes[1]	Metal Panels with Footer [1,3]
Subtotal	$1,091,100	$1,065,900	$1,059,700	$1,463,300
Gate/Road Crossings	n/a [4]	$147,700	$140,900	$196,700
Single Technology Total	**$1,091,100**	**$1,213,600**	**$1,200,600**	**$1,660,000**

[1] Technology costs were determined using cost estimates (as of September 2012) based on sole source use of flood protection technology based on a linear foot calculation.

[2] Concrete floodwall unit cost for estimate provided by USACE.

[3] Metal panels includes the cost of a typically footer construction. Foundation and footer costs may vary significantly depending on geotechnical analysis.

[4] Concrete floodwall technology does not include cost for gate/road crossing. Any temporary flood protection technology can be utilized at these locations.

For comparison purposes, it is important to note that only the concrete wall unit cost includes installation, as this is a one-time expense. Both the concrete wall and the metal panel unit costs include an estimate of a typical footer cost, installed, as required for installation. All other technologies are represented by material cost only, as installation cost will be required for each flood event in use. Additionally, there are costs associated with the temporary flood control technologies that are not in Table 4-2 costs. These include storage, annual training costs, material replacement cost, and flood event installation costs (set-up and breakdown).

4.3 Recommended Flood Protection for Downtown Parkville

A blend of flood protection technologies is recommended based on the City's preferred flood protection alignment for the Downtown study area and the review parameters of maintenance, installation and cost. Use of permanent concrete walls and metal panels (with sill plate) road crossings is recommended as shown on Figure 4-4. An estimated conceptual cost for this recommendation is shown in Table 4-3. Please note that this cost could vary significantly based on geotechnical investigations and decisions on final aesthetics of proposed concrete wall.

Table 4-3 Downtown Recommended Flood Protection Technology Conceptual Costs

Description	Estimated Cost
Permanent Flood Protection (Concrete Floodwall)	$1,091,000
Gate/Road Crossings (Metal Panels w/footer)	$197,000
Subtotal	***$1,288,000***
Easement and Acquisition (5% of Construction Cost)	$65,000
Utility Coordination/Relocation (16% of Construction Cost) [1]	$206,000
Local/State/Federal Permitting (5% of Construction Cost)	$65,000
Engineering Design, Borings, Surveys (25% of Construction Cost) [1]	$321,000
Contingency (35% of Construction Cost) [1]	$460,000
Subtotal	***$1,117,000***
Total	**$2,405,000**

[1] Percent per USACE

Figure 4-4 Recommended Flood Protection Technology Placement

With this recommendation, the City could achieve protection of the Downtown area for the preliminary base flood elevation, while retaining its connection with the Missouri River and providing services to its residents. This recommendation has several benefits:

- **Maintenance.** Maintenance requirements for the concrete wall would be limited to annual inspections and items identified during these inspections. Metal panels can be stacked and stored at existing City facilities.
- **Installation.** With one-time installation for the concrete wall, there would be a decreased need for both City staff time and volunteer time for flood fighting activities in the Downtown study area. Installation would only be required during a flood event for the metal panels at the road crossings. While this will affect vehicular traffic in the area, Downtown would still be accessible from the north. In addition, this installation meets the width constraints present on the alignment.
- **Cost.** The cost incurred with construction of the recommended system would primarily be a one-time construction cost. Annual inspection and maintenance costs would also be required.
- **Regulatory.** Precedence has been set in FEMA Region VII for use of concrete walls and metal panels in updating the FIS. The City could pursue a LOMR to remove the protected areas from the SFHA zone.
- **Aesthetics.** A permanent concrete floodwall can incorporate with current Downtown historical features, as shown on Figure 4-5 (view heading west along Highway 9) and Figure 4-6 (view south on Main Street).

Figure 4-5 View of Simulated Concrete Floodwall, Facing West along Highway 9

Figure 4-6 View of Simulated Concrete Floodwall, Facing South along Main Street

The following assumptions were made as part of this recommendation:

- All recommendations are conceptual in nature. Prior to construction, recommendations should go through a formal design process and be sealed and signed by a registered professional engineer in the State of Missouri.
- All cost estimates are conceptual in nature. Prior to construction, design drawings should undergo a detailed cost review based on final design.
- Coordination and permits with the USACE and FEMA may be required due to the preferred flood protection alignment and construction location along the White Aloe Branch.
- Coordination with BNSF is required due to the preferred flood protection alignment and construction location in the proximity of the railroad tracks.
- Attainment of right-of-way and/or easements may be required along portions of the preferred protection alignment.
- Utility locates were not performed or surveyed as part of this study. Sanitary and storm sewer-line crossing were identified via City provided shapefiles; however, the actual location of lines was not verified.
- Stormwater drainage on the dry side of the proposed flood protection alignment was not evaluated as part of this study.

- Geotechnical investigation is necessary to adequately design the proposed concrete floodwall. Information obtained during a geotechnical investigation impacts the structural design of the wall, including depth, width, and reinforcing requirements.
- A topographic survey of flood protection alignment area was not performed as part of this study.
- The effect of flood protection on the WSE of the Missouri River was not evaluated as part of this study.

  The effect of flood protection on White Aloe Branch was evaluated using HEC-RAS. Utilizing the preliminary modeling information from FEMA for White Aloe Branch, no significant rise in WSE on White Aloe Branch occurs with the building of flood protection of this alignment. A memorandum with details of this analysis is included in Appendix B.

Section 5

Flood Protection Plan and Cost Estimate for English Landing Park

Flood protection consisting of a low levee/embankment (berm) system to protect the Park was reviewed. The study area is from the east bank of White Aloe Branch extending downstream along the Missouri River to the point where the Riverfront Trail has its first loop back toward the Railroad embankment and the Park's interior, as shown on Figure 5-1. An alignment further downstream past where the Riverfront Trails merge, as shown in Figure 5-1, was also initially considered.

5.1 Park Flood Protection Planning Considerations

Items considered for the Park flood protection included the previous Missouri River flood elevation estimates, ground elevations in the Park and along the trail, opportunities for flood protection tie-in based on natural and manmade high ground (such as the railroad embankment), constraints due to mature tree location along the proposed levee alignment, and the City's goals for flood protection. The City's goals for flood protection of the Park include:

- Building a berm to achieve a level of protection that protects the Park from frequent floods that damage the Park, generally within the 5- to 25-year event range
- Retaining existing large mature trees
- Retaining trail alignment
- Retaining the trail width of 12 feet
- Retaining the Park's connection with the Missouri River (aesthetic views)

Building on the City's goals, CDM Smith evaluated the project area from a regulatory and constructability perspective. This included the following parameters:

- All proposed fill would be outside of the FEMA floodway. A levee designed and certifiable to FEMA or USACE design standards was not required. Another consideration and constraint for this plan is the FEMA floodplain impacts upstream, downstream and across the river.
- Keeping the flood protection level between 5- to 25-year level should cause no significant impacts on the base (100-year) flood; however, the Missouri River was not hydraulically modeled as part of this study.
- Since the proposed berm is intended to protect a low risk area, under seepage protection was not evaluated nor was a permanent pump stations considered to dewater the dry side of the berm.
- Overtopping of the proposed berm for events beyond the level of protection was considered acceptable.
- Physical constraints of berm caused by the trail height and width, trees, and tie-in points.

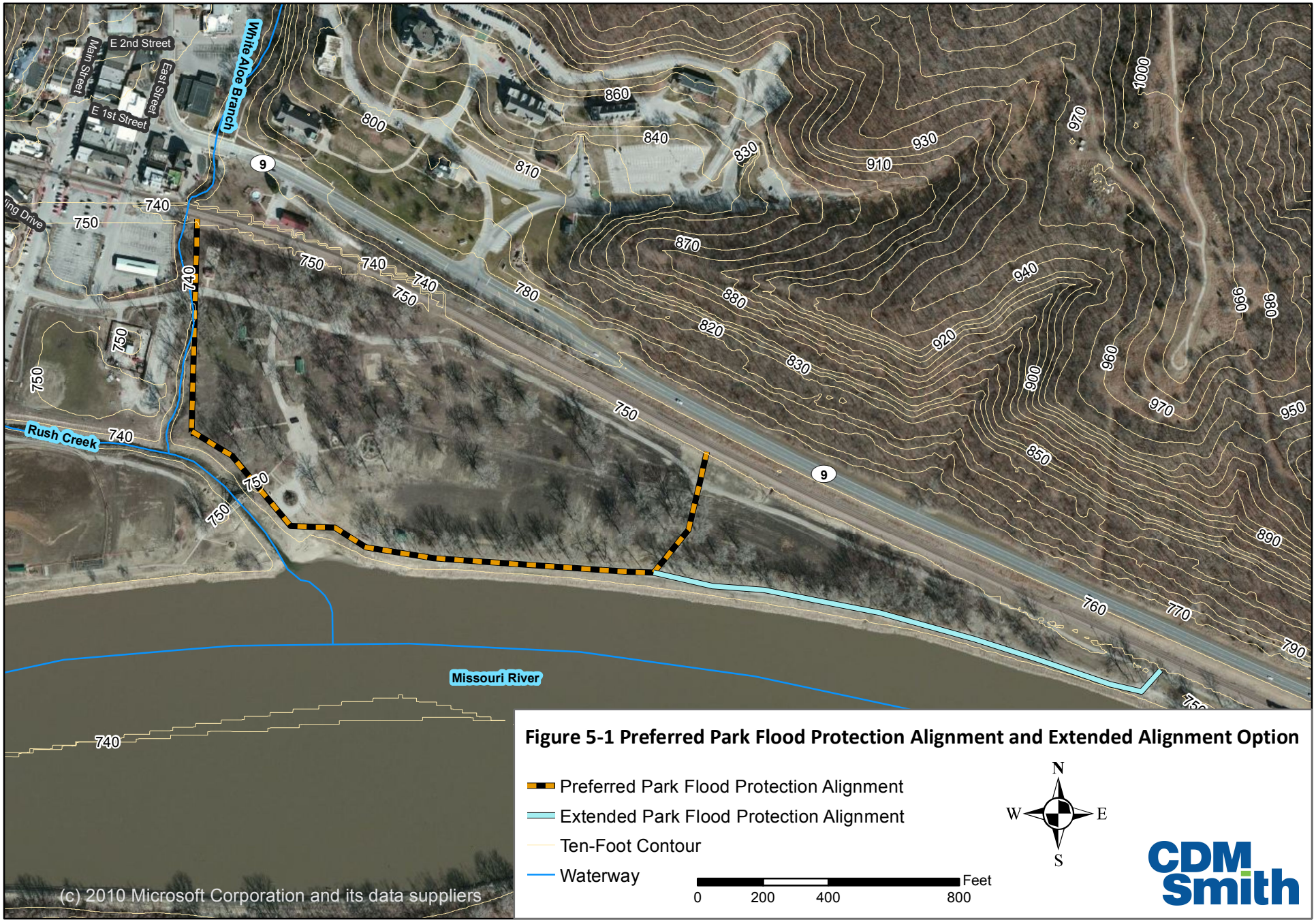


Figure 5-1 Preferred Park Flood Protection Alignment and Extended Alignment Option