METRO WATER SERVICES

UNIFIED FLOOD PREPAREDNESS PLAN

METRO WATER SERVICES

UFPP
Unified Flood Preparedness Plan

JAN 2013

BWSC Barge Waggoner Sumner & Cannon, Inc.®

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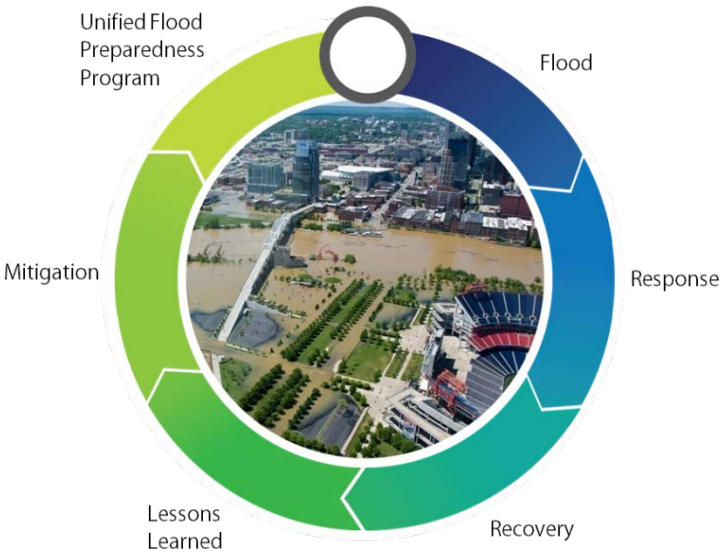
EXECUTIVE SUMMARY

During the first weekend of May, 2010, Middle Tennessee experienced unprecedented rainfalls totaling between 10 to 20 inches, which led to widespread catastrophic flooding. The flooding followed a historical two-day rainfall with a statistical recurrence interval of greater than 1,000 years. Widespread flooding in the region led to 26 flood-related deaths, including 11 in the Nashville area, with a disproportionate number of elderly victims.

In addition to the loss of life, record flood stages on the Harpeth and Cumberland Rivers and the tributaries led to more than $2 billion in damages, more than 11,000 damaged structures, and to the closing of 115 roads including two major interstates (I-24 and I-40). Infrastructure damage was also extensive, with significant damage to water and wastewater treatment plants, pump stations, and distribution and collection systems, along with damage to roads, and electrical substations, including the system that provides power to the downtown business core. Some of the City's main tourist attractions, including the Opryland Resort and Convention Center, the Opry Mills Mall, the Country Music Hall of Fame, the Schermerhorn Symphony Center, Bridgestone Arena and LP Field, incurred millions of dollars in damage. In all, over 13,000 jobs were temporarily or permanently lost, and an estimated $3.6 billion of commerce was permanently disrupted.

Even before the rains stopped, the community began a united effort of response and recovery to the flood. By the city's own estimates, over 29,000 volunteers provided over 375,000 service hours to help neighbors and businesses recover from the flood. As the recovery process was transitioning into the mitigation phase of the disaster preparedness cycle, the effort became more fragmented as agencies, businesses, and property owners began the process of developing individual flood mitigation plans. It was obvious to City leaders, led by Mayor Karl F. Dean, that a unified approach to flood preparedness was necessary to avoid overlap of efforts, coordinate benefits of combined solutions, and maximize the available resources of all the stakeholders. Therefore, Mayor Dean commissioned a deliberate study, called the Unified Flood Preparedness Plan (UFPP), to identify and evaluate flood damage reduction measures on the Cumberland River and



its five major tributaries – Harpeth River, Whites Creek, Browns Creek, Mill Creek and Richland Creek– through a collaborative approach with the stakeholders. The intent of the plan is to identify the locations that would benefit from flood damage reduction projects and the types of solutions that would be most beneficial for each location so that as funding became available, Metro would have completed the due diligence to know what and where to invest the funds.

Stakeholder Involvement

The objective of the UFPP was to collaborate with stakeholders on the development of the plan, engage them in the process, inform them throughout the process, seek their involvement, and build consensus on the final recommendations included in the UFPP.

The first step in this process was the identification of the stakeholder groups and development of the communications plan. Stakeholders were categorized into three distinct groups: Advisory Committee, Key Stakeholders and the Public. The Advisory Committee included representatives from local, state and federal agencies that have funding and/or permitting responsibilities for the implementation of flood damage reduction projects. The Key Stakeholders included representation from utility providers, satellite cites, elected officials, and active community members with constituents that were impacted by flooding. The public included residential citizens, business owners and the media.

Several meetings were conducted with each of the stakeholder groups throughout the development of the UFPP. These meetings allowed for sharing of information and gathering of input from stakeholders. Names of the members of the stakeholders groups and details of the meetings are included in Appendix 2.

Development of Decision Criteria

It is important to develop the criteria and methodology for comparing alternatives at the outset of the study in order to not bias the evaluation process. Therefore, input from the stakeholders on the criteria and the relative importance of the criteria was requested at the beginning of the study. The five primary criteria identified for use in evaluating the alternatives, listed in the order of relative importance established by the stakeholders, were:

1. Flood Damage Reduction Benefits,
2. Economic Considerations,
3. Environmental Impacts,
4. Social Considerations and
5. Schedule.

Subcriteria were identified for each of the primary criteria to provide additional detail for evaluating the alternatives. The final decision criteria with the associated weights are included below in Figure ES.1.

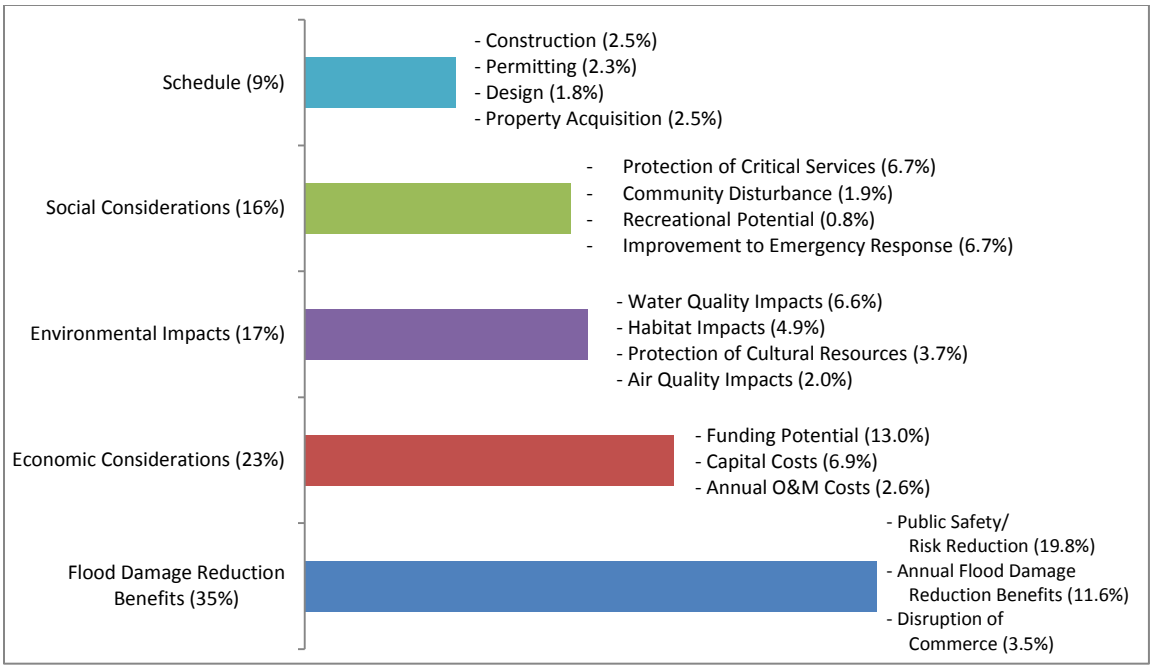


Figure ES.1: Criteria Weighting Used for the Evaluation of Alternatives in Damage Centers

The primary and subcriteria were loaded in the decision software Criterium Decision Plus to provide the final ranking of the alternatives. Each flood damage reduction alternative was rated for each of the subcriteria. The software accumulates the individual subcriteria ratings based on the corresponding weights to provide an overall rating for each alternative.

The use of stakeholder input on the decision criteria allowed the results of the evaluations to reflect what is most important to the stakeholders. The use of the decision software allowed the results to be defensible and unbiased.

Damage Center Identification

One of the objectives of the UFPP was to identify the areas in the county that have the potential to suffer the most flood-related damage and which would benefit the most from flood damage reduction measures. To accomplish this, a number of geospatial data sets were prepared and analyzed to provide an indication of those locations in the county that have the potential to flood based on available flood mapping and related data. The geospatial data can be grouped into three data subsets:

- Areas of Potential Damage,
- Areas of Actual Damages and,
- Special Considerations datasets.

Geospatial data from these three subsets were added to a Geographic Information System (GIS) to identify areas with the most concentrated damage. Initially, areas which had the highest potential for damage (within the 500-yr floodplain and within the 2010 flood inundation zone) were identified. Areas with high potential that had been the subject of past Metro or USACE

studies were subsequently highlighted. These high potential areas were screened further by adding map layers of actual concentrated property damage during the 2010 flood. Areas that had high flooding potential and high actual damages were prioritized if any of the special consideration data fell within the damage area. Those sites from across Davidson County which had the highest potential and actual damages, and which contained the most special considerations, were selected as damage centers.

In all, 22 damage centers were identified across the county. The general location of the damage centers are shown on the map at the end of the Executive Summary.

Potential Flood Damage Reduction Alternatives

Eleven flood damage reduction alternatives were considered at each of the damage centers. The alternatives can be grouped into three major categories based upon how they would reduce flood damage:

- Flood mitigation,
- Flood protection, and
- Flood control.

Flood mitigation alternatives do not try to control or minimize flood waters but seek to reduce damage of property and protect the lives of citizens by removing people from harm's way. A flood protection alternative seeks to eliminate flood waters from entering a particular area and consequently minimize flood damage. Flood control alternatives aim to reduce the damage of a flood by lowering the flood elevation.

The following is the list of the alternatives considered for each damage center:

<u>Flood Mitigation</u>
Floodproofing/elevation
Acquisition/buyout
Flood warning/preparedness
Land use regulations
Stream debris removal

<u>Flood Protection</u>
Levees/Floodwalls

<u>Flood Control</u>
Reservoir
Off-channel storage
Diversion
Bridge improvement
Channel modification

Each of the eleven alternatives were reviewed and considered for each of the 22 damage centers. An initial screening of the alternatives was performed based on the practical implementation of the solution given the specific conditions of the damage center. Based on the initial screening, three to four alternatives were selected in each damage center for more detailed evaluation.

The selected alternatives were conceptually developed for each damage center to enable construction cost opinions to be calculated. Opinions of operation and maintenance costs were also developed for each alternative. The flood damage reduction benefits were estimated using the hydraulic models developed by the U.S. Army Corps of Engineers (USACE) for the rivers and creeks. The models were run with and without the flood damage reduction alternative, and flood damages were calculated for each scenario. The benefits of the alternative were calculated as the difference in the flood damages with and without the flood damage reduction measure in place. For the Reconnaissance Level evaluation, the damages calculated by the model included the structure damages of private property in the damage center based on the value in the Metro Tax Assessor's database. The calculated damages also included contents including commercial inventory, personal property and automobiles. Damages to public property, infrastructure or any emergency operations costs were not included. The evaluation of alternatives includes a comparison of the relative benefits for each solution. The objective of the Reconnaissance Level evaluation is to determine if the calculated benefits are high enough to warrant a more detailed evaluation in a Feasibility Study. The Feasibility Study will include a more comprehensive determination of benefits to be utilized in a benefit-cost analysis.

Each of the selected alternatives for the 22 damage centers was evaluated utilizing the decision criteria. The results of the evaluation identified which alternative rated highest for each damage center based on preliminary cost and benefits typical of a reconnaissance-level study. The results of the evaluations for each damage center are included at the end of the Executive Summary. Additional details can be found in Section 8 – Findings.

Results

The feedback received during the first round of public meetings emphasized the principal desire of residents was to be provided better notification of pending flooding so that they can safely evacuate the area. The evaluation of flood damage reduction alternatives yielded flood warning as one of the best solutions for each damage center. Metro recognized the importance of a flood warning system based on the lessons learned from the May 2010 flood and, therefore, developed the Situational Awareness for Flooding Events tool and the Nashville Emergency Response Viewing Engine. These tools are some of the most advanced flood inundation forecasting and warning systems in the country. The use of these tools for future flooding events will improve public safety and reduce property damage.

Another alternative that rated high for residential damage centers is home buyout. Removing a home from the floodplain that has received significant flood damage and is not built at an elevation that meets current Metro building code is an effective measure for reducing future property damage and removing residents from the risk of flooding. Metro has identified 305 homes eligible for the initial buyout program since the May 2010 flood and is continuing to seek funding for future buyout programs. Home buyouts are a proven solution to reducing flood damages and are evaluated on a case-by-case basis to determine the cost-effectiveness. Metro should continue to seek opportunities to buyout residential properties in the floodplain where it can be proven cost-effective and restrict building in flood prone areas.

In addition to flood warning and home buyout, Metro's on-going flood damage reduction programs are discussed in Section 9 of the report including, Treatment Plant Mitigation Measures and the National Flood Insurance Program.

The other alternatives were evaluated and determined to be worthy of further consideration in a subsequent Feasibility Study led by the USACE. The Feasibility Study is the next step in the federal funding process as shown in Figure ES.2.

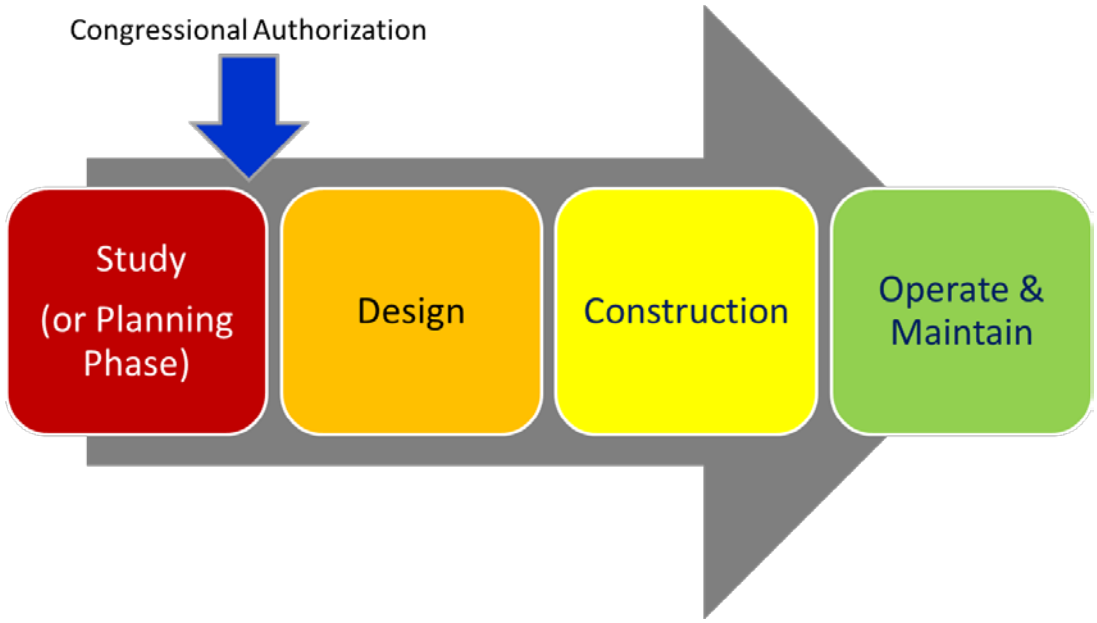


Figure ES.2: USACE Project Delivery Process

Typically, a Feasibility Study is 50% funded by the USACE and 50% funded by a local partner. Once the funding has been appropriated, the feasibility studies will commence and should be completed within three years. At the completion of the feasibility studies, the USACE will assess the cost-effectiveness of each project, and those projects deemed cost-effective will be recommended for design and construction. The magnitude and corresponding cost of flood control and flood protection alternatives usually require funding from the USACE or other Federal Agency to be affordable. Therefore, assisting in the development of the Reconnaissance and Feasibility Studies is a good investment to determine the funding availability for these large projects.

The Unified Flood Preparedness Program has resulted in the acceleration of this planning process. By reducing the number of damage center-specific alternatives from 11 to approximately three for each damage center, and by generating cost opinions for the construction, operation, and maintenance of these alternatives, the planning process has progressed beyond the stage that would be expected for a typical reconnaissance-level study.

A summary of the results for the evaluation of each damage center follows the damage center location map shown on Figure ES.3. Details to support these summary figures are found in the body of the report.

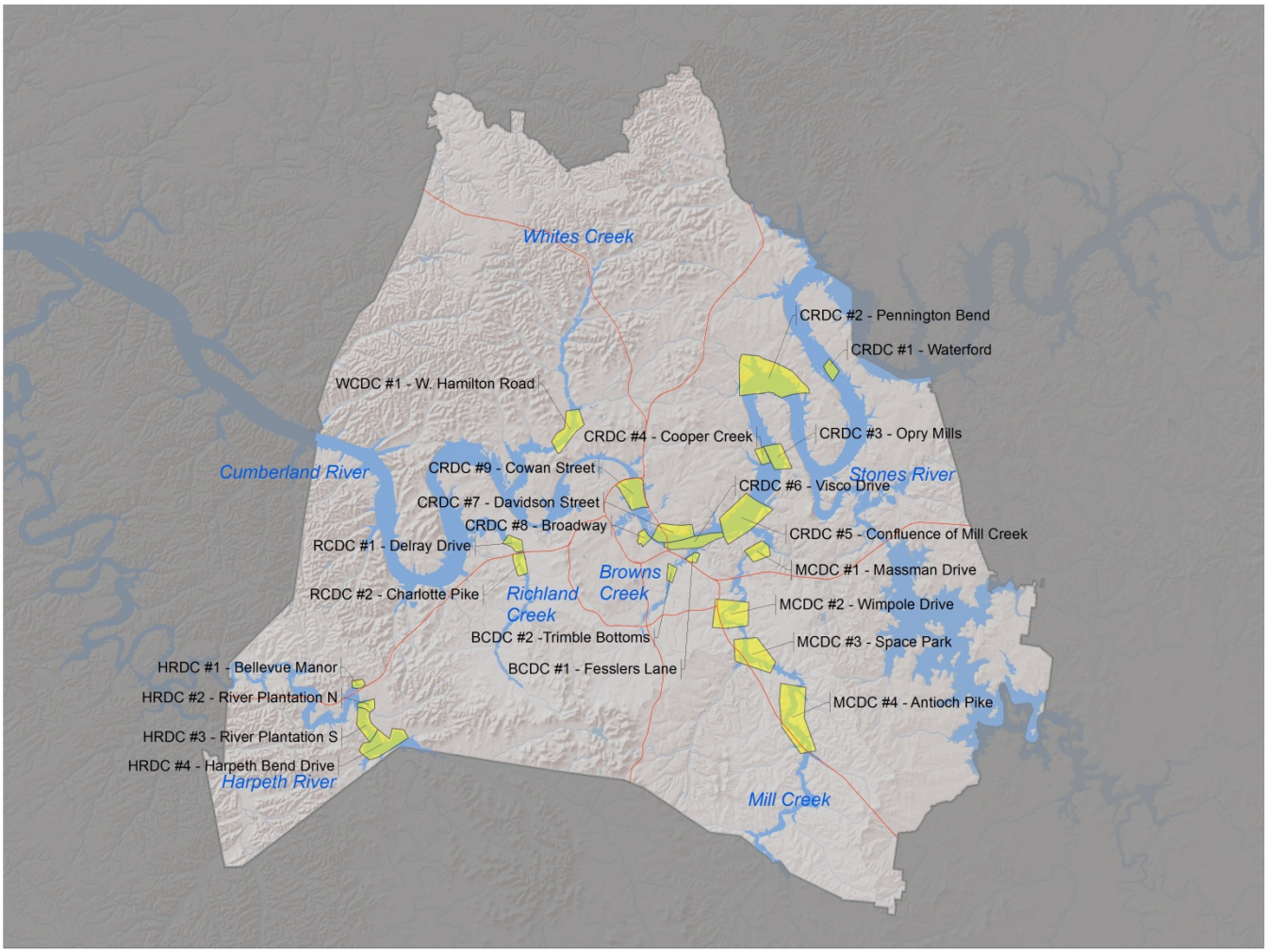


Figure ES.3: 22 Damage Center Locations

Results of the Evaluations of Each Damage Center
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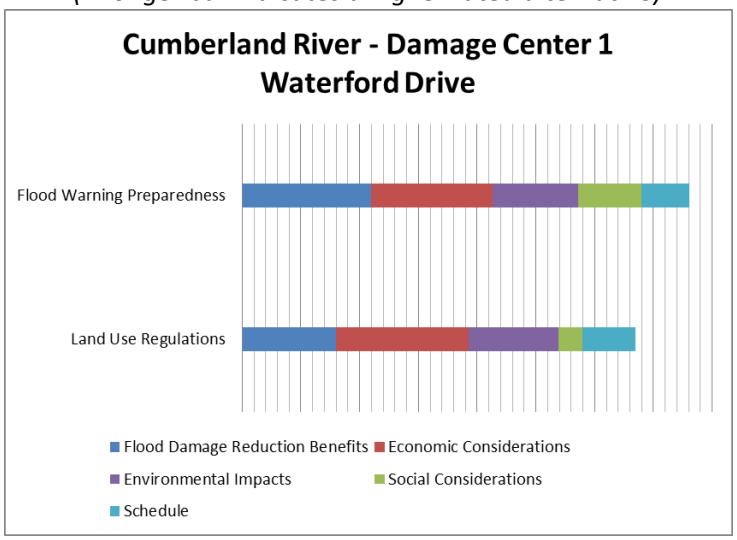

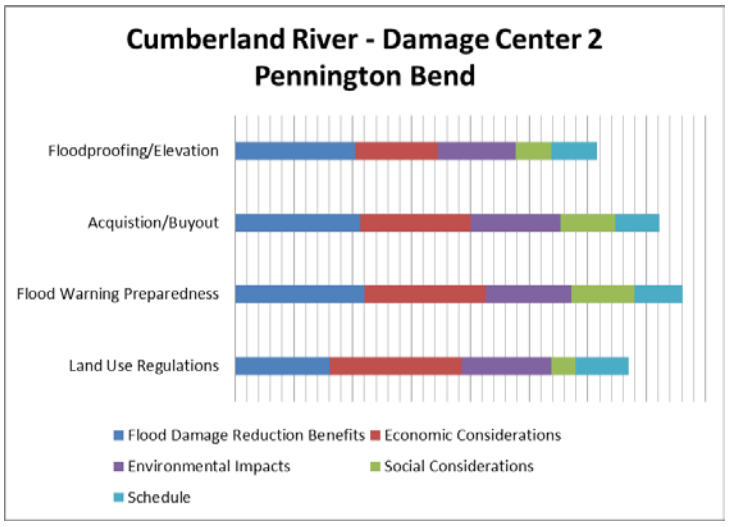

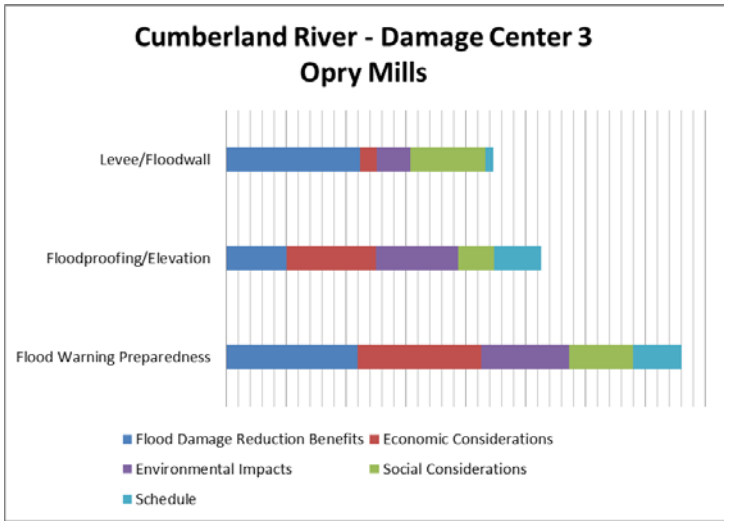

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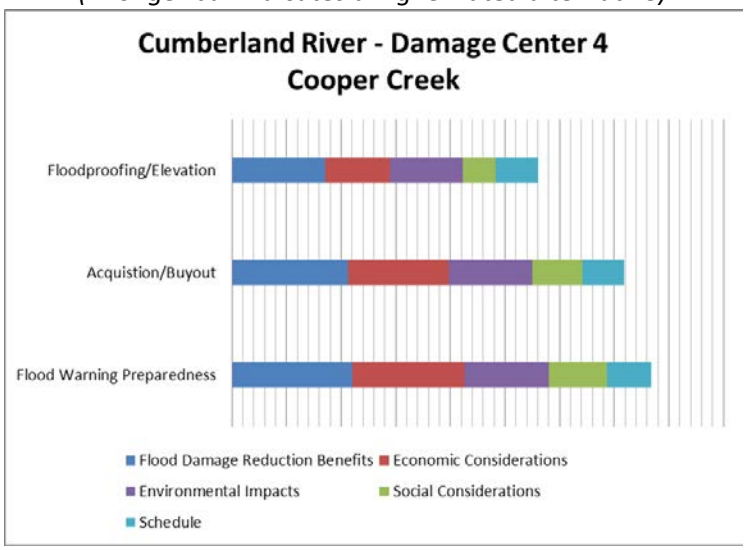

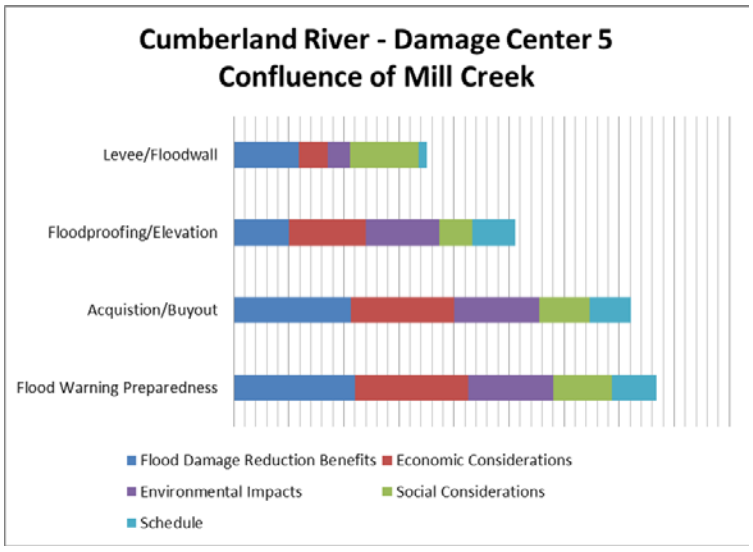

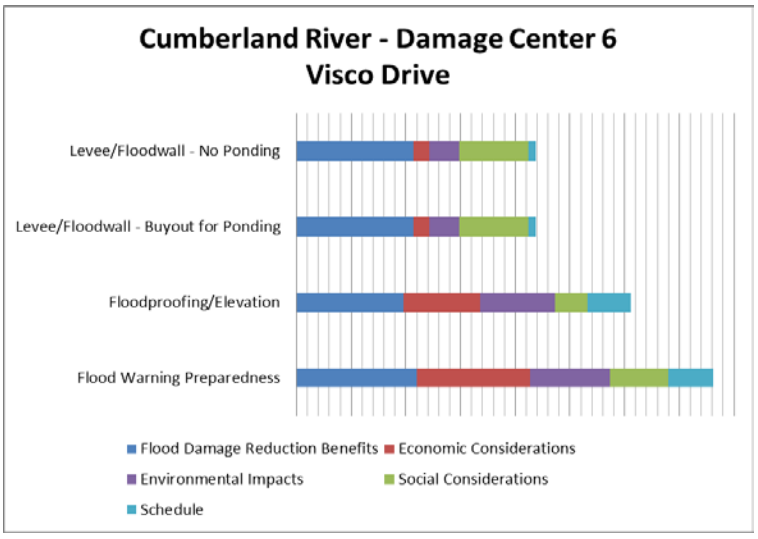

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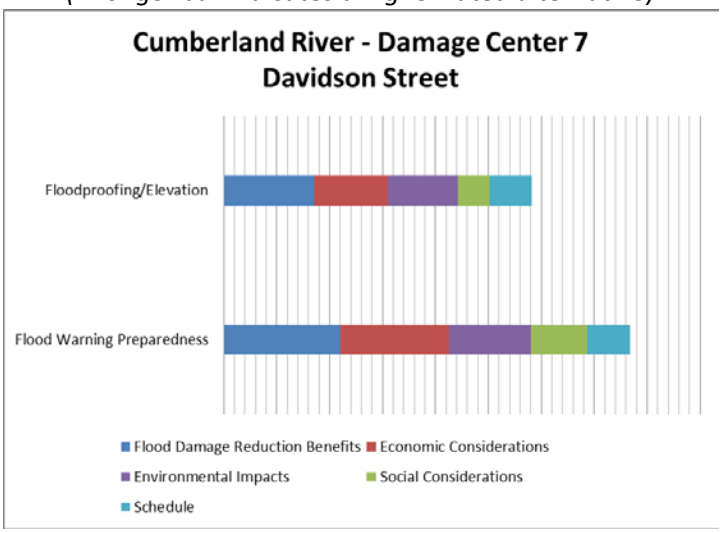

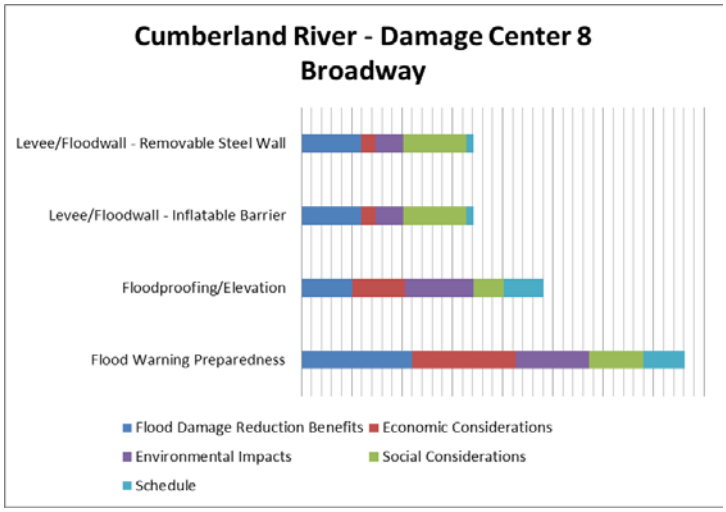

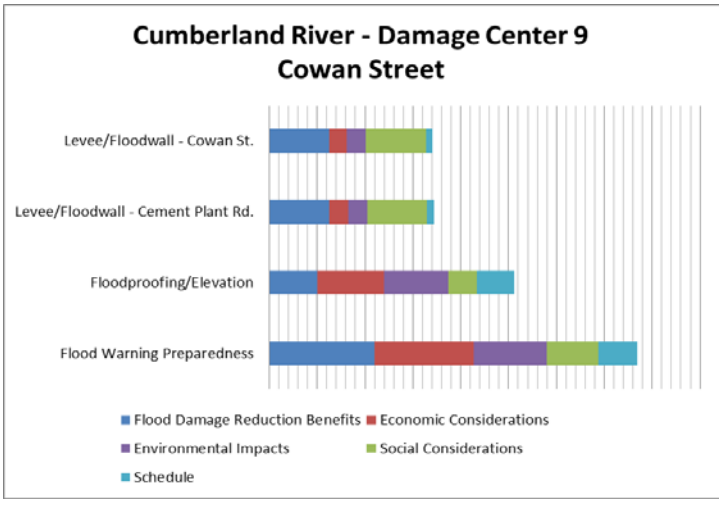

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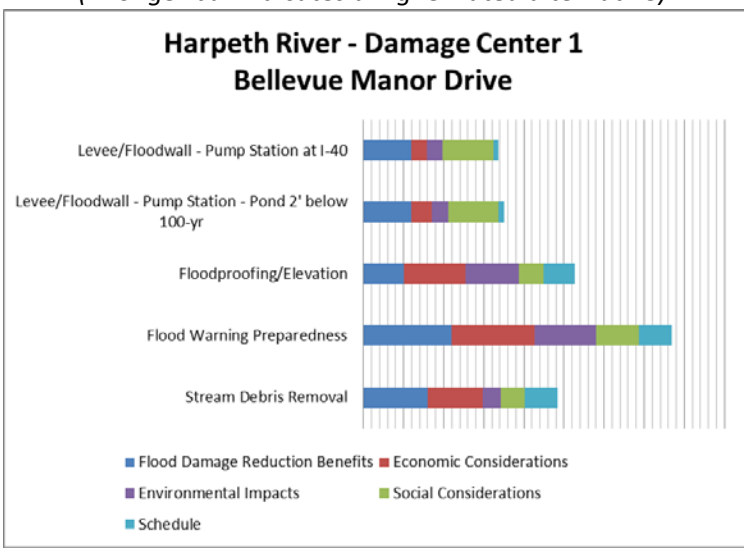

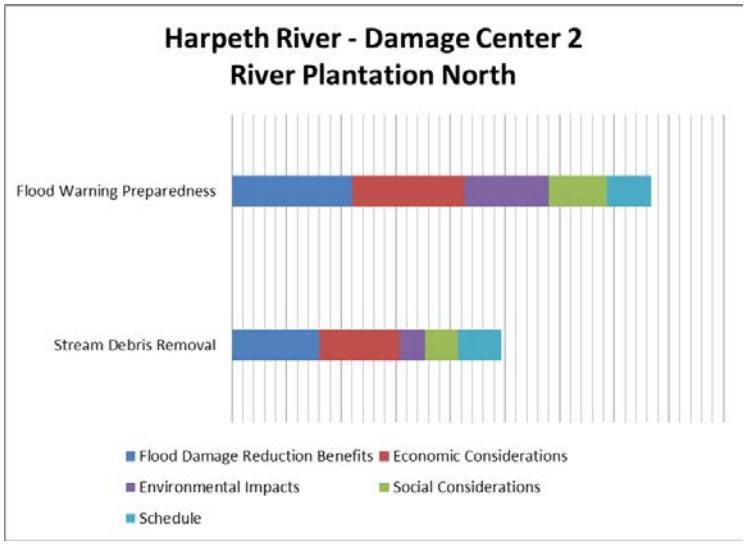

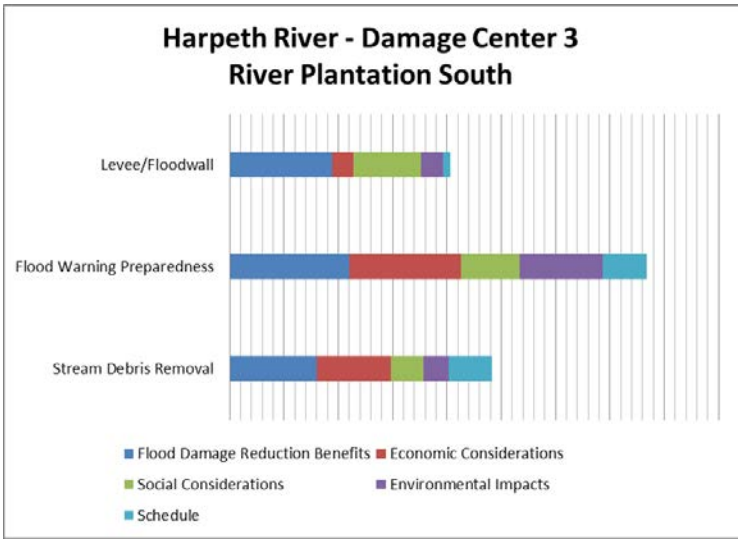

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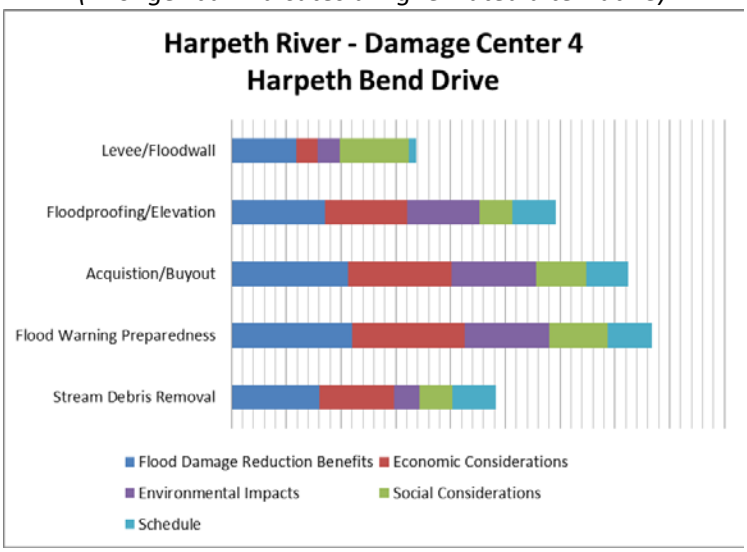

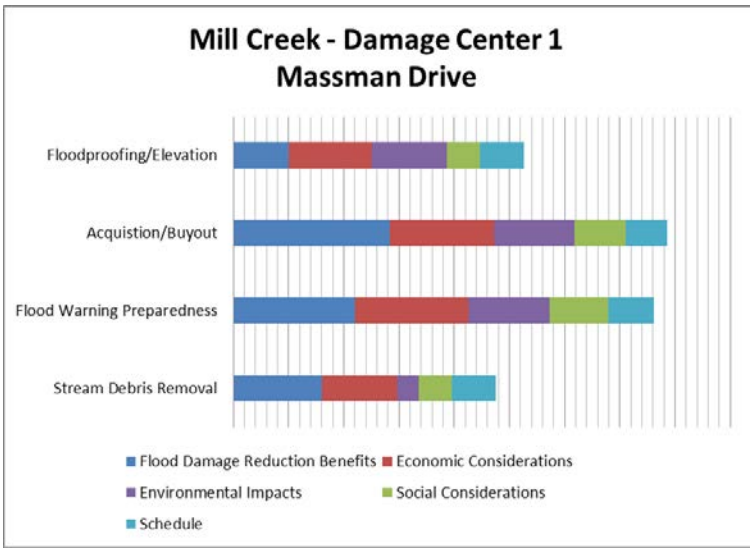

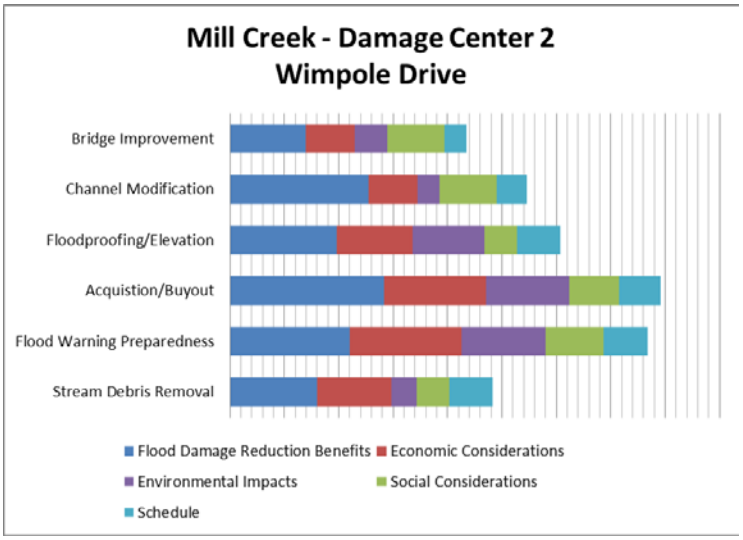

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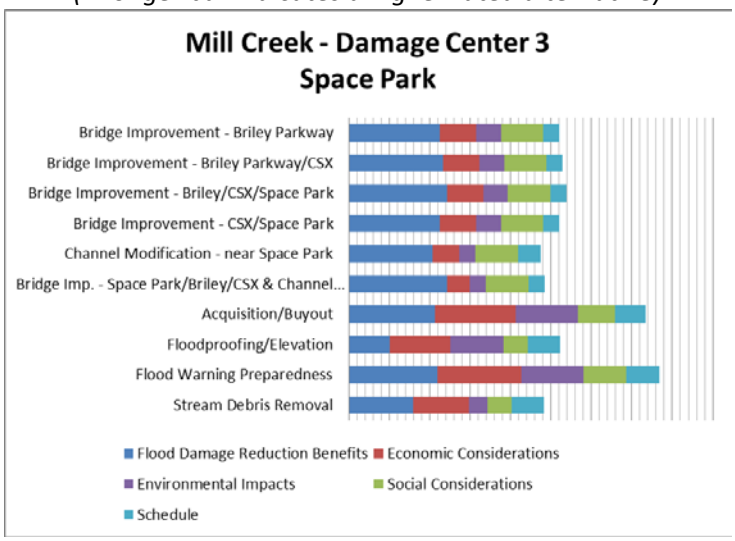

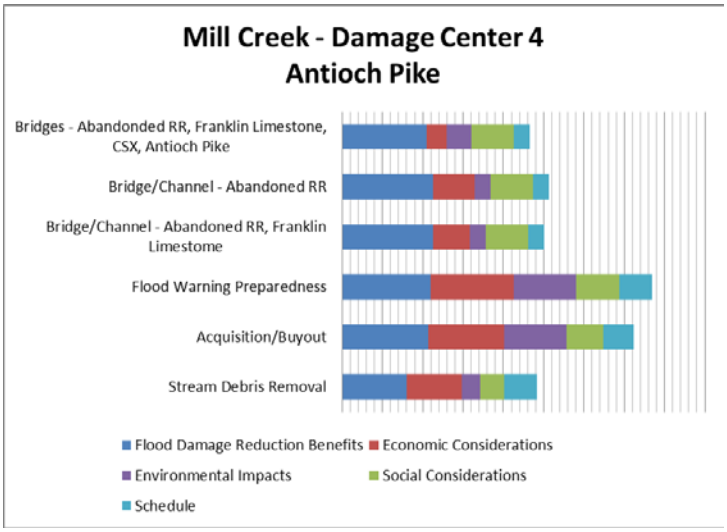

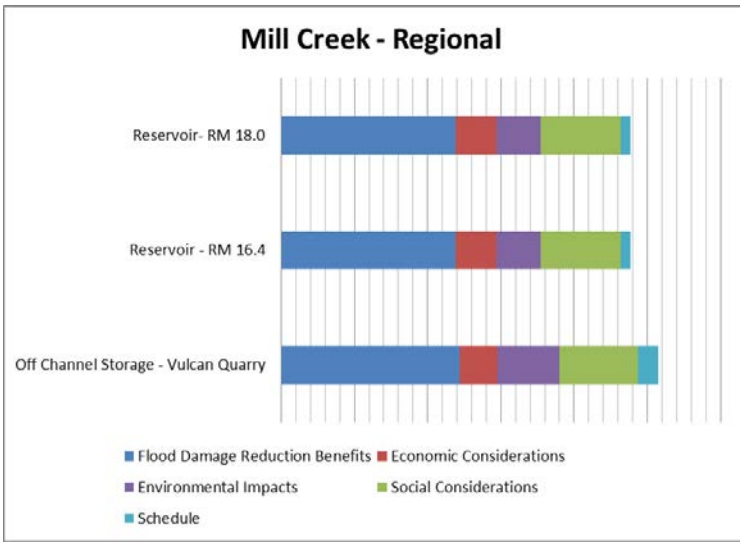

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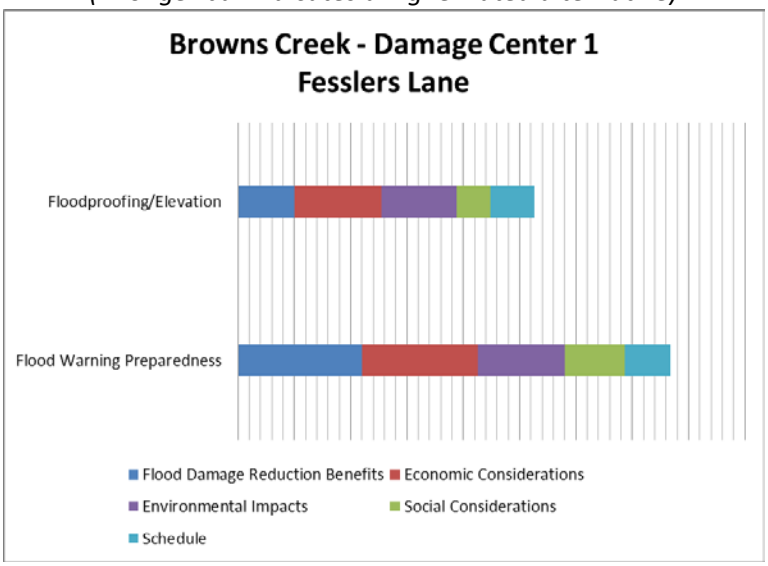

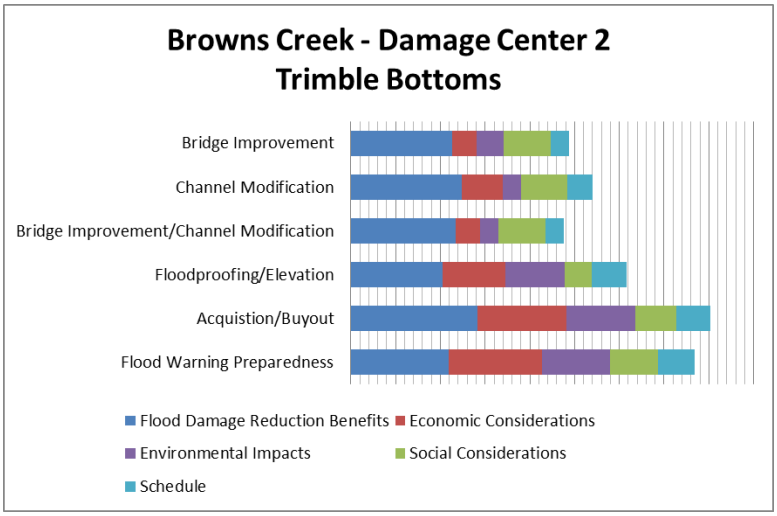

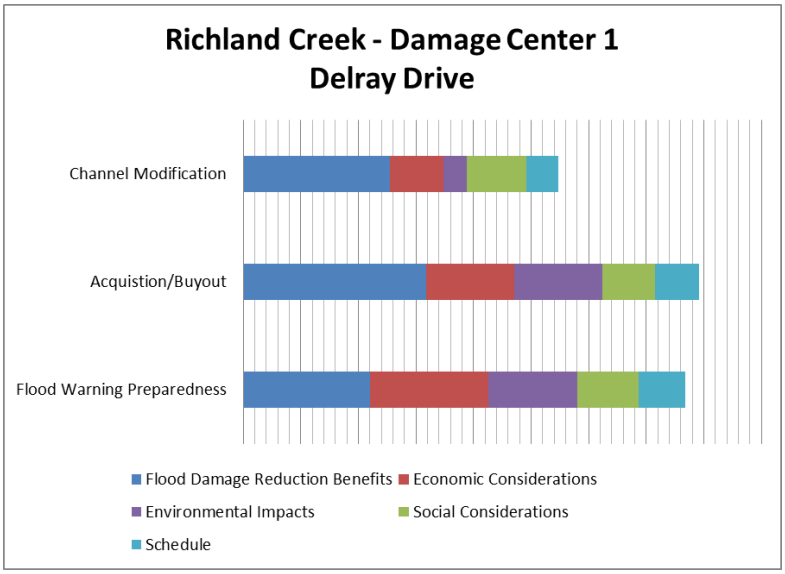

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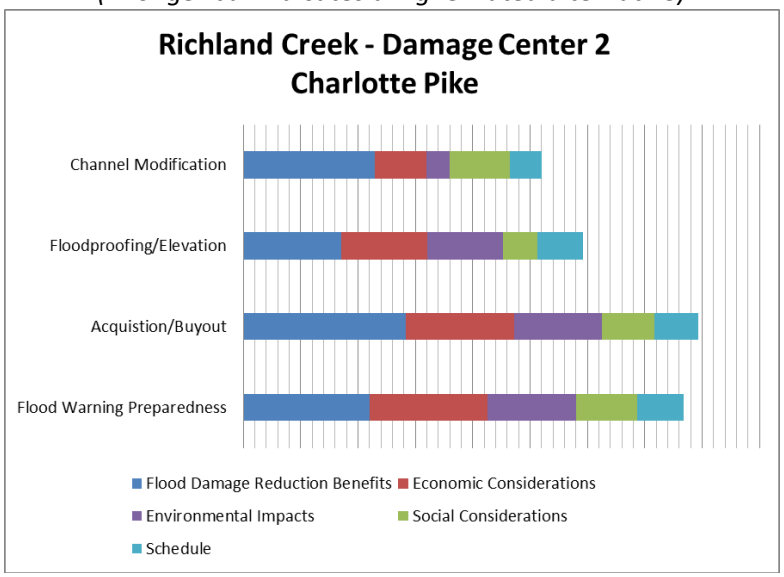
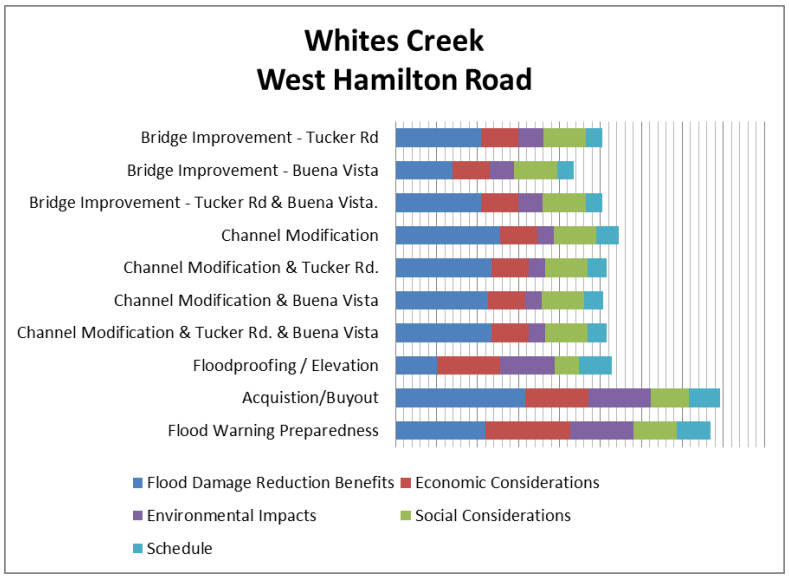




1.0 Background

During the first weekend of May, 2010, Western Kentucky and Middle Tennessee experienced unprecedented rainfalls totaling between 10 to 20 inches, which led to widespread catastrophic flooding. Rainfall and flooding were greatest in and around Greater Nashville, where the third highest (6.23 in.) and highest (7.25 in.) 24-hour rainfall amounts in 139 years of record keeping fell on consecutive days, breaking the previous 24-hour record (6.60 in.) and doubling the previous record 48-hour rainfall total. Widespread flooding in the region led to 26 flood-related deaths, including 11 in the Nashville area, with a disproportionate number of elderly victims.

In addition to the loss of life, record flood stages on the Harpeth and Cumberland Rivers and the tributaries led to more than $2 billion in damages, more than 11,000 damaged structures, and to the closing of 115 roads including two major interstates (I-24 and I-40). Infrastructure damage was also extensive, with significant damage to water and wastewater treatment plants, pump stations, and distribution and collection systems, along with damage to roads, and electrical substations, including the system that provides power to the downtown business core. Some of the City's main tourist attractions, including the Opryland Resort and Convention Center, the Opry Mills Mall, the Country Music Hall of Fame, the Schermerhorn Symphony Center, Bridgestone Arena and LP Field, incurred millions of dollars in damage. In all, over 13,000 jobs were temporarily or permanently lost, and an estimated $3.6 billion of commerce was permanently disrupted.

1.1 Unified Flood Preparedness Plan

Even before the rains stopped, the community began the process of digging out and recovering from the flood. By the city's own estimates, over 29,000 volunteers provided over 375,000 service hours to help neighbors and businesses recover from the flood. After the immediate recovery effort was under way, City leaders, led by Mayor Karl F. Dean, embarked on a deliberate study, called the Unified Flood Preparedness Plan (UFPP), to identify and evaluate flood damage reduction measures on the Cumberland River and its five major tributaries – Harpeth River, Whites Creek, Browns Creek, Mill Creek and Richland Creek.

1.2 Project Goal and Approach

The goal of the UFPP is to develop a sustainable flood protection program that improves public safety, protects environmental and cultural resources, and supports economic growth by promoting a unified approach to lowering the damages caused by flooding. The UFPP's goal of long-term preparedness is based on a program approach that is collaborative, integrated, comprehensive, and implementable:

1. Collaborative – The UFPP focused on reaching out to the community at large to seek involvement, gather information, communicate progress, and build consensus among the many and disparate stakeholder groups. In order to ensure that a wide cross-section of the community at large was able to participate in the program, stakeholder groups were constituted consisting of representatives from:

   - *Government entities* from local, state, and federal agencies including the Metro Government; local, state, and federal government including elected officials; U.S. Army Corps of Engineers (USACE), Federal Emergency Management Agency (FEMA), Tennessee Emergency Management Agency (TEMA), and the Tennessee Department of Environment and Conservation (TDEC).
   - *Critical Service Providers*, including police, fire, EMS, utilities, transportation, and medical representatives.
   - *Environmental Groups*, including representatives from the Cumberland River Compact, the Harpeth River Watershed Association, the Mill Creek Watershed Association, and the Richland Creek Watershed Association.
   - *Business Community* representatives from the Downtown Partnership, the Chamber of Commerce, and individual businesses.
   - *Public at Large*, including neighborhood groups, homeowners, and the television, radio, and print media.

2. Integrated – The UFPP was intended to integrate the knowledge and efforts of the various entities studying or actively participating in flood response to avoid overlap of efforts, coordinate the benefits of the various solutions, and optimize the available flood

recovery resources of the various entities investigating flood response strategies. To avoid starting the program from scratch, each of the 15 previous watershed studies performed in the County since 1988 were reviewed to determine what recommendations were made at the time and to assess if these recommendations were still viable. The previous studies are listed in Appendix 1.A. In addition, the BWSC Team worked closely with the USACE as they completed their update to the hydrologic and hydraulic (H&H) models in the county. The BWSC Team also worked with representatives of Metro Stormwater to coordinate the UFPP with the existing home buyout program, the flood warning system (SAFE and NERVE), and the Metro Water Services (MWS) mitigation plans for the water and wastewater treatment plants and wastewater pumping stations.

In addition to integrating the knowledge and experience of the past and present flood mitigation efforts, the approach is to integrate the lessons learned from the May 2010 flood. The May 2010 flood exposed a number of community vulnerabilities shown in Table 1.1.

Table 1.1: Lessons Learned through May 2010 Flood

Flood Vulnerabilities	Flood Consequences
Highly developed areas are in the floodplain	Loss of life
Navigation dams on the Cumberland River can only do so much to control flooding	Building damage
Uncontrolled tributaries to the Cumberland River can be significant contributors to area-wide flooding	Public Infrastructure damage
Sustaining critical services during a disaster is of utmost importance	Utility systems disruption
o Drinking water	Loss of business productivity
o Power	Loss of tourism revenue
o Telecommunications	Traffic disruption
o Transportation	

3. Comprehensive – Early in the process, it was recognized that the 2010 Flood was not a localized event. In addition to the flooding along the Cumberland River, flooding was reported from Belleview to Goodlettsville and from Whites Creek to Mill Creek. Therefore, the UFPP had to be a county-wide plan. It was also recognized that flooding in some parts of Nashville was influenced by rainfall in neighboring counties. Therefore, the UFPP had to coordinate with neighboring counties to provide the most effective solutions.

To provide a comprehensive response to flooding, the Plan must identify the reasons why flood damages and public safety risk occur. Flooding and the associated consequences can occur due to:

- flood water quantity (a flood event exceeds the level of protection afforded by the existing flood protection design criteria),
- building location (buildings located within the floodway and floodplain, buildings constructed prior to existing Metro code requirements for first floor elevation, or improper construction), and/or
- lack of education or awareness during flood events (slow reaction time or lack of respect for the dangers of high or swiftly moving waters).

To address these factors, realistic flood solutions were evaluated based on flood causes to determine a solution that is viable for a given location and set of conditions. These solutions may take the form of:

- Flood Protection Measures (floodwalls, levees, ring walls, or inflatable barriers),

- Flood Control Strategies (flood water storage, channel improvements, bridge crossing modifications, or flood water diversion), or

- Flood Mitigation Measures (structure floodproofing, building buyout or relocation, building elevation, flood forecasting/warning, or public education).

4. Implementable – For the plan to be successful, the solutions to the causes of flooding in a specific area must represent the optimal balance of economic benefits, social considerations, and environmental impacts. The development of this optimal mix of solution considerations is defined by input from the advisory group, key stakeholders, and the general public gathered through public meetings and workshops. The feedback from these three groups defines the relative importance of the various criteria that will form the basis of a decision rating for a given solution. By using the feedback from the various groups, the rating for a given solution will be that of the community, and not the sole decision of a local, state, or federal agency, consulting company, or advocacy group.

1.3 Methodology

The UFPP is a county-wide plan involving two major rivers (Cumberland and Harpeth) and four tributary streams (Whites, Mill, Richland, and Browns Creek). In order to develop a sustainable flood preparedness program, areas of concentrated and significant flooding were identified by overlaying the location of damaged buildings and parcels (determined by Metro Water Services and Metro Codes post-flood damage surveys), with aerial photos of the May 2010 flood. Twenty-two damage centers on each of the aforementioned rivers and creeks were identified using this analysis.

Once identified, each damage center was visited to obtain site-specific information and to assess the suitability of flood damage reduction strategies in the specified damage center. Flood Damage Reduction Alternatives that were deemed viable after a site visit and office research were developed for the damage center, and costs of constructing and maintaining the alternative were prepared. Subsequently, the annual benefits derived from the implementation of the specific alternative were also quantified. The costs and benefits developed were consistent with a reconnaissance-level study.

The calculated reconnaissance-level costs and benefits, along with a number of subjective

factors specific to a given alternative, were entered into a decision model to identify the highest rated alternative. The value of each of these qualitative and quantitative factors was weighted based on input developed from feedback provided by stakeholders, technical advisors, and the general public. Using these community-derived weights and the ratings for each factor, the highest rated alternative for each damage center was identified.

1.4 Prior Studies

The UFPP represents the most recent study concerning flooding in Davidson County. As such, the study builds on the previous studies that have been conducted along individual tributaries, the Cumberland or Harpeth Rivers, or across the county. Where applicable, the UFPP incorporated prior recommendations to reduce flood damage be reconsidered as part of the UFPP evaluation. A list of the previous studies considered as part of the UFPP is listed in Appendix 1.A. References to documents considered in the preparation of this report are found in Appendix 1.B.

2.0 Stakeholder Involvement

One of the goals of the UFPP was to develop long-term solutions to flooding in Davidson County. Such solutions require broad consensus and support from the various stakeholders in the community. Therefore, a significant point of emphasis of the UFPP has been placed on developing consensus among engaged stakeholders regarding the relative importance of the various criteria used to evaluate the suitability of a specific alternative for a given damage center. By considering and addressing the perspectives of a wide cross-section of the community including elected officials; local, state, and federal regulators; advocacy groups; business leaders; and individual citizens; the UFPP represents the will of the community, not simply the perspective of a select few. Plans developed with this type of broad support are generally more successful than plans crafted in isolation. A number of individuals, businesses, utility departments, and groups were affected directly or indirectly by the flood, have jurisdictional authority with respect to proposed changes to address future flooding or represent segments of the community that may be impacted by changes to address flooding. The following three stakeholder groups were identified and their roles in the UFPP are described below.

2.1 Advisory Committee

The Advisory Committee was composed of local, state, and federal representatives of departments and agencies tasked with issues that impact flooding or flood control. The members of this Committee were selected because of their technical experience and permitting authority for flood damage reduction solutions. Appendix 2.A lists the names and departments or agencies of the members of the Advisory Committee.

The Advisory Committee was charged with providing guidance in developing program goals and priorities, developing a public participation and education plan, identifying available stakeholder resources, establishing a process for decision-making and defining success for the program.

Specifically, the Advisory Committee was tasked to:

- Participate in the development of program goals,
- Participate in in the development of decision criteria and in the valuation of relative weights for each decision criteria, and
- Provide feedback and constructive criticism on the direction of the UFPP through Advisory Committee meetings.

Throughout the UFPP development process, the Advisory Committee was convened and updated on the program status and given an opportunity to critique and offer recommendations to the plan. Appendix 2.A contains a listing of the Advisory Committee meeting dates, attendees, and the topics discussed at those meetings.

2.2 Key Stakeholders

The Key Stakeholders represented Utility providers, satellite cites, elected officials, and active community members with constituents that were impacted by flooding or remedial flood activities.

The Key Stakeholders were asked to:

- Provide input on decision criteria and the weighting of decision criteria, and
- Attend periodic meetings to discuss the progress of the program and to provide input and feedback related to their respective areas of interest

Meetings were conducted periodically with the Key Stakeholders to update progress and to gather feedback. Appendix 2.B lists the dates, attendees and topics of discussion at each of the Key Stakeholders meetings.

2.3 General Public

The UFPP Management Team coordinated three rounds of public meetings during the course of the project. Appendix 2.C lists the dates and locations of the public meetings and a copy of the agenda.

Public meetings provided the UFPP Management Team an opportunity to educate the public about the purpose and scope of the UFPP and to provide an opportunity for all citizens of the county to provide input and feedback on program goals, decision criteria, and progress. These meetings were particularly valuable because they allowed citizens to communicate issues relevant to their specific community or neighborhood.

3.0 Evaluation Criteria Development

3.1 Criteria Formulation

A fundamental goal of the UFPP is to propose flood damage reduction solutions for each damage center that represent an optimal balance of economic benefits, social considerations, and environmental impacts. Therefore, before a decision on a particular flood damage reduction measure can be made, the various factors, or criteria that influence a decision must be identified and weighted in a way that reflects the communities' values.

Brainstorming sessions were conducted with consultants and members of the Advisory Committee to generate a list of the various criteria that would factor into a decision on the viability of a flood damage reduction remedy. These brainstorming sessions were informal, with a goal of identifying as many of the criteria as possible that would contribute to a flood damage reduction decision. In addition to the obvious criteria like the cost of flood damage reduction measures and financial benefits derived from these measures, less quantitative criteria, like habitat impacts or the potential for community disruption due to a flood damage reduction measure, were also put forward. After generating a list of several dozen factors, similar criteria were grouped together so that primary criteria and subcriteria groups were developed.

A draft decision structure was presented to the Advisory Committee for review and comment at the July 12, 2011 meeting. A vigorous discussion of both the grouping of the subcriteria, as well as the completeness of the criteria took place and the draft decision structure was adjusted to reflect the comments of the Advisory Committee. The modified decision structure was finalized after review by the Advisory Committee and is presented in Figure 3.1.

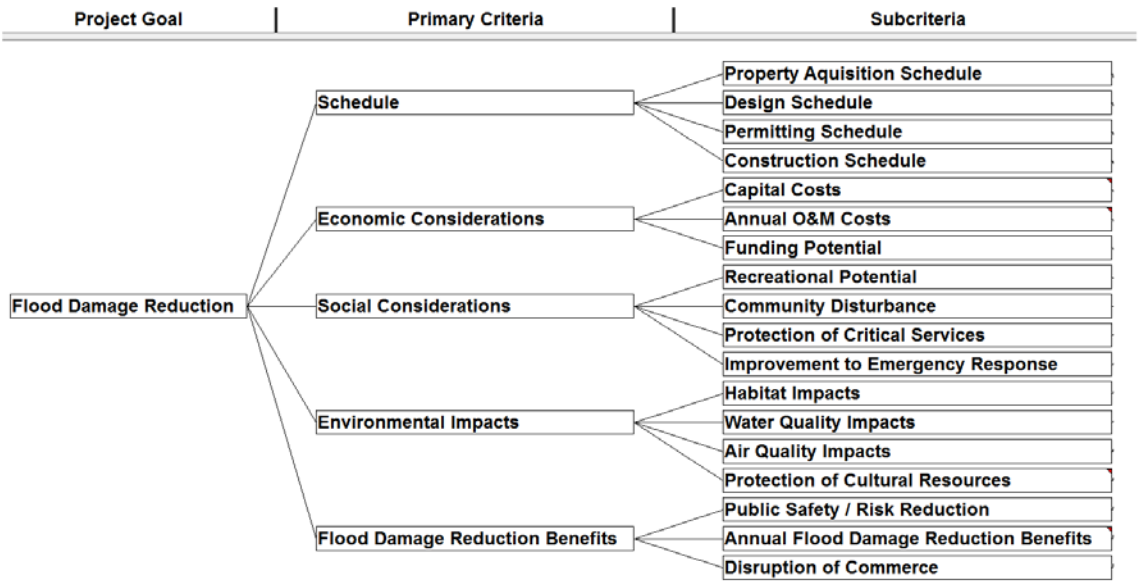


Figure 3.1: Relationship between the Project Goal and Primary Criteria and Subcriteria in a Decision Structure.

3.2 Relative Criteria Weighting Development

Once the decision structure was finalized, the relative value of each of the decision criteria had to be established. To determine the relative weights of the various decision criteria, surveys were sent to members of the Advisory Committee and to the members of the Key Stakeholders. In addition, members of the public were requested to complete surveys during public meetings held in July 2011. The surveys included a description of the flood damage reduction solutions, explained that each damaged area had unique factors that may affect the viability of individual solutions, and then asked respondents to weight the importance of each primary criteria on a scale of 1 (most important) to 5 (least important). A copy of the primary criteria survey is provided in Appendix 3.A.

Results from the Advisory Committee, the Key Stakeholders, and the public were tabulated and compared. A total of 49 public surveys were completed after public meetings, while 20 members of the Advisory Committee and six members of the Key Stakeholders responded. The results of their responses are presented in Figure 3.2.

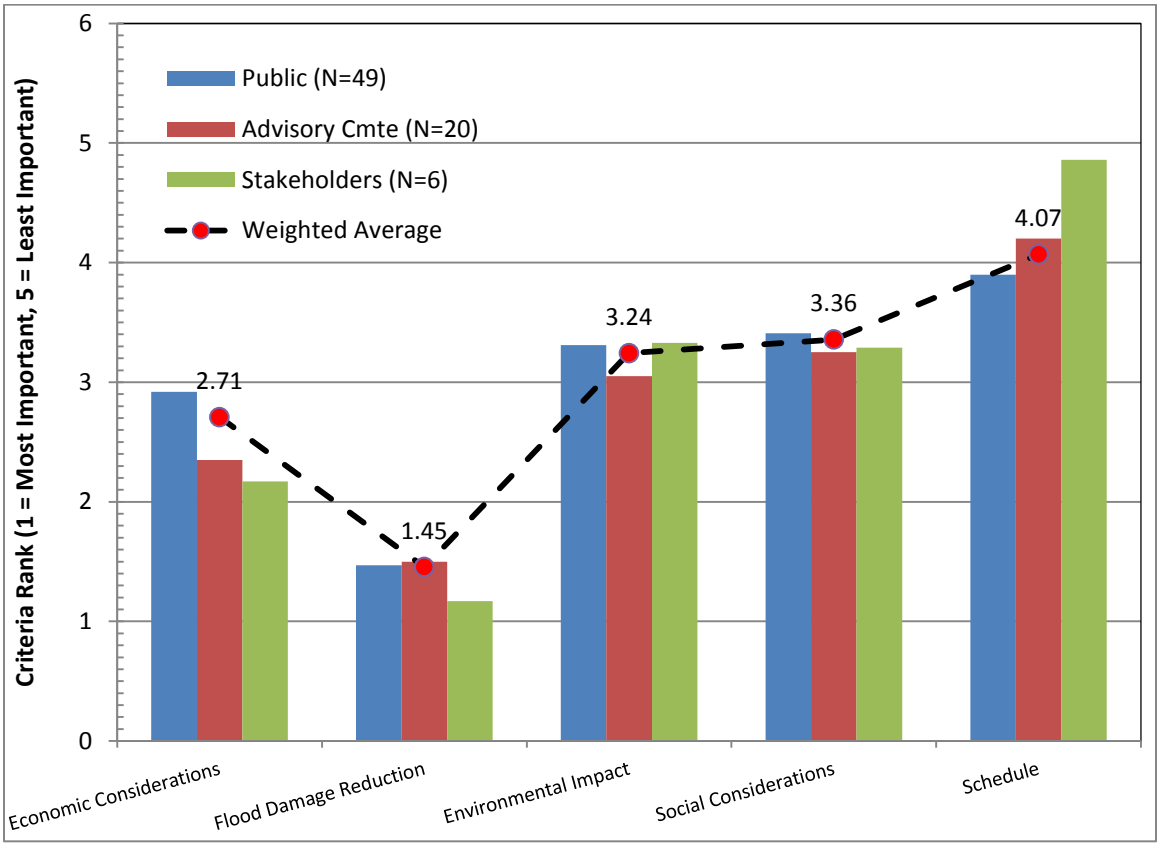


Figure 3.2: Ranking of Primary Criteria by the Public, Advisory Committee, and Key Stakeholders

As the figure indicates, rankings were generally consistent among the various groups. Note that values on Figure 3.2 with the smallest column represent the most valued criterion, given the language and ranking values of the survey. Flood Damage Reduction (1.45) was uniformly seen as the most important criterion, followed by Economic Considerations (2.71). Environmental (3.24) and Social (3.36) Considerations were given nearly equal weight by all respondents, while Scheduling Considerations (4.07) was valued the least. The similarity of the responses indicated that the communities' values were consistent between the separate groups, and allowed the use of the average value in establishing weighting for the various decision criteria.

The weights of the various subcriteria were determined by a focus group of the Advisory Committee. Because the relative importance of the various factors that influence the decision criteria can involve specific or technical knowledge, not all members of the Advisory Committee felt comfortable providing feedback on the values of the various subcriteria. Therefore, a select group of Advisory Committee members from the USACE and Metro Water Services - Stormwater and consultants completed a survey on the relative importance of subcriteria. A copy of this survey is included in Appendix 3.B. A total of eight respondents completed surveys of the relative importance of subcriteria. These responses are summarized in Figure 3.3.

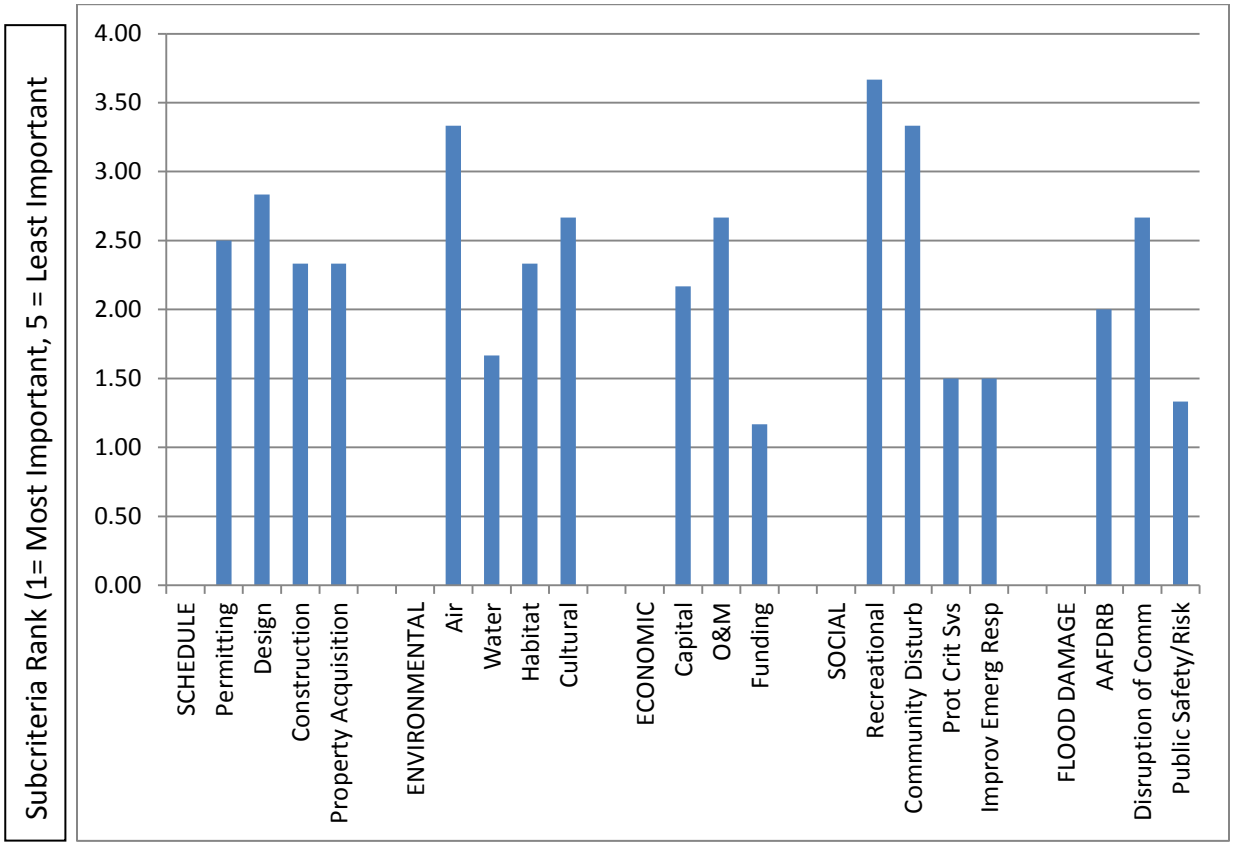


Figure 3.3: Ranking of Subcriteria (1 = Most Important, 5 = Least Important)

The results of this survey were used to assign weights to the subcriteria that make up the decision criteria. Note that values in Figure 3.3 with the smallest column represent the most valued subcriteria. (No change was made to the weights of the primary criteria, described above.) At the completion of this exercise, weights for both the primary criteria and the associated subcriteria had been assigned. These weights were presented to the Advisory Committee and approved at the August 30, 2011 meeting and subsequently presented to the Key Stakeholders on October 26, 2011 and in the Public in February 2012. The final criteria weighting subsequently used to evaluate various alternatives in individual damage centers is illustrated in Figure 3.4.

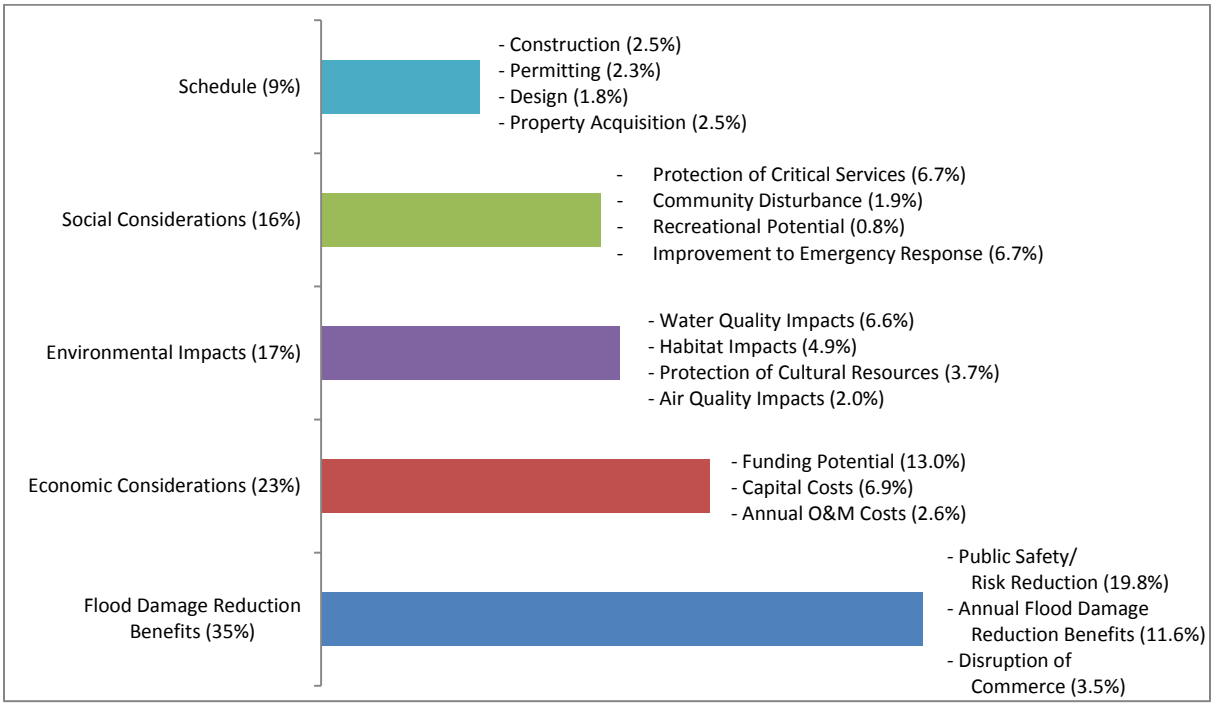


Figure 3.4: Criteria Weighting Used for the Evaluation of Alternatives in Damage Centers

3.3 Decision Model Development

Data from the surveys along with values of the primary decision criteria and subcriteria were incorporated into a computer program to evaluate alternatives for each damage center. The computer program selected was Criterium Decision Plus (CDP) by InfoHarvest, Inc., a decision software that provides a framework for making informed, supportable decisions using user-supplied data. For the UFPP, CDP was employed using the Simple Multiattribute Rating Technique (SMART) decision making approach based on the Multiattribute Utility Theory (MAUT) developed by Ward Edwards in 1977.

When using SMART in decision-making, the decision problem is broken down into the primary decision - and subcriteria developed and discussed earlier. Each criterion is assigned a value with respect to a specific alternative. For example, SMART assigns a value between 0 and 1 to the

impact that the construction of a levee (the alternative) has on water quality (the subcriteria of the environmental impacts decision criteria). Values (the weight assigned to a specific subcriteria multiplied by the value for the alternative) are determined for each decision criteria. Finally, individual values for each criterion are aggregated, providing an overall value for a given alternative. This process was replicated for various alternatives in a given damage center to allow various alternative to be quantitatively compared.

These topics will be covered in more detail later when discussing the evaluation of alternatives in Section 8.

4.0 Damage Center Identification

4.1 Geospatial Data Analysis

One of the objectives of the UFPP was to identify the areas in the county that have the potential to suffer the most flood-related damage and which would benefit the most from flood damage reduction measures. To accomplish this, a number of geospatial data sets were prepared and analyzed to provide an indication of those structures in the county that have the potential to flood based on available flood mapping and related data. The geospatial data can be grouped into three data subsets:

- Areas of Potential Damage,
- Areas of Actual Damages, and
- Special Considerations datasets.

The following map layers were either obtained from the relevant agencies or were prepared for this analysis:

Potential Damages

- Floodway, 100-yr floodplain and 500-yr floodplain delineation and repetitive loss areas from the Federal Emergency Management Agency (FEMA). Digitized maps of the extent of the various floodplains and the locations of repetitive loss areas were obtained from FEMA's Digital Flood Insurance Rate Map (DFIRM) Database. The DFIRM database contains georeferenced mapping and engineering data elements, providing the ability to overlay the mapping and engineering data on a single map.

- Inundation maps for all water bodies in Davidson County for the May, 2010 flood. Inundation maps were generated by the USACE to provide a measure of the extent of flooding during the flood crest for a given watercourse.

- Extent of past watershed studies by Metro Water Services (MWS) and past Recon and Feasibility Studies by USACE. Both MWS and the USACE have conducted flood studies in the past on both the major rivers and tributary streams. A list of those previous studies is included in Appendix 1.A. Maps were prepared that highlighted the reaches in these studies that were identified as potential flood zones.

Actual Damages

- Results of the May 2010 Metro Codes Initial (Windshield) Damage Survey. Metro Codes, Fire, and the Assessor's Office conducted an windshield survey of flooded streams and neighborhoods in Metro Nashville in the days following the flood. (Referred to in subsequent sections as the Metro Codes Windshield Survey.) The level of damage for each property was classified as No Damage

(Damage Level 1), Limited Damage (Damage Level 2), Moderate Damage (Damage Level 3) or Major Damage (Damage Level 4). Metro Planning prepared maps of this information.

- Results of the Post-Flood Damage Estimates conducted by Metro Water Services. To get a relative estimate of damage costs, MWS reviewed structures which were observed to be damaged during the Metro Codes Windshield Survey to determine the estimated damage costs (expressed as a percentage of the value of each structure using a FEMA guide sheet as a basis). Properties were categorized as less than 40% damaged, between 40% and 50% damaged, or more than 50% damaged. Metro Planning developed maps of this data.

- Locations of past or ongoing home buyout programs. Metro has a successful, ongoing home buyout program and has been actively pursuing additional home buyout in response to the May 2010 flood in areas that suffered substantial damage. Locations that have been offered home buyout in response to past or recent flooding were identified and mapped by MWS.

- Location of FEMA repetitive loss structures. Structures that are classified as Repetitive Loss Structures by FEMA have received two or more claim payments of more than $1,000 from the National Flood Insurance Program within any rolling 10-year period.

Special Considerations

- Critical Facilities. Facilities (1) essential in providing services during the response and recovery operations, (2) that house discrete populations that may require greater assistance in the event of a hazard.

- Population density maps. Digital data from the US Census Bureau.

- Locations of road closures during the May 2010 flood. Provided by Metro Public Works.

- Location of fatalities reported during the May 2010 flood. The locations of the 11 people who died in the Nashville area as a result of the May 2010 flood were identified.

- Critical utilities. Location of water, wastewater, electric, gas and telephone utilities within 2010 flood inundation areas.

4.2 Damage Center Selection Methodology

Geospatial data from the three subsets described above were added to a Geographic Information System (GIS) to identify areas with the most concentrated damage. Initially, areas which had the highest potential for damage (within the 500-yr floodplain and within the 2010 flood inundation zone) were identified. Areas with high potential that had been the subject of past Metro or USACE studies were highlighted. These high potential areas were screened further by adding map layers of actual concentrated property damage during the 2010 flood. Areas that had high flooding potential and high actual damages were prioritized if any of the special consideration data fell within the damage area. Those sites from across Davidson County which had the highest potential and actual damages, and which contained the most special considerations, were selected as damage centers.

An example of this process is illustrated below. (See Figures 4.1 to 4.4) An evaluation of a reach of Whites Creek below Ewing Creek indicates a number of properties built within the 500-yr. floodplain, and which were identified to have been inundated during the May 2010 flood. This area had been identified as flood prone previously in both MWS and USACE studies, and several properties were categorized as repetitive loss structures by FEMA. The Metro Codes Windshield Survey conducted immediately after the flood indicated that a number of the structures in this area incurred Major Damage (Damage Level 4), and subsequent post-flood damage estimates by MWS indicated that a number of these structures sustained damage that exceeded greater than 50% of their value. Due to all of these factors, this area was identified as one of the 22 damage centers in Metro Nashville.

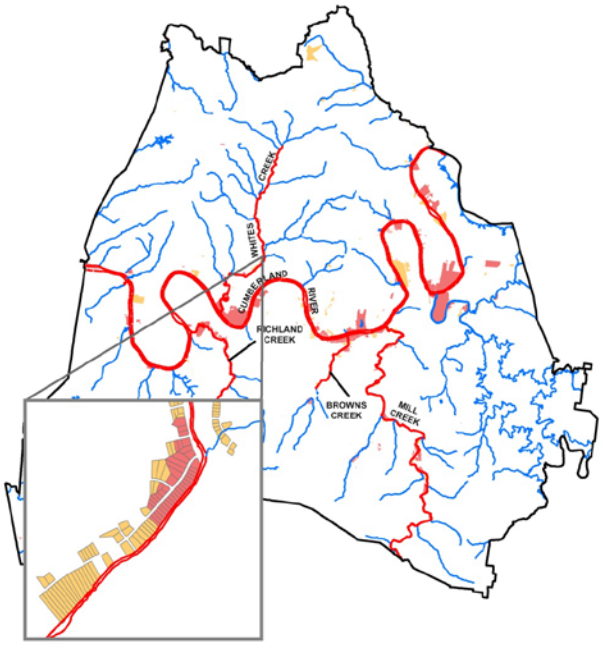


Figure 4.1: Example Construction of a Geographic Information System Map Using Layers of Different Geospatial Datasets. Inset Illustrates - Metro Codes post-flood windshield survey data

Figure 4.2: Example Construction of a Geographic Information System Map Using Layers of Different Geospatial Datasets. Inset Illustrates - Metro Water Services damage assessment data

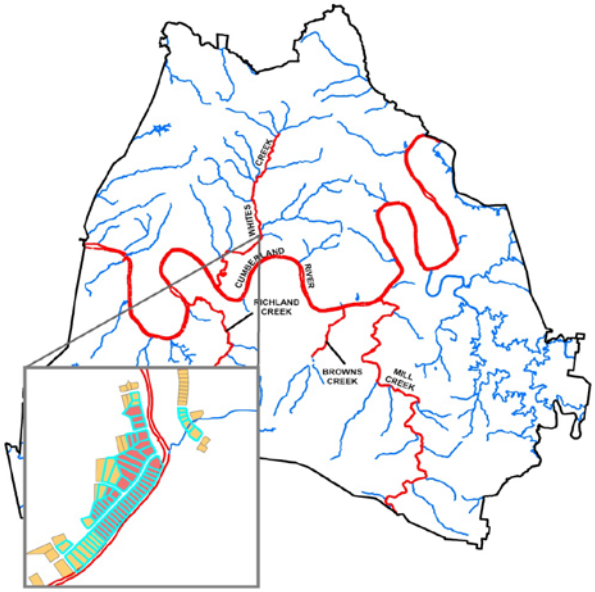


Figure 4.3: Example Construction of a Geographic Information System Map Using Layers of Different Geospatial Datasets. Inset Illustrates - existing Home Buyout Program data.

Figure 4.4: Example Construction of a Geographic Information System Map Using Layers of Different Geospatial Datasets. Resulting map segment with each layer included.

5.0 Potential Flood Damage Reduction Alternatives

In this study, eleven flood damage reduction alternatives were considered. The alternatives can be grouped in to three major categories based upon how they would reduce flood damage:

- Flood mitigation,
- Flood protection, and
- Flood control.

Flood mitigation alternatives do not try to control or minimize flood waters but seek to reduce damage of property and protect the lives of citizens by removing people from harm's way. A flood protection alternative seeks to eliminate flood waters from a particular area and consequently minimize flood damage. Flood control alternatives aim to reduce the damage of a flood by influencing where and how the water will flow.

5.1 Flood Mitigation Alternatives

Of the eleven alternatives considered, five were considered mitigation alternatives:

- floodproofing/elevation,
- acquisition/buyout,
- flood warning/preparedness,
- land use regulations, and
- stream debris removal.

Some alternatives were combined for analysis purposes. A combination of the flood mitigation alternatives were included in some damage centers based on the criteria established for the application of the mitigation measure on a property by property basis.

Floodproofing and Elevation have similar functions but are implemented differently. Wet floodproofing "relies on the use of flood-damage-resistant materials and construction techniques to minimize flood damages to areas below the design flood elevation of a structure intentionally allowed to flood" (ASCE 24-05). Measures are taken to prevent or minimize damage and protect critical equipment when the waters enter the property. This is typically done for structures below the flood elevation which are not used as living space. Dry floodproofing is "used to render a structure envelope substantially impermeable to the entrance of flood waters" (ASCE 24-05). Protective coatings or membranes may be used on walls, while shields and panels protect window and door openings. Elevating critical electrical and mechanical systems above the flood elevation can reduce flood damage and recovery schedules. Measures are also taken to prevent sewer and drain backups into the structure. Floodproofing was considered only for non-residential structures. While this is a viable alternative for flood damage reduction, the cost of implementation is the responsibility of the property owner.

By contrast, elevation is used to physically raise the first floor of an existing residential structure

up to a community's current flood elevation requirement, thereby reducing flood damage (but not necessarily the flood hazard). Raising the occupied space above the flood elevation reduces the likelihood of property damage in the event of a flood. While it is technically possible to elevate any structure, it should be noted that home elevation has certain physical and economic limitations. Large structures or structures with complex foundations or utility connections will be difficult and considerably more costly to elevate. The following conditions were established as the criteria for elevation as an alternative:

- The property was substantially damaged in the May 2010 flood, and
- The first floor elevation is below the base flood elevation + 1ft.

While elevation is a viable alternative for flood damage reduction, the cost of implementation is the responsibility of the property owner.

Acquisition and Buyout is an alternative that has been successfully implemented by Metro at several locations. This alternative is restricted to residential properties and completely removes the structure in the floodplain. This alternative is used to remove structures and reduce flooding hazards in the floodway and floodplain. Damaged properties are purchased from home owners and demolished, removing the threat of property damage and the risk to individuals. At times, a community park may be developed to utilize the space in place of homes that have been removed.

Flood Warning and Preparedness refers to a system or set of procedures intended to mitigate flood damages by removing people and protecting property from dangerous areas before a flood occurs. A flood warning system would detect an impending flood event and communicate necessary warnings in enough time to evacuate residents and close roads. Those warnings would primarily be to people living in potentially affected homes and motorists traveling on potentially flooded roads, but would also extend to commercial businesses and afford them the opportunity to move inventory and equipment and secure their facilities for pending flood waters.

Land Use Regulations is an alternative that seeks to use building codes, zoning ordinances, or subdivision regulation to prevent future developments from taking place in areas below a particular flood elevation. This would mitigate damages by eliminating or minimizing new structures in areas that would be affected by a flood. Land use regulations might also limit storage of material within the floodway that could be swept away by flood waters and create blockages in the channel that could worsen the flood impacts.

5.2 Flood Protection Alternatives

Levees and Floodwalls are functionally very similar in that they are a physical barrier along a floodway designed to keep floodwaters out of low lying areas. Levees are primarily earthen embankments while floodwalls are typically vertical concrete or steel walls. These structures

protect areas from flood waters up to a predetermined level (i.e. the 100-yr. or 500-yr. flood elevation) and therefore, protect people and property. Floodwalls and levels do not completely mitigate flood hazards, and can give a false sense of security. As mentioned, floodwalls and levees only provide protection up to a certain level; beyond that level, floodwalls and levels offer no protection. In addition, floodwalls and levees can fail subjecting residents behind the structure to immediate and rapidly rising floodwaters. This was dramatically illustrated in New Orleans during Hurricane Katrina.

5.3 Flood Control Alternatives

Five flood control alternatives were considered:

- Reservoir,
- Off channel storage,
- Diversion,
- Bridge replacement/improvement, and
- Channel modification.

A *Reservoi*r is a method of controlling floods by storing waters on the river or creek by use of a dam. By collecting and storing floodwaters behind a dam or impoundment, and then releasing to the downstream channel the accumulated waters over a longer period of time, the peak flow rate, and thus the maximum flood stage, in the channel is reduced, thereby reducing flood damage.

Off Channel Storage is an alternative that would capture the extra volume of flow during a flood event and release that volume after the flood waters recede. The extra water would be held at a location off of the channel, allowing normal flow through the channel under normal circumstances. This method reduces the peak of the flood in a manner similar to a reservoir.

Diversion is an alternative that "reduces damage by reducing discharge directly" (USACE 1110-2-1419). This alternative takes excess flow from the channel and diverts it through a secondary channel to protect a particular area. This secondary channel may be an open channel or a closed pipe. The flows of the two channels converge downstream of the area to be protected.

Channel Modification is an alternative that seeks to increase the capacity of a particular channel by either modifying the geometry of the channel or by reducing the hydraulic energy lost in the channel. Typically this occurs by widening the channel or relocating the banks of the channel. Channel modification allows for a greater volume of water to pass downstream. Depending on the rainfall, this can eliminate a flood event all together or increase the amount of time before the water leaves the banks and floods surrounding areas.

A subset of channel modification is debris removal. Debris removal reduces the headloss of a given stream segment by removing accumulated vegetative debris or trash from the shoreline or

from around in-channel abutments, thus improving the channel hydraulics, and allowing a greater volume of water to pass through a stream reach in a given amount of time.

Bridge Improvement is an alternative that acts in a similar manner to channel modification. Improving bridges by elevating them, removing piers, or moving foundations allows more flow to easily pass by the bridge. This alternative reduces the local significance of a flood event by not reducing the hydraulic profile upstream of the bridge.

6.0 Development of Alternatives

6.1 Damage Center Initial Map Review

Prior to conducting site visits, GIS aerial photos, including aerials taken on May 3, 2010, and United States Geological Survey topographical maps of the damage centers were reviewed. With the aid of each map, the extent of the 2010 flood and the existing 100-yr. and 500-yr. floodplain extent could be examined and their locations identified in the damage center. In addition, low points that would have received the most damage were identified. Overlays of post-flood reconnaissance surveys conducted by Metro Water Services were added to these maps to indicate structures or parcels that were significantly damaged.

6.2 Damage Center Site Visits

A site visit to each of the damage centers was conducted to gain familiarity with the terrain and drainage of the site and to identify any site specific issues that would affect the feasibility of a potential alternative within a damage center. Examples of site specific issues that might impact the suitability of a particular alternative are:

- The presence of bridges or bridge abutments constructed in the floodway that would constrict flow, leading to impounded water during flood events,
- Dense population or commercial construction in or near the floodplain extent, limiting the potential for flood wall or levee construction,
- Suitable floodplain for construction of channel modification or diversion, and
- Accumulation of debris or illegal dumping that would alter drainage or floodway.

During site surveys, structures that had been identified as significantly damaged during post-flood surveys were visited, and the areas were surveyed for remaining damage or for damages not indicated during post-flood surveys. These surveys were helpful to identify vacant structures and the true elevation of industrial buildings for which complete survey data was not available. In addition, significant utilities (electrical substations, water or sewer pump stations, equalization basins, etc.) were identified and located.

Site visits also provided an opportunity to engage residents and businesses to gain first-hand accounts of the conditions during the 2010 flood. For instance, residents described the elevation of floodwaters which may not have been captured on the aerial flood photo, or described the extent of destruction that had been repaired by the time the site visits took place. One resident recommended viewing videos that had been posted on YouTube to observe the flood levels and extent of damage. (This practice was subsequently added to routine office research.) Photos of typical buildings, drainage structures, and possible obstructions to flow were taken and are provided in Appendix 8 for each damage center.

6.3 Post Site Visit Office Research

After the site visit was completed, office research was conducted to determine what, if any, studies had been conducted on a damage center site in the past, what recommendations had been made to minimize flood impacts, and whether these past recommendations were still viable alternatives. A number of past studies of the impact of flooding and the potential for flood damage reduction had been conducted by the USACE and Metro Stormwater Division on tributary streams (Whites, Richland, Mill, and Browns Creeks) and the Cumberland River. In addition, recent county-wide studies by the Mayor's Office of Flood Recovery, the Mayor's Office of Emergency Management, the National Weather Service, and the USACE detail flood response efforts and proposed mitigation and recovery plans for the region. These reports were reviewed and recommendations for flood damage reduction cited in these reports were documented and reviewed to determine whether they were still feasible. Appendix 1.A contains the past reports that were reviewed as part of office research.

The Flood Insurance Study for Davidson County (April 2001) was reviewed to determine if bridges or other natural obstructions in the rivers or creeks were creating conveyance restrictions during high flows. Locations with high headlosses or impounded water indicated sites where channel modification or bridge modifications could potentially reduce flood levels upstream of these locations.

Maps were also inspected beyond the boundaries of the damage center to look for regional solutions to reduce the risk of flooding. For instance, dry reservoir sites outside of the extent of damage centers on Mill Creek and the Harpeth River were identified. These dry reservoirs could be activated during high flow periods to attenuate the flows downstream and lower the flood levels, reducing the impact of flooding at damage centers downstream of the reservoir. In addition, the potential for off-channel storage was identified in a rock quarry near a damage center on Mill Creek. Employing the quarry as an emergency off-channel storage site could reduce the level of flooding to downstream damage centers.

6.4 Alternative Screening Criteria

Upon completion of the map review, site visit, and office research, each damage center was screened against each potential flood damage reduction alternative to determine which, if any, potential solutions were viable for the particular damage center. An alternatives matrix was developed for each damage center identifying each alternative considered, whether the alternative was determined to be viable after site visit and investigation, and the basis for each decision.

Large structural alternatives such as reservoirs, off-channel storage or diversion, channel modification, or levee construction were often limited by available real estate. Reservoirs were considered viable alternatives if (a) there were natural topographical features that would favor the construction of an impoundment and (b) if the impounded area was generally rural or uninhabited to avoid the significant impact of homeowner relocation.

Off-channel Storage was only considered if a quarry existed in the vicinity of the stream with a volume that could have an impact on attenuating downstream flows. There were few locations that fit this condition.

Diversion was only considered in one location as a means of avoiding head losses generated by bridges. In most locations, there was not enough available land to make diversion a practical solution.

Bridge Improvement was considered a viable alternative if a given bridge was responsible for significant headloss through a given reach at the 100-yr and 500-yr flows. The viability of bridge improvement at a particular location was a matter of engineering judgment, but typically headlosses of several feet were required to consider bridge improvement viable.

Channel Modification was considered when there was floodplain area available to increase the channel cross section in a particular reach. For larger river systems (Cumberland River, Harpeth River) where the stream runs in a deep, well-defined channel, channel modification was considered non-viable. For streams running through densely-populated areas or in areas with endangered species or protected habitat, channel modification was considered non-viable.

Levees or Floodwalls were deemed viable (a) if there was available real estate for construction of a levee or floodwall outside the floodway limits, and (b) if the value of the collected damaged properties in the protected area were estimated to be high enough to offset the considerable cost of construction. In general, the value of residential properties is seldom high enough to offset the high cost of levee construction. However; where the levee would protect areas that include numerous, densely situated homes, it was considered as a potential solution.

Nonstructural Wet Floodproofing was limited to commercial and industrial properties. Wet floodproofing was considered non-viable for residential structures. Wet floodproofing was limited to buildings that have finished floors less than one foot above base flood (100-yr. recurrence) elevation. Floodproofing is a solution that would be implemented by the individual property owners and privately funded.

Structure Elevation was only considered for residential properties. No commercial or industrial structures were considered for elevation. Elevation candidates were limited to single-family homes or duplexes. Therefore, apartment buildings or condominium developments were not considered for elevation. Homes were evaluated for elevation based on the property's finished floor elevation (FFE). The FFE of a property is the elevation, above mean sea level, of the first finished floor. To qualify for elevation, the FFE of a given residential property had to be no more than 1 ft. above the 100-yr. flood elevation. Homes with FFEs in excess of 1 ft. above the 100-yr. flood elevation were not considered for elevation. Groups of homes requiring elevation were

also preferred over single homes. These homes would be elevated to the existing code (FFE = 100-yr. flood elevation + 4 ft.). Homes that required greater than 8 ft. of elevation to meet existing codes were not considered for elevation due to the impracticability of elevating a house this much. Finally, if a home had been previously offered a buyout by Metro, it was not considered for elevation, even if the buyout offer had been rejected. Structure elevation is a solution that would be implemented and paid for by the individual property owners and privately funded.

Structure Buyout was only considered for residential structures; no commercial, industrial, or multifamily structures (apartments or condominiums) were considered for buyout. Residential structures that suffered damage estimated at more than 50% of its value and which had FFE lower than 1 ft. above the 100-yr. flood level were considered for buyout. These parameters were expanded in order to provide neighborhood continuity; that is, homes incurring less damage or built to a higher elevation were considered for buyout to provide continuity of larger zones of home removal in the floodplain when possible. Metro has a successful on-going home buyout program.

Flood Warning was considered a viable alternative for all structure types in all damage centers in Davidson County. Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepared for flooding to minimize the extent of flood damage.

Land Use Regulations were assessed for each damage center on a case-by-case basis. Metro has conservative requirements for the elevation of residential structures constructed in the floodplain compared to other jurisdictions. The requirement of the first floor of homes be built four feet above the base flood elevation (100-yr.) effectively reduces flood damage. Further consideration of limitations on development in the floodplain could also reduce flood damages.

7.0 Evaluation of Selected Alternatives

Selected alternatives (alternatives that were not excluded during the initial alternative screening exercise) were evaluated against the various quantitative and qualitative subcriteria outlined in Section 3. Most of the subcriteria involved qualitative evaluation. (For instance, does the construction of a levee have a positive, negative, or marginal impact on water quality?) Quantitative values for three subcriteria required calculations: Capital costs of an alternative, annual operating and maintenance (O&M) costs for an alternative, and annual flood reduction benefits for an alternative. Summaries of the conceptual-level cost opinions for each damage center can be found in Appendix 8.

7.1 Costs

In order to provide consistency in cost analyses for selected alternatives, standard assumptions and processes were developed. Unit costs for civil/site items were determined from the latest edition of the Tennessee Department of Transportation (TDOT) Average Bid Prices (http://www.tdot.state.tn.us/construction/Average_Bid_Prices.htm). Costs for items not included in the TDOT listing were determined from historical databases and discussions with contractors and owners. Unit prices utilized for the construction cost opinion calculation are summarized in Appendix 7.A.

Property costs for easements necessary for the implementation of a flood damage reduction solution were assumed to be 90% of the assessed value of the property and improvements in the Metro database. Rent of facilities utilized for stormwater control (i.e. a quarry used for offsite storage) was assumed to be 1% of the total construction cost.

Additional costs related to construction, such as those required by contractor's general conditions, were assumed to be 15% of the total construction cost. Engineering and permitting costs were also assumed to be 15% of the total construction cost. Legal and administrative fees were assumed to be 1% of the total construction cost. Taxes were accounted for at 5% of construction subtotal. A 35% contingency was applied to both the capital and O&M cost.

Operation and maintenance (O&M) expenses for selected alternatives were not factored into the capital costs as a present value; rather, they were listed as a separate line item as an annual expense. Annual O&M was calculated as 1% of civil and general items, and 2.5% of process and electrical items. Maintaining properties (principally mowing grass) such as buyout property, levees, and diversion channels were calculated at $80 per acre and assumed to require cutting eight times per year.

Other assumptions used to develop quantities and costs for specific flood damage reduction solutions are detailed below.

Reservoir

Reservoir embankments were assumed to be homogeneous and roller compacted concrete, with 1:1 (horizontal: vertical) side slopes. The top of the embankment was assumed to be wide enough to accommodate a single-lane road for access. Dams were assumed to be constructed of select import fill material, since sufficient embankment material is unlikely to be onsite. A 10-foot deep muck trench consisting of slurry material was assumed in lieu of sheet piling to serve as a groundwater cutoff wall.

Flood control would be accomplished by temporarily detaining water within the dry reservoir area, and flow control would be served by culverts and sluice gates. It was assumed that the reservoir would be used to primarily serve storm events above the 50-year event. Since TDOT design standards do not require major highways to pass floodwater in excess of the 50-year event, roads within the reservoir limits were not raised above the top of dam elevation. Homes, barns, and outbuildings located within the reservoir limits were assumed to be purchased and removed. The dam was assumed to receive regular mowing to prevent trees, but no maintenance was assumed for the reservoir area. Figure 7.1 shows a sketch of a reservoir.

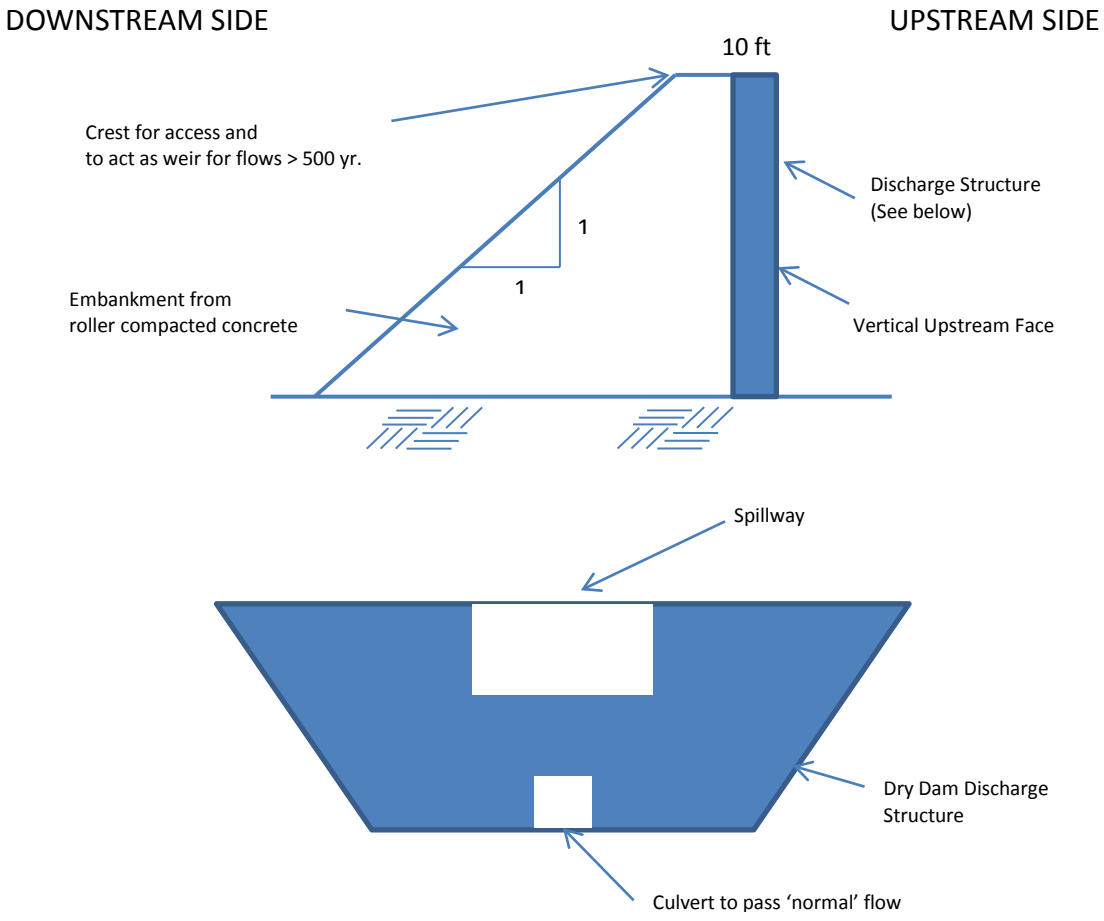


Figure 7.1: Typical Sections for a Dry Dam Reservoir

Off-Channel Storage/Reservoir

Costs to implement an off-channel reservoir using an existing rock quarry include acquisition of easements for flood storage, construction of the infrastructure improvements, dewatering, and restoration of the quarry after large flood events where the off-line storage is activated, and loss of use of the quarry. At this reconnaissance level, the property owners were not approached to discuss the alternative. The actual costs of an easement for the use of flood storage would require discussions with the property owner which would be warranted in a subsequent Feasibility Study. These reservoirs were only assumed to be used for storm events greater than the 50-year return period. Since the size and use of these reservoirs could vary significantly, dewatering and restoration were analyzed on a case-by-case basis.

Diversion

Diversion costs included the costs of easements and infrastructure to construct and operate this alternative. Diversion measures were assumed to serve storm events greater than the 100-year return period, and were assumed to serve in conjunction with the existing channel. Open channels were assumed to have trapezoidal cross sections, and be grass-lined. Side slopes for these channels were assumed to have a 3:1 (horizontal: vertical) grade to facilitate mowing. These channels were assumed to be mowed two times a year to prevent the growth of trees and provide consistent flow characteristics. Inlets and outlets for these channels were assumed to be armored with concrete. Figure 7.2 shows a sketch of a diversion channel.

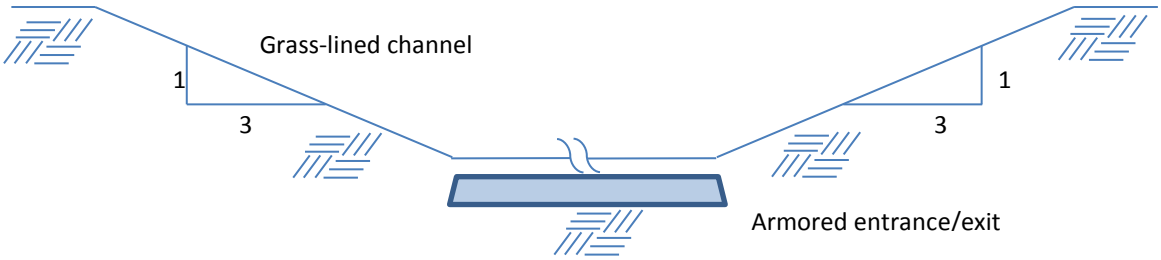


Figure 7.2: Typical Diversion Cross Section

Bridge Improvement

Bridge improvement includes permanent structural measures to modify an existing bridge to improve channel flow characteristics. Removal of accumulated debris at piers was considered as another alternative. Bridges were assumed to be modified so the bottom chord was above the 100-year flow level. Bridge approaches were assumed to be graded to provide for appropriate grades. Bridge improvement costs were calculated at $100 per square foot of bridge deck. Bridge demolition was calculated at $30 per square foot. New bridge construction will not constrict the floodway.

Channel Modification

Channel modification costs were considered similarly to diversion costs. Figure 7.3 shows a sketch of channel modification.

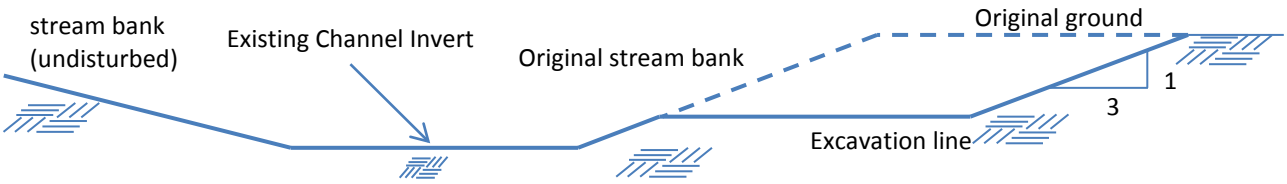


Figure 7.3: Typical Channel Modification Cross Section

Levee/Floodwall

Generalized cross sections were assumed for levees and floodwalls. Levees were assumed to be constructed of select import fill material. A homogeneous trapezoidal cross section was assumed, with 3:1 (horizontal: vertical) side slopes, and a ten-foot wide top for vehicle access. Embankments were assumed to be grassed. Levees and floodwalls were assumed to be constructed to the 500-year flood level plus three feet. Figure 7.4 shows the design cross-section of a levee.

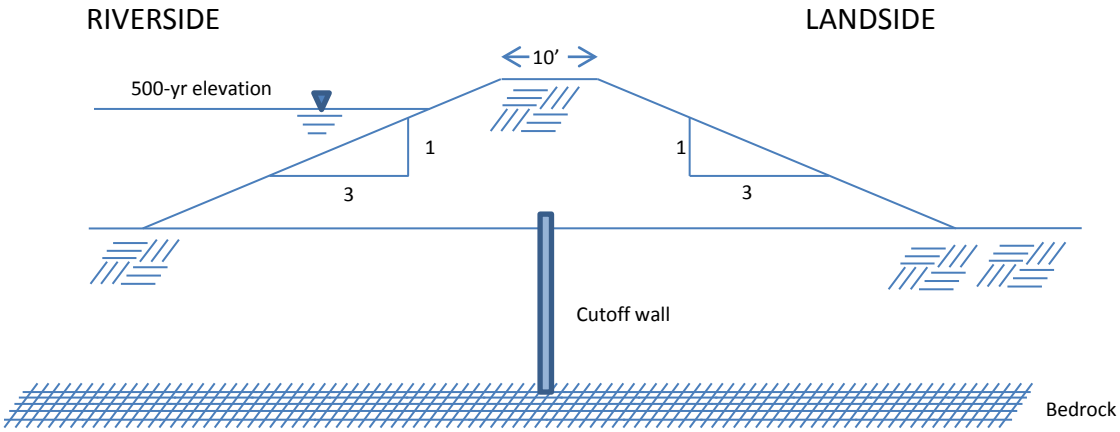


Figure 7.4: Typical Levee Cross Section

The floodwall cross section was modeled after the Gaylord Opryland floodwall. This wall was selected as the typical design because of its recent construction, its location on the Cumberland River, and availability of the design drawings. The detail containing this typical cross section is included as Figure 7.5. H-piles on 10-foot centers driven to assumed bedrock levels were added to this cross section for foundation support. This bedrock depth was deemed typical of the Cumberland River after review of local geotechnical reports.

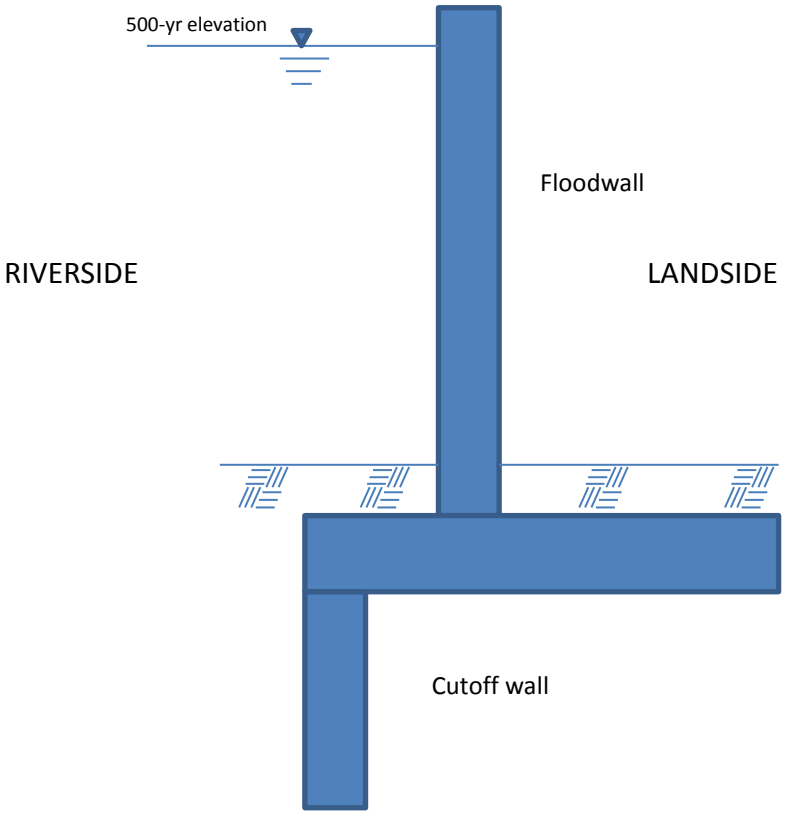


Figure 7.5: Typical Floodwall Cross Section

Cutoff walls were provided in order to prevent groundwater migration below levees and floodwalls. For structures located along the Cumberland River, a 20-foot deep sheet-pile cutoff wall was assumed to bedrock depth. For tributaries, a 10-foot deep muck trench consisting of slurry material was assumed in place of sheet piling.

Excel spreadsheets were generated to provide quick and consistent unit costs (per linear foot) for levees and floodwalls. These spreadsheets are included in Appendix 7.A.

Stormwater Infrastructure

TR-55 methodology employed by Hydraflow Hydrographs 2004 was used to produce hydrographs and predict volumes generated by storms up to the 500-year event. Stormwater infrastructure, such as subterranean pipes and catch basins, was sized for the 10-year event, which is typical of local codes. Large conveyance to pump stations was sized for the 500-year storm event. Pump stations were sized to convey the peak flow from the 500-year event in the respective basins. The pumps were conceptually sized to lift the stormwater 50 feet to discharge above the 500-yr flood level of the river. Piping was sized to convey the peak flow with a maximum velocity of 3 feet per second using the Manning's Equation. Pump discharge requirements were calculated using modeling output of surface runoff from a hydrology model

(Hydraflow Hydrographs, IntelliSolve, 2004). Power requirements were calculated from peak discharge requirements, assuming a pumping head of 50 ft. and a pump efficiency of 0.75.

$$hp = \frac{Q(gpm) \times H(ft)}{3960 \times 0.75}$$

Pump Stations

Pump station costs include mechanical and structural components, but do not include emergency power or the costs of the diversion structure carrying floodwater to the pump station. These costs were considered separately. Pump station cost data was obtained from the Texas Water Development Board Region H Water Planning Group as well as historical data from large stormwater pump stations constructed in St. Louis, Missouri. Cost data was analyzed to provide a cost curve as a function of the required pumping horsepower, up to 1,000 horsepower. (See Appendix 7.B.) Estimated costs for pump stations above 1,000 horsepower were based on cost curves for stations with similar performance requirements.

Structure Elevation

For residential areas, only home elevation was considered. Home elevation was limited to homes that have finished floors less than one foot above base flood elevation. The homes are to be raised to four feet above base flood elevation. Home elevation costs were gathered from home-moving companies, and are based on the square footage of the house and the height the home was elevated. Costs were estimated using the following formula:

Cost = $13/square foot x house square footage + $1400/vertical foot x feet elevated

Floodproofing

For industrial and commercial properties, wet floodproofing costs were based on a percentage of improvement value. Wet floodproofing was limited to buildings that have finished floors less than one foot above base flood elevation. Studies conducted by the Canadian National Research Council suggest wet floodproofing costs of 2-4% of the cost of improvement value to be appropriate for industrial sites. Four percent of the improvement value included in the Metro property database was allotted to wet floodproofing measures.

Acquisition/Buyout

Property acquisition for demolition was assumed to be the current assessed value of the land and improvements. Demolition costs for houses were provided by Metro Water Services based on recent data from the Existing Home Buyout Program. The cost of demolition, removal, and re-vegetation of each site included in the evaluation was $25,000.

Flood Warning/Preparedness

Metro Water Services provided the cost for flood warning based on the development cost of the Situation Awareness for Flooding Events (SAFE) for Metro Nashville. The SAFE tool was developed to better forecast flood inundation levels to allow for improved evacuation and road

closures. The development cost and maintenance cost for SAFE was divided evenly over the 22 damage centers. The capital cost equated to $200,000 per damage center and $100,000 per year in O&M costs.

Land Use Regulations
No costing guidelines were assumed for this alternative.

7.2 Flood Damage Reduction Benefits Calculations

The USACE used model output to calculate annual benefits for flood damage reduction measures. Benefits were defined as the difference in the damages accrued during a flood with and without the specific flood damage reduction measure in place. For instance, a 100-yr. flood passing through one of the damage centers identified in this report would result in flood waters rising to the 100-yr. flood elevation (i.e., extending to the 100-yr. floodplain.) Structures within the damage center with finished floor elevations below this flood elevation would sustain damage. The extent of the damage was calculated based on depth-damage curves established by the USACE. These curves estimate the damage to the structure based on the depth of the water above the finished floor elevation and the assessed value of the structure. Content damage was estimated as a percentage of the structure value for residential and commercial property only. (Public property, infrastructure, industrial inventories and emergency operations costs were not included in the calculation of damages at the reconnaissance level.) If a 100-yr. flood passes through the same damage center with a flood damage reduction measure (such as a levee built to the 500-yr. flood elevation) in place, the water surface elevation in the protected area is lowered and the corresponding flood damages are reduced due to the presence of the measure (the levee). The benefits are therefore the difference in the damages sustained without the levee and the damages sustained with the levee.

The USACE used hydrology and hydraulic models (HEC-HMS and HEC-RAS) to predict flood peak flows and associated elevations and used flood damage models (HEC-FDA and HEC-FIA) to estimate flood damages for floods predicted during a 50-yr. period in each damage center. Flood likelihood was based on the probability that a flood of any given magnitude could occur in any year during the 50-yr. planning period. The damages associated with the predicted flood elevations for each year, with and without flood damage reduction alternatives, were summed up over the 50-yr. planning period, factored to present values and then annualized to determine the average annual flood damage reduction benefit for a given alternative. Flood damages for these analyses were limited to the degree of damage to private structures, commercial inventory, personal property, and automobiles. A much more thorough assessment of all of the flood damages, including public property, infrastructure, industrial inventories, and emergency operations costs, would be considered in a Feasibility Level Study to determine if the annual benefits due to a given flood reduction measure are greater than the annual costs.

7.3 Decision Model

Four of the decision subcriteria—capital expense, O&M expense, protection of cultural resources, and annual flood reduction benefits—are dependent on damage center specific information. For example, capital expense and O&M expense are dependent upon an alternative's specific dimensions and site conditions. Similarly, annual flood damage reduction benefits vary by location and implementation and cultural resources may not be present at the damage center.

The remaining decision subcriteria used to evaluate each selected alternative are qualitative in nature. Rather than using a numerical value to establish the alternative rating for a given subcriterion, categories were established for each subcriterion. As an example, the Water Quality subcriterion was broken down into water quality improvement, no impact on water quality, slight negative impact on water quality, temporary negative impact on water quality, and permanent impact on water quality categories. Each of these categories was assigned ratings. Alternatives were placed into the category which most closely applied. Appendix 7.C summarizes the categories and identifies which alternatives fit in each category. Ratings were developed by the UFPP Program Management Team and reviewed with members of the Advisory Committee for each category. Note that for each category, the category that produces the best outcome (i.e., shortest schedule, least cost, certain funding, etc.) received a rating of 1, while categories that produce less favorable outcomes receive ratings less than 1. The graphs in Appendix 7.C summarize the variation in the qualitative rating for each category. Note that the variation of ratings between categories is not linear. Steeper variations in ratings between categories indicate a large difference between categories, while more horizontal variation in ratings indicates less difference between categories. Table 7.1 shows the final weights for the subcriteria and ratings for each alternative for each subcriterion.

Table 7.1: Qualitative Subcriteria Ratings for Each Alternative.

Decision Model Criteria and Weights				Alternatives: Flood Control				
Primary Criteria	Primary Criteria Weight	Subcriteria	Subcriteria Weight	Reservoir	Off Channel Storage	Diversion	Bridge Improvement	Channel Modification
Schedule	9.2%	Property Acquisition Schedule	2.5%	0.10	0.10	0.10	0.60	1.00
		Design Schedule	1.8%	0.10	0.60	0.10	0.60	0.60
		Permitting Schedule	2.3%	0.20	0.20	0.20	0.20	0.20
		Construction Schedule	2.5%	0.20	0.40	0.20	0.40	0.60
Economic Consideration	22.5%	Capital Expense	6.9%	Varies by Damage Center				
		O&M Expense	2.6%	Varies by Damage Center				
		Funding Potential	13.0%	0.15	0.15	0.15	0.15	0.15
Social Consideration	16.2%	Recreational Potential	0.8%	0.10	0.75	1.00	0.10	0.10
		Community Disturbance	1.9%	0.25	0.25	0.10	0.70	0.70
		Protection of Critical Services	6.7%	0.95	0.85	0.75	0.75	0.75
		Improvement to Emergency Response	6.7%	0.60	0.60	0.60	0.60	0.60
Environmental Impacts	17.3%	Habitat Impacts	4.9%	0.50	1.00	0.20	0.50	0.10
		Water Quality Impacts	6.6%	0.20	0.20	0.20	0.20	0.20
		Air Impacts	2.0%	0.20	0.20	0.20	0.20	0.20
		Protection of Cultural Resources	3.7%	Varies by Damage Center				
Flood Damage Reduction Benefits	34.9%	Public Safety / Risk Reduction	19.8%	0.60	0.60	0.60	0.60	0.60
		Annual Flood Damage Reduction Benefits	11.6%	Varies by Damage Center				
		Disruption of Commerce	3.5%	0.10	0.25	0.10	0.25	0.85

Table 7.1 (Continued): Qualitative Subcriteria Ratings for Each Alternative.

Decision Model Criteria and Weights				Alternatives (Con't.)					
				Flood Protection	Flood Mitigation				
Primary Criteria	Primary Criteria Weight	Subcriteria	Subcriteria Weight	Levee/ Floodwall	Elevation/ Floodproofing	Acquisition / Buyout	Flood Warning/ Preparedness	Land Use Regulations	Stream Debris Removal
Schedule	9.2%	Property Acquisition Schedule	2.5%	0.10	1.00	0.90	0.90	1.00	1.00
		Design Schedule	1.8%	0.10	0.90	0.90	0.90	1.00	1.00
		Permitting Schedule	2.3%	0.20	0.75	0.75	1.00	1.00	0.75
		Construction Schedule	2.5%	0.20	0.80	0.80	0.80	1.00	0.80
Economic Consideration	22.5%	Capital Expense	6.9%	Varies by Damage Center					
		O&M Expense	2.6%	Varies by Damage Center					
		Funding Potential	13.0%	0.15	0.50	0.90	1.00	1.00	0.50
Social Consideration	16.2%	Recreational Potential	0.8%	0.75	0.10	1.00	0.10	0.10	0.10
		Community Disturbance	1.9%	0.10	1.00	0.90	1.00	1.00	1.00
		Protection of Critical Services	6.7%	0.95	0.30	0.00	0.50	0.00	0.00
		Improvement to Emergency Response	6.7%	0.80	0.30	1.00	0.80	0.30	0.60
Environmental Impacts	17.3%	Habitat Impacts	4.9%	0.10	0.85	1.00	1.00	1.00	0.20
		Water Quality Impacts	6.6%	0.20	0.85	1.00	1.00	1.00	0.20
		Air Impacts	2.0%	0.20	0.85	1.00	1.00	1.00	0.20
		Protection of Cultural Resources	3.7%	Varies by Damage Center					
Flood Damage Reduction Benefits	34.9%	Public Safety / Risk Reduction	19.8%	0.80	0.30	1.00	0.90	0.60	0.60
		Annual Flood Damage Reduction Benefits	11.6%	Varies by Damage Center					
		Disruption of Commerce	3.5%	0.80	0.85	0.10	0.85	0.85	0.85

In a manner similar to the qualitative rating, the four quantitative subcriteria were placed into categories based on the calculated value of each subcritrion. Table 7.2 displays the numerical ranges for each category and the associated values of each rating for these four subcriteria.

Table 7.2: Quantitative Subcriteria Rating Scales.

Capital Expense		Annual Flood Reduction Benefits	
None ($0)	1.00	Exceptional (>$350K)	1.00
Slight (<$100K)	0.92	Very Large ($250K-$350K)	0.92
Moderate (($100K to $1 MM)	0.85	Large ($150K-$250K)	0.85
Large ($1 MM to $10 MM)	0.70	Moderate ($50K-$100K)	0.70
Very Large ($10 MM to $50 MM)	0.20	Slight (<$50K)	0.10
Exceptionally Large (>$50 MM)	0.10		
Annual O&M Expense		**Protection of Cultural Resources**	
None ($0)	1.00	Protection/Control	0.90
Slight (<$10K)	0.92	Mitigation	0.60
Moderate (($10K to $100K)	0.85	Warning	0.30
Large ($100K to $250K)	0.70		
Very Large ($250K to $500K)	0.20	No Cultural Resource	0.50
Exceptionally Large (>$500K)	0.10		

7.4 Alternative Evaluation

Each selected alternative was entered into Criterium Decision Plus (CDP) software for analysis for each damage center. The alternative evaluation model was constructed using the criteria weights discussed in Section 3, the alternatives ratings from Table 7.1, and the numerical ranges for each category from Table 7.2. To illustrate the resulting damage center flood reduction alternatives evaluation methodology, the following example is provided for a fictional damage center.

Example Scenario – Fictional Damage Center A has three alternatives for consideration: Levee, Channel Modification, and Floodproofing.

Table 7.1 provides the qualitative ratings for 14 of the 18 subcriteria for the three alternatives. Ratings from the remaining four subcriteria vary depending on the specifics of the particular alternative. Table 7.2 provides the numerical ranges for the quantitative subcriteria and the associated ratings. Table 7.3 illustrates the quantitative ratings for each alternative in the fictional Damage Center A. In this case, it was assumed that a culture resource was present in the damage center.

Table 7.3: Quantitative Ratings for the Alternatives for Damage Center A

	Capital Expense		O&M Expense		Annual Flood Reduction Benefits		Protection of Cultural Resources	
Alternative	Estimated Opinion of Construction Cost	Rating	Estimated Opinion of Annual O&M Cost	Rating	Calculated Annual Benefits	Rating	Present in Damage Center?	Rating
Levee	$25M	0.20	$190K	0.70	$300K	0.92	Yes	0.90
Channel Modification	$3M	0.70	$50K	0.85	$35K	0.10		0.90
Floodproofing	$0.75M	0.85	$12K	0.85	$160K	0.85		0.60

These ratings were entered into the CDP program which analyzed each alternative on the 18 subcriteria. Figure 7.6 is a graphical representation of CDP's decision model. With the end goal of flood damage reduction, the highest rated alternative of those considered is derived from a composite rating of all evaluation criteria. The subcriteria further break down the five primary criteria, and each alternative is evaluated individually against the subcriteria.

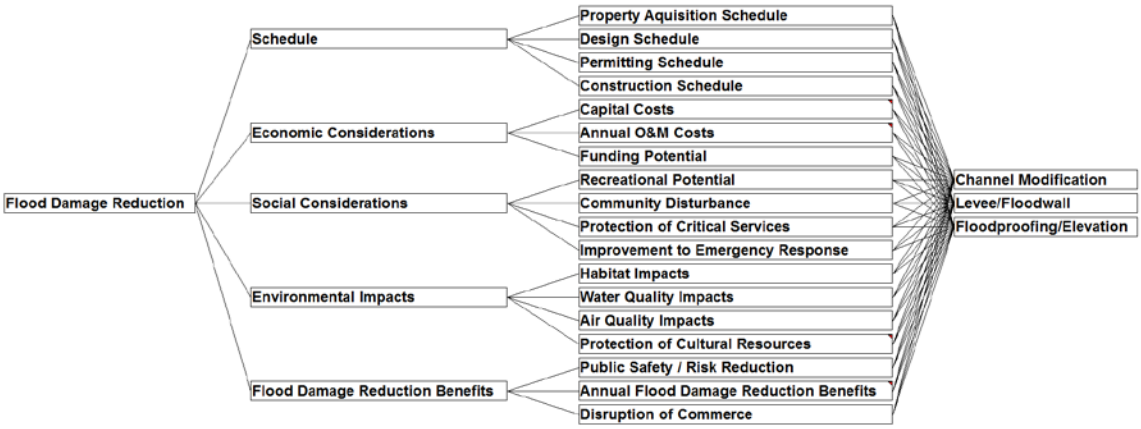


Figure 7.6: Relationship between five primary decision criteria, subcriteria, and flood damage reduction alternatives for Damage Center A

The calculations behind the decision model are quite simple. Each criteria weight is multiplied by the alternative rating. For example, to calculate the results for the alternative of floodproofing in the subcriterion of permitting schedule: $0.75 * 0.023 = 0.017$. This simple multiplication is done for every alternative with every subcriterion. The same calculation is repeated for each line on Figure 7.6 that connects a subcriterion with an alternative. The results of each calculation are summed for the decision criteria to provide a final, cumulative rating for each alternative. Figure 7.7 is an excerpt from Table 7.1 that illustrates how the calculations were made.

				Alternatives				
				Flood Mitigation				
Criteria	Criteria Weight	Sub Criteria	Sub-Criteria Weight	Elevation/ Floodproofing	Acquisition/ Buyout	Flood Warning/ Preparedness	Land Use Regulations	Stream Debris Removal
Schedule	9.2%	Property Acquisition Schedule	2.5%	1.00	0.90	0.90	1.00	1.00
		Design Schedule	1.8%	0.90	0.90	0.90	1.00	1.00
		Permitting Schedule	2.3%	0.75	0.75	1.00	1.00	0.75
		Construction Schedule	2.5%	0.80	0.80	0.80	1.00	0.80

Figure 7.7: Excerpt from Table 7.1

It is worth noting that if there is a perfect alternative, it would receive ratings of 1.00 for each subcriterion. Its overall rating would be a perfect 1.00 by receiving a 0.092 for Schedule, 0.225 for Economic Considerations, 0.162 for Social Considerations, 0.173 for Environmental Impacts, and a 0.349 for Flood Damage Reduction Benefits. Every alternative that is less than perfect receives a total rating that is less than 1.00. Figure 7.8 shows the results for fictional Damage Center A in a bar chart form.

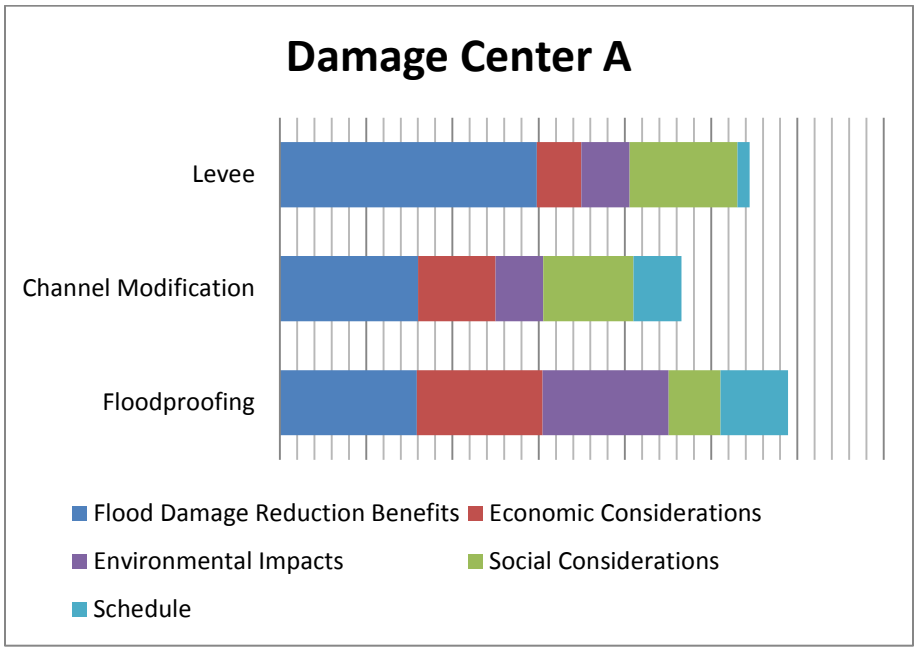


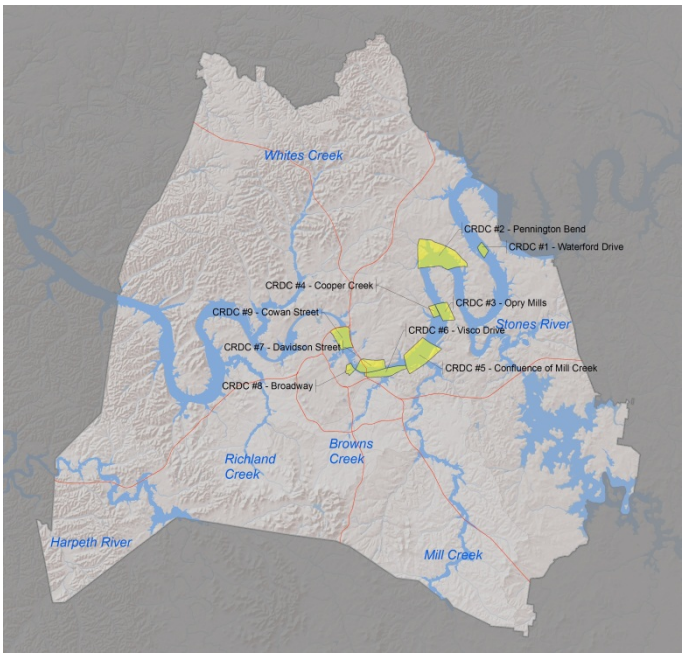
Figure 7.8: Example Decision Output for Hypothetical Damage Center

To better understand the performance of each alternative, the bars on the chart of the results are broken into five different parts, each representing one of the primary decision criterion. This breakdown gives an insight into where an alternative was rated high and where it was not. The levee, for example, rated high in Flood Damage Reduction Benefits and Social Considerations. However, it rated so poorly in the other three primary decision criteria that its overall rating was lower than that of the floodproofing alternative. Channel modification did not rate high in any category which caused it to rate lower than the other alternatives. Floodproofing was the highest rated alternative in the fictitious Damage Center A because it did very well in all categories except Social Considerations.

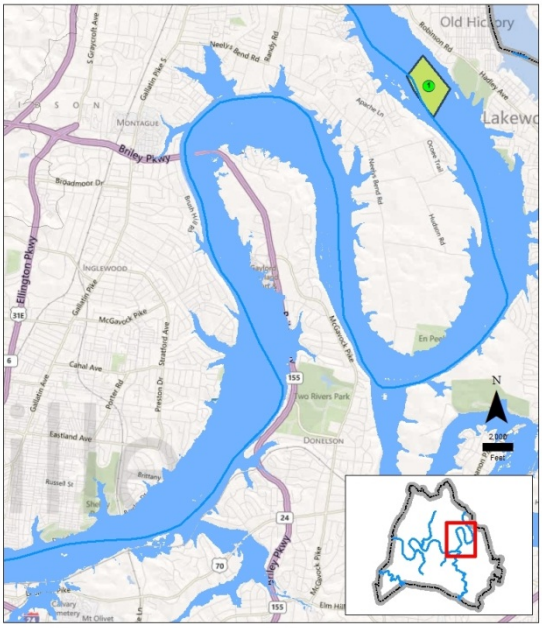
8.0 Findings

8.1 Cumberland River

Using the methodology outlined in Section 4 of this report, nine damage centers were identified along both the right and left banks (looking downstream) of the Cumberland River, from the east end of the County (Old Hickory Lake) to west of downtown Nashville. Being the largest river in the region and the only regulated stream included in the study area, the Cumberland River was unique in a few respects from the other streams assessed in the UFPP. Firstly, the USACE has developed flood control on the Cumberland River with a series of flood control dams and reservoirs upstream of Nashville (Wolf Creek, Dale Hollow, Center Hill, and J. Percy Priest). Additional reservoir sites are not feasible on the Cumberland River. A review of the FEMA flood profiles along the Cumberland River found no measureable losses at any of the bridge crossings; therefore, no benefit would be derived from modifying any bridges over the Cumberland River. In addition, due to the flow rates in the river, there are no potential off-channel storage sites or potential diversion sites along the Cumberland River. Finally, since the river flows in a deep, well-defined channel, and because of its high flow rates, Cumberland River channel modification would not have a measurable reduction in flood stage anywhere in the study area.



8.1.1 Cumberland River Damage Center 1 – Waterford Subdivision



Cumberland River damage center Number 1 is located in the eastern end of Davidson County along the left (looking downstream) bank of the Cumberland River in what is known as the Waterford Subdivision. Figure 1 in Appendix 8.A illustrates the extent of the damage center. Waterford is located off Merritt St., west of Hadley Blvd. /Robinson Rd. (SR-45 or Old Hickory Blvd) in Old Hickory, Tennessee. The neighborhood is a relatively new development (early 1990s), with approximately 250 one- and two-story single family homes covering approximately 70 acres. Homes feature crawl space construction with a combination of brick and vinyl fascia. The homes were built to Metro's current code requirement of the first floor finished elevation at four feet above the base flood elevation. Photos of typical construction in the neighborhood can be found in Appendix 8.A.

The Waterford development lies entirely within the 100-yr. floodplain. During the May 2010 flood, the entire neighborhood was inundated. Figure 2 in Appendix 8.A illustrates the extent of the floodwaters within the damage center during the May, 2010 flood. Video taken during the flood (http://www.youtube.com/watch?v=YMdI1Y9TtXc) showed floodwaters over the first floor of homes, and access to the neighborhood along Merritt St. was cut off by flood waters. Damage assessments conducted by Metro Codes, summarized on Figure 1 in Appendix 8.A, indicated 22 properties incurred moderate damage (damage level 3) and 2 properties sustained major damage (damage level 4). The post-flood residential damage assessment conducted by Metro Water Services indicated that every home in the development was impacted. Two homes sustained damages estimated between 40% and 50% of the structures value; the balance of homes incurred damages estimated at less than 40% of the structures value.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Cumberland River Damage Center 1, and a summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.A.

The following alternatives were selected for consideration and were carried forward for further evaluation.

- Flood Warning/Preparedness – Due to the single point of egress from Waterford, flood warning is critical to prevent citizens from becoming trapped in rising floodwaters. Flood warning is highly beneficial for public safety as it provided flood forecast and flood

inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

- Land Use Regulations – The homes in the Waterford Subdivision were built in compliance with Metro's building code for first floor elevation at least four foot above the base flood elevation. This is a conservative code requirement compared to many other municipalities who only require first floor elevation one foot above the base flood elevation. Metro's code requirement resulted in property damage much less than what could have been realized. While nothing can be done to impact the Waterford subdivision directly, developing the property adjacent to Waterford in a manner that reduces flood risk would be a beneficial consideration.

Figure 3 in Appendix 8.A identifies the location of the specific parcels that could benefit from the selected alternatives. Cost opinions for the selected alternatives are summarized in Appendix 8.A.

Comparison of Alternatives

Figure 8.1 summarizes the comparison of the selected alternatives for Cumberland River Damage Center 1. After analysis, Flood Warning/Preparedness was the highest rated alternative for this damage center. However, Land Use Regulations did have a higher rating than Flood Warning/Preparedness in three of the five primary criteria: Schedule, Economic Considerations, and Environmental Impacts. Flood Warning/Preparedness excelled in Social Considerations and Flood Damage Reduction Benefits which caused the alternative to be rated higher than Land Use Regulations.

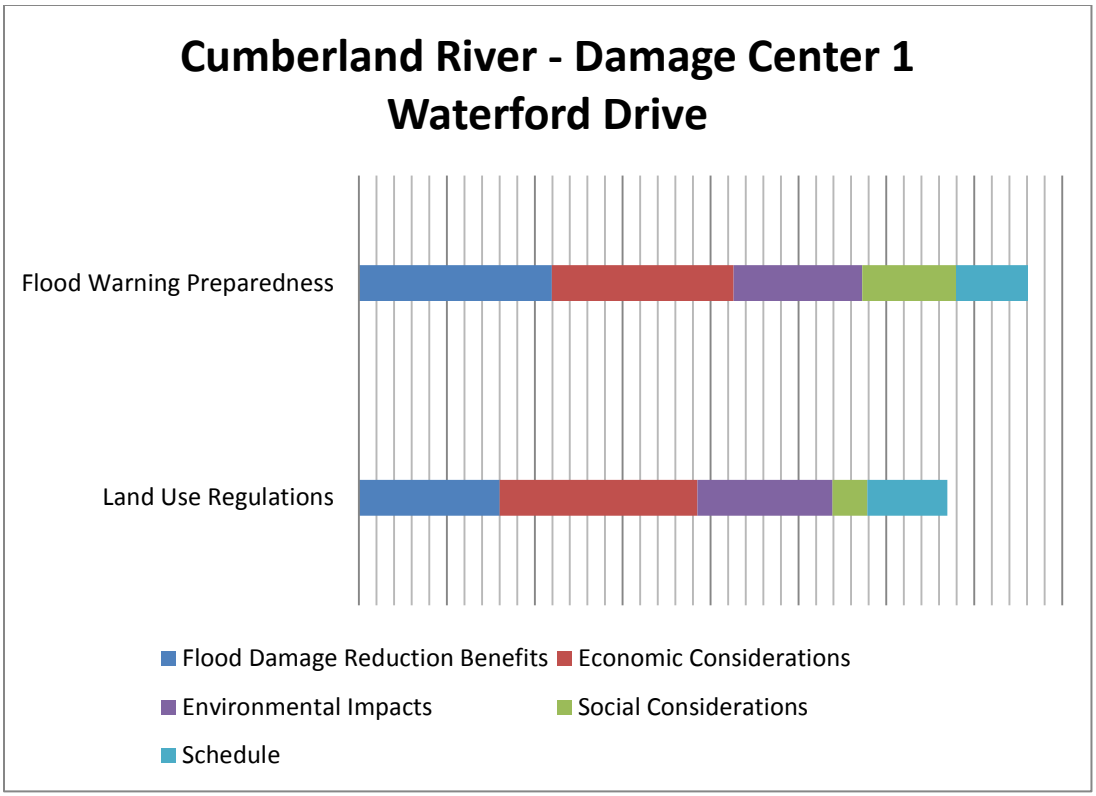


Figure 8.1: Comparison of the Selected Alternatives for Cumberland River Damage Center 1.

Table 8.1 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.1: Evaluation Summary Cumberland River Damage Center 1.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Land Use Regulations	Better	None	100 year	Average	Local	N/A	N/A	N/A	N/A

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

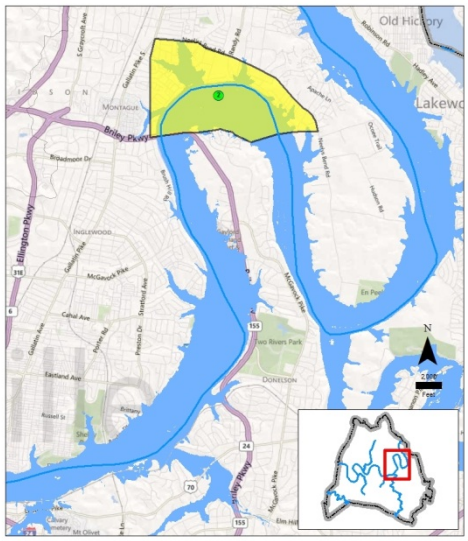
[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.1.2 Cumberland River Damage Center 2 – Pennington Bend

Cumberland River Damage Center 2 is located in the eastern part of Davidson County near the confluence of the Cumberland River and Gibson Creek. Figure 1 in Appendix 8.B illustrates the extent of the damage center. The damage center covers both banks of the river and is roughly located between Briley Parkway and Neelys Bend Road, East of Gallatin Blvd. The damage center is primarily residential. The north side of the river (right bank looking downstream) is made up of smaller, older, single family homes, while the developments along the south side of the damage center (left bank looking downstream) is mostly a newer development. Photos of typical construction in the neighborhoods can be found in Appendix 8.B.



The damage center contains a number of homes built within the 100-yr. floodplain, especially on the left bank of the river. Figure 2 in Appendix 8.B illustrates the extent of the floodwaters within the damage center during the May, 2010 flood. During the May 2010 flood, waters rose several feet or more above finished floor elevations in homes on the left bank, especially in homes immediately adjacent to the river. On the right bank, flooding was also severe, with damage concentrated in the Gibson Creek and Neely's Branch floodplain and along the main stem of the river at low-lying areas along Burwick Trail. Video taken during the flood on the left bank (http://www.youtube.com/watch?v=I6qWmEm9JXc) showed floodwaters over the first floor of homes and vehicles partially submerged. Damage assessments conducted by Metro Codes, summarized on Figure 1 in Appendix 8.A, indicated 130 properties incurred moderate damage and 262 properties received major damage. The post-flood residential damage assessment conducted by Metro Water Services indicated 394 homes sustained damages estimated at 40% or less of the structure value, while 42 homes sustained damage estimated between 40% and 50% of the structure value, and 84 homes sustained damage that was estimated greater than 50% of the structure value.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Cumberland River Damage Center 2, and a summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.B.

After consideration of the available alternatives with regards to site specific conditions, the following alternatives were selected and carried forward for further evaluation:

- Floodproofing/Elevation – Several properties were considered for home elevation.

- Acquisition/Buyout – A number of the properties in the damage center were considered for home buyout.

- Flood Warning/Preparedness – Due to the single point of egress from Pennington Bend, flood warning is critical to prevent citizens from becoming trapped in rising floodwaters. Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

- Land Use Regulations – While nothing can be done to impact the existing homes in the damage center directly, future development of the property on the right bank in a manner that reduces flood risk would be beneficial.

Figure 3 in Appendix 8.B identifies the location of the specific parcels that were considered in the evaluation of alternatives. Cost opinions for the selected alternatives are summarized in Appendix 8.B.

Comparison of Alternatives

Figure 8.2 summarizes the comparison of the selected alternatives for Cumberland River Damage Center 2. The rating of alternatives for this damage center was, in order from highest to lowest: Flood Warning/Preparedness, Acquisition/Buyout, Land Use Regulations, and Floodproofing/Elevation. Flood Warning/Preparedness was set apart by having the highest rating in Flood Damage Reduction Benefits and Social Considerations. Acquisition Buyout only tied for the highest rated alternative in Environmental Impacts. It did rate strongly in every other category which positioned the alternative to be the next highest rated solution. Floodproofing/Elevation did not do exceptionally poor or exceptionally well in any category which resulted in the alternative being the lowest rated for this damage center.

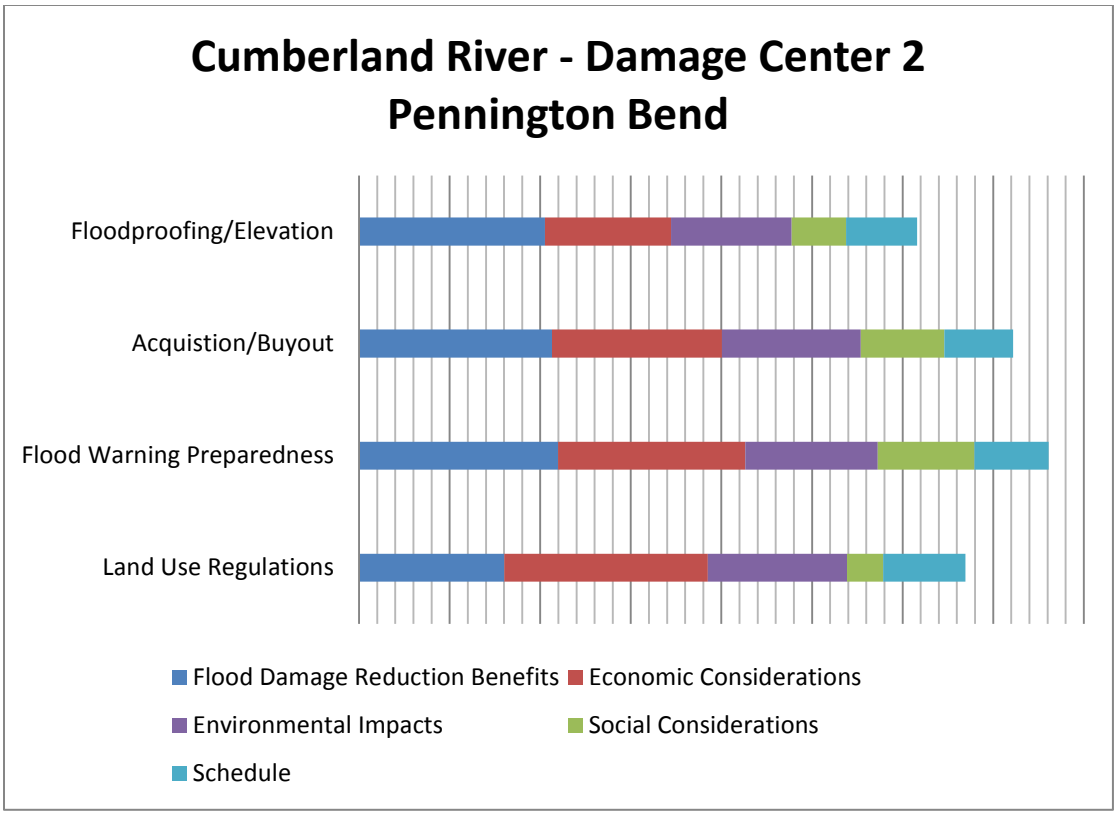


Figure 8.2: Comparison of the Viable Alternatives for Cumberland River Damage Center 2.

Table 8.2 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.2: Evaluation Summary Cumberland River Damage Center 2.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Floodproofing/ Elevation	Good	Minimal	100 year	Average	Private	$4,137,600	$192,600	N/A	$192,600
Acquisition/ Buyout	Better	Significant	500 year	Very High	Local/ Federal	$9,919,700	$461,800	$27,600	$489,300
Land Use Regulations	Better	None	100 year	Average	Local	N/A	N/A	N/A	N/A

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

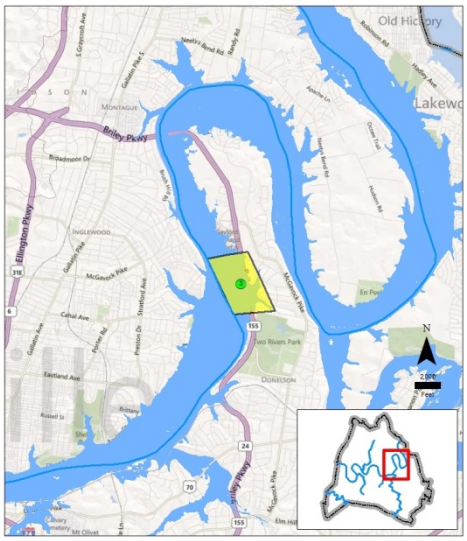
[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.1.3 Cumberland River Damage Center 3 – Opry Mills



Cumberland River Damage Center 3 is located in the Donnelson community along the left bank (looking downstream) of the Cumberland River. Figure 1 in Appendix 8.C illustrates the extent of the damage center. This damage center includes the Grand Ole Opry and Opry Mills Mall which encompasses all of the property in the damage center between the Cumberland River to the east and Briley Parkway to the west. The remaining portion of the damage center east of Briley Parkway and west of McGavock Pike is a residential community made up of single family brick homes on large (approx. 1 acre) lots. Damage in this residential area was concentrated roughly along Cabin Hill Road, where floodwaters accumulated in a natural low area along an unnamed stream. Photos of typical home construction in the neighborhood can be found in Appendix 8.C.

During the May 2010 Flood, Opry Mills Mall and several of the residences along Cabin Hill Road were inundated. Figure 2 in Appendix 8.C illustrates the extent of the floodwaters within the damage center during the May 2010 flood. With the exception of the Opryhouse and Roy Acuff Theatre, the entire Opry Mills development was classified by Metro Codes as moderately damaged, as were three of the properties on Cabin Hill Road. Damages to the Opryland Resort were estimated at $200 million. The hotel was closed for six months as repairs were made. The Opry Mills Mall also received over $100 million in damages and was closed for nearly two years. One of the properties on Cabin Hill Road sustained major damage. The post-flood residential damage assessment conducted by Metro Water Services indicated that eight of the residences on Cabin Hill Road were significantly damaged, with two structures sustaining damage that estimated between 40% and 50% of the structure's value; and one structure sustained damage that was estimated at more than 50% of its value. Figure 1 in Appendix 8.C summarizes the finding of the post-flood damage assessments.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Cumberland River Damage Center 3, and a summary of the alternatives screening assessment is located in the Alternatives Matrix in Appendix 8.C.

The following alternatives were selected and were carried forward for further evaluation:

- Levee/Floodwall – A combination levee and floodwall was evaluated to protect the Opryland Resort and Convention Center and the residential development along the left bank in Damage Center 3. The project was composed of two parts: the first part of the

project would be a new 3,800 ft. levee / floodwall system beginning at the southern end of the damage center and extending northward to the existing floodwall. The second part of the project would be an extension of the existing 100-yr. floodwall from roughly the General Jackson Riverboat dock north to end of the damage center.

- Floodproofing/Elevation – Single family homes on the right bank along Brittany and Barclay Drives, and single family homes along the left bank at Guaranty and Barker Roads, are candidates for Floodproofing. Duplexes and commercial developments could benefit from inventory management and utility elevation.

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

Figure 3 in Appendix 8.C identifies the location of the specific parcels that could benefit from floodproofing/elevation. Figure 4 in Appendix 8.C identifies the location for a proposed levee and floodwall system to protect the Opry Mills Mall and the residential property on the east side of Briley Parkway. Cost opinions for the selected alternatives are summarized in Appendix 8.C.

Comparison of Alternatives

Figure 8.3 summarizes the comparison of the selected alternatives for Cumberland River Damage Center 3. The highest rated alternative for this damage center was Flood Warning/Preparedness. Levee/Floodwall was the lowest rated alternative, leaving Floodproofing/Elevation in the middle of the three. Despite being rated slightly below Levee/Floodwall in Flood Damage Reduction Benefits and Social Considerations, Flood Warning/Preparedness excelled in all five of the primary criteria. Levee/Floodwall rated low in Economic Considerations, Environmental Impacts, and Schedule causing it to finish the lowest rated.

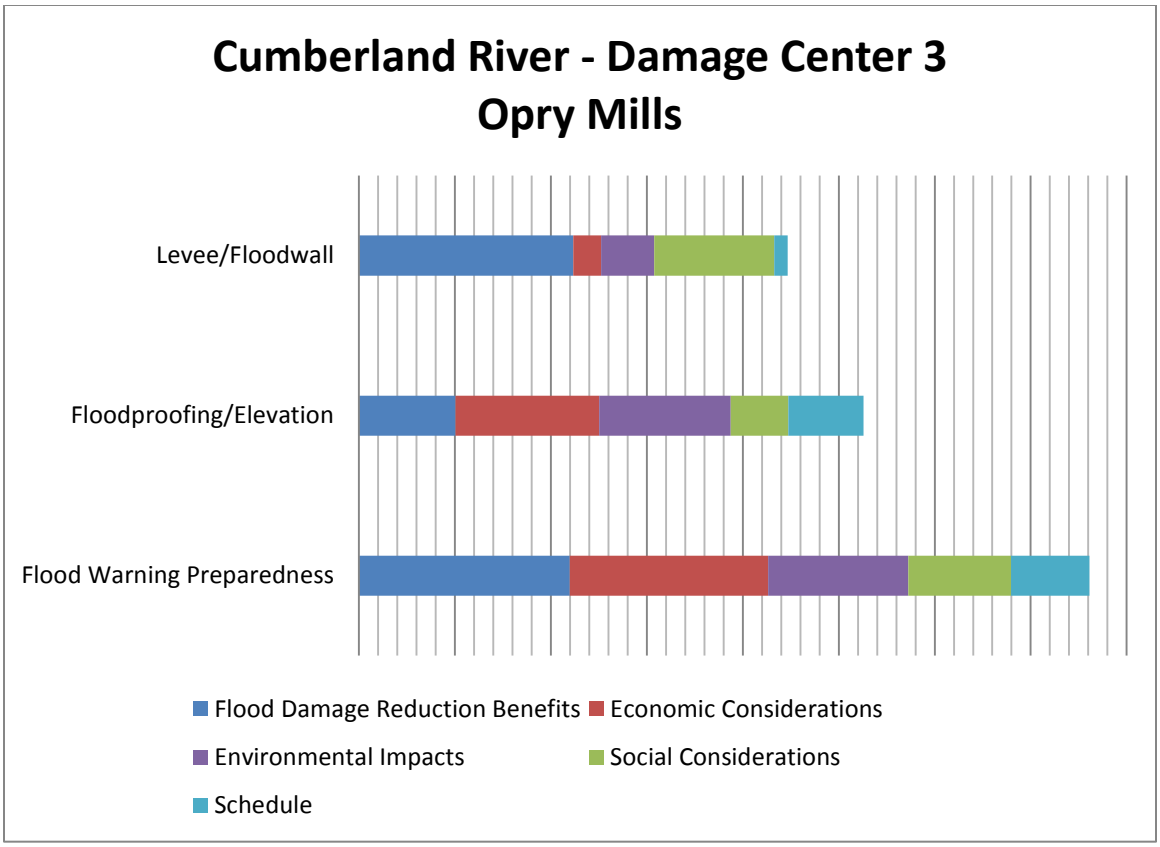


Figure 8.3: Comparison of the Viable Alternatives for Cumberland River Damage Center 3.

Table 8.3 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.3: Evaluation Summary Cumberland River Damage Center 3.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Floodproofing/ Elevation	Good	Minimal	100 year	Average	Private	$736,400	$34,300	N/A	$34,300
Levee/ Floodwall	Better	Significant	500 year	Very High	Federal	$50,418,800	$2,347,000	$939,800	$3,286,800

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

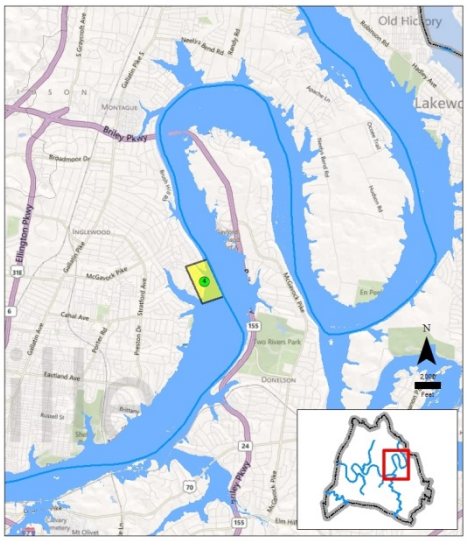
[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.1.4 Cumberland River Damage Center 4 – Cooper Creek

Cumberland River Damage Center Number 4 is located in the Donnelson community, along the right bank (looking downstream) of the Cumberland River near the confluence of Cooper Creek and the Cumberland River. Figure 1 in Appendix 8.D illustrates the extent of the damage center. The damage center is bounded roughly by Cooper Creek to the south, Shadow lane to the West, and the Cumberland River to the East. The Opryland Resort and Convention Center is directly across the Cumberland River to the east. The neighborhood is composed of older, one- and two-story single family homes and is 100 percent residential. Photos of typical construction in the neighborhood can be found in Appendix 8.D.



The damage center lies almost entirely within the 100-yr. floodplain. During the May 2010 flood, the entire neighborhood was inundated. Figure 2 in Appendix 8.D illustrates the extent of the floodwaters within the damage center during the May 2010 flood. Video taken from a canoe during the flood (http://www.youtube.com/watch?NR=1&v=qc0-iA3ueHE) shows floodwaters several feet over the first floor of homes, and cars completely submerged. Damage assessments conducted by Metro Codes, summarized on Figure 1 in Appendix 8.D, indicated 20 properties sustained moderate damage and 20 properties sustained major damage. The post-flood residential damage assessment conducted by Metro Water Services indicated that almost every home in the damage center was impacted. Eight homes had estimated damages more than 50% of the structure value and nine had estimated damages between 40% and 50% of the structure value. The balance of homes suffered damages estimated less than 40% of the structure value.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Cumberland River Damage Center 4, and a summary of alternative screening assessment is found in the Alternatives Matrix in Appendix 8.D.

The following alternatives were selected and were carried forward for further evaluation.

- Floodproofing/Elevation – Most of the residential structures within the damage center along Moss Rose Drive, Moss Rose Court, Morganmeade Drive, Morganmeade Court, and Cooper Terrace were considered for elevation. In addition, select homes on McGinnis Drive were considered for elevation. Homes that have been previously offered a buyout package by Metro but which have refused the offer were not considered candidates for elevation.

- Acquisition/Buyout – Seven homes along Moss Rose Drive were offered buyout packages due to extensive damage to the structure; four of the property owners refused the offer for buyout. These properties remain in consideration for acquisition. In addition, six properties on Goode Court have been offered buyout by Metro due to extensive damage to the structure.

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

Figure 3 in Appendix 8.D identifies the location of the specific parcels that could benefit from the selected alternatives. Cost opinions for the selected alternatives are summarized in Appendix 8.D.

Comparison of Alternatives

Figure 8.4 summarizes the comparison of the selected alternatives for Cumberland River Damage Center 4. The highest-rated alternative for this damage center was Flood Warning/Preparedness. Flood Warning/Preparedness was rated slightly higher than Acquisition/Buyout in all categories but Environmental Impacts, in which they were considered equal. Floodproofing/Elevation rated lower in each category, in this damage center, leaving it as the lowest rated alternative for this damage center.

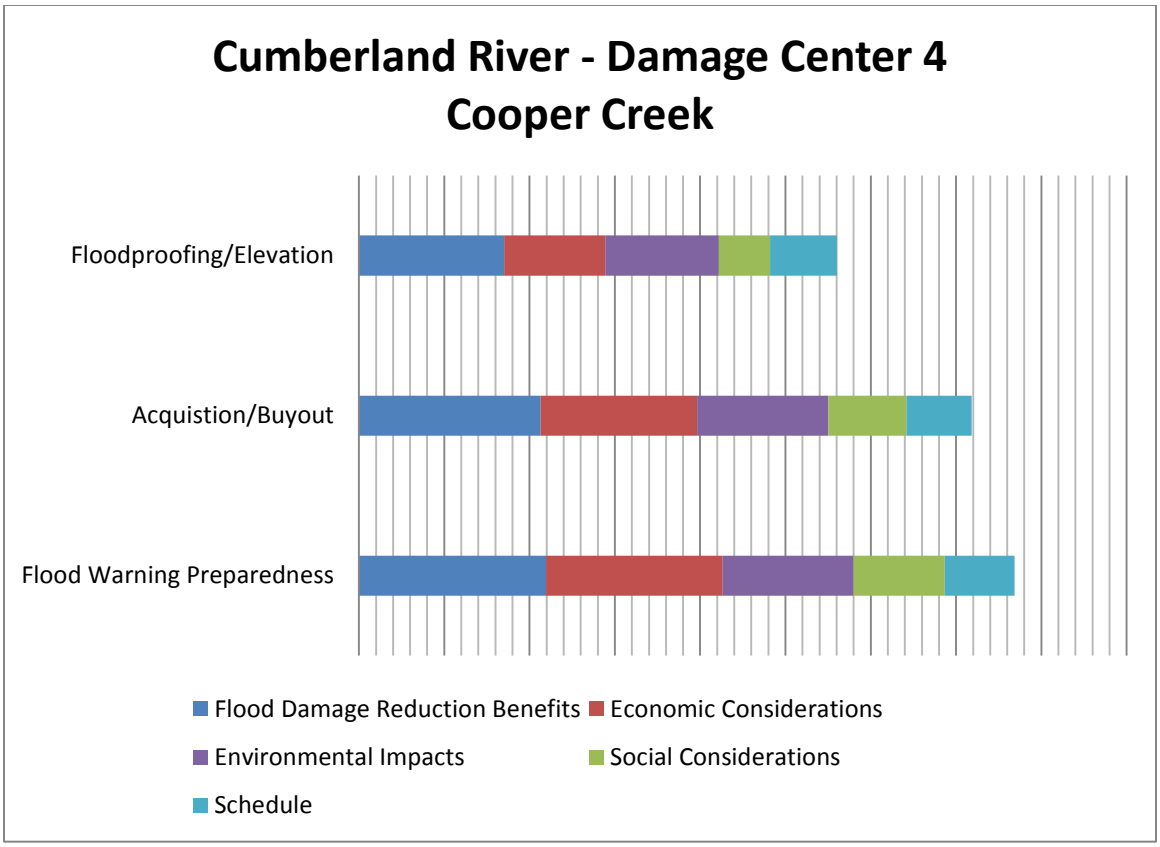


Figure 8.4: Comparison of the Viable Alternatives for Cumberland River Damage Center 4.

Table 8.4 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.4: Evaluation Summary Cumberland River Damage Center 4.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Floodproofing/ Elevation	Good	Minimal	100 year	Average	Private	$5,212,800	$242,700	N/A	$242,700
Acquisition/ Buyout	Best	Minimal	100 year	Average	Local/ Federal	$2,169,600	$101,000	$2,500	$103,500

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

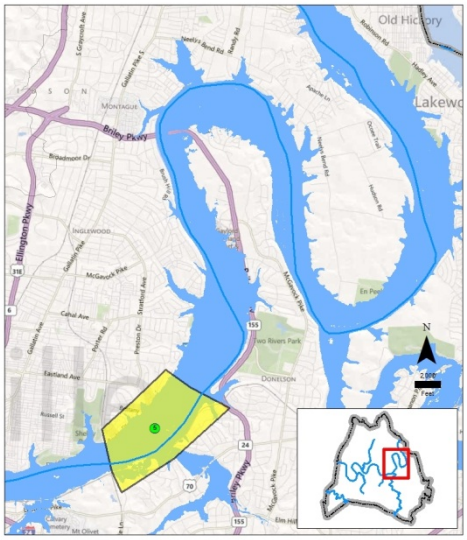
[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.1.5 Cumberland River Damage Center 5 – Confluence of Mill Creek

Cumberland River Damage Center 5 is located near the confluence of Mill Creek and the Cumberland River. Figure 1 in Appendix 8.E illustrates the extent of the damage center. The damage center occupies portions of the left bank (looking downstream), from the CSX railroad trestle in the southwest to Briley Parkway in the northeast. The area southwest of Mill Creek is primarily commercial and industrial, while the area northeast of Mill Creek is primarily residential with brick fascia, one- and two- story single family homes on relatively large (1/2 acre to 1 acre) lots.



The damage center extends to the right bank (looking downstream) of the Cumberland River bordering Shelby Bottoms Park in East Nashville. In this portion of the damage center, roughly defined by the CSX railroad to the southwest and Eastland Avenue to the northwest, the structures are similar to those found on the left bank, with single family brick homes on relatively large lots. One section of the development along Beth Drive, in the northeast corner of the damage center on the right bank, is slightly divergent in character. Along this street, a new development of single family multistory wood homes built on an elevated grade borders approximately 10 older multistory duplex units. Photos of typical construction in the damage center can be found in Appendix 8.E.

During the May 2010 Flood, several of the businesses and residences were inundated. Figure 2 in Appendix 8.E illustrates the extent of the floodwaters within the damage center during the May 2010 flood. In areas on the right and left bank that were within the 100-yr. floodplain and to a lesser extent the 500-yr. floodplain, damage was significant, with some structures incurring damage that estimated at more than 50% of the structure's value. Video taken during the flood (http://www.youtube.com/watch?v=nk68NEhjG0Q) showed flood waters along the lower elevations of Beth Drive (duplexes) rising more than 4 ft. above the first floor elevation, and cars either fully or partially submerged. Damage Assessments by Metro Codes found numerous structures incurred minor to major damage, while post-flood surveys conducted by Metro Water Services indicated 7 residential structures sustained damages estimated to be in excess of 50% of the structures' value. In addition, 15 structures incurred damages estimated to be between 40% and 50% of their value, while 36 structures incurred damages estimated to be less than 40% of the structures' value. Figure 1 in Appendix 8.E summarizes the finding of the post-flood damage assessments.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Cumberland River Damage Center 5, and a summary of

the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.E.

The following alternatives were selected and were carried forward for further evaluation:

- Levee/Floodwall – A combination levee and floodwall was proposed to protect the commercial and industrial development on the left bank (looking downstream) in Damage Center 5.

- Floodproofing/Elevation – Single family homes on the right bank along Brittany and Barclay Drives, and single family homes along the left bank at Guaranty and Barker Roads were considered for floodproofing. Duplexes and commercial developments could benefit from inventory management and utility elevation.

- Acquisition/Buyout – No homes on the left bank were considered for buyout; a number of the homes on the right bank were considered for buyout.

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

Figure 3 in Appendix 8.E identifies the location of the specific parcels that could benefit from floodproofing, including residential elevation, or acquisition. Figure 4 in Appendix 8.E identifies the location for a proposed levee and floodwall system to protect the commercial and industrial development in the southwest (left bank) section of the damage center. Cost opinions for the selected alternatives are summarized in Appendix 8.E.

Comparison of Alternatives

Figure 8.5 summarizes the comparison of the selected alternatives for Cumberland River Damage Center 5. This damage center's highest rated alternatives were, in order of highest to lowest: Flood Warning/Preparedness, Acquisition/Buyout, Floodproofing/Elevation, and Levee/Floodwall. Flood Warning/Preparedness rated higher than Acquisition/Buyout in all categories except Environmental Impacts, in which they rated the same. Levee/Floodwall rated lower in all categories except Social Considerations, making it the lowest rated alternative.

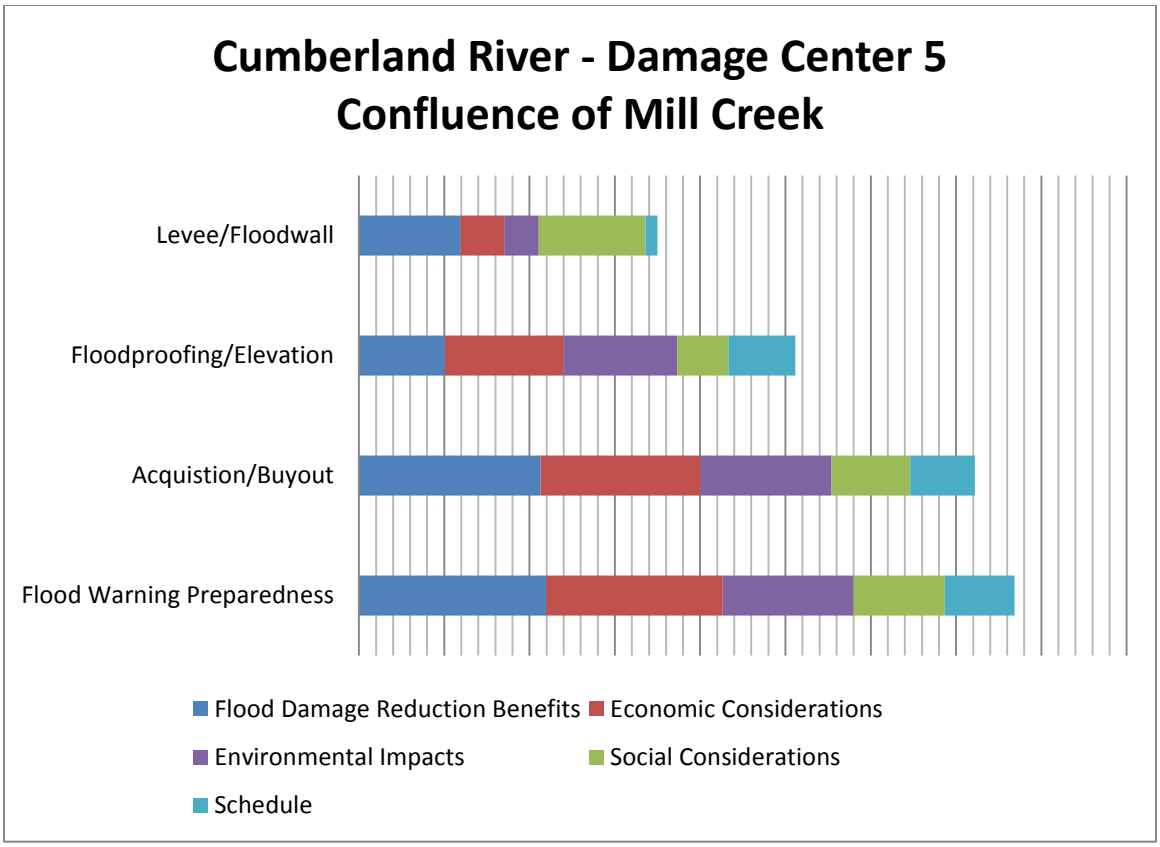


Figure 8.5: Comparison of the Viable Alternatives for Cumberland River Damage Center 5.

Table 8.5 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.5: Evaluation Summary Cumberland River Damage Center 5.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Floodproofing/ Elevation	Good	Minimal	100 year	Average	Private	$2,572,400	$119,700	N/A	$119,700
Levee/ Floodwall (South of River)	Better	Significant	500 year	Very High	Federal	$21,690,000	$1,009,700	$190,700	$1,200,300
Acquisition/ Buyout	Best	Minimal	100 year	Average	Local/ Federal	$5,939,200	$276,500	$11,000	$287,500

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.1.6 Cumberland River Damage Center 6 – Visco Drive

Cumberland River Damage Center 6 is located southeast of Downtown Nashville at the confluence of Browns Creek on the left bank (looking downstream) of the Cumberland River. Figure 1 in Appendix 8.F illustrates the extent of the damage center. The damage center extends from the CSX railroad trestle westward to the Interstate 24 Bridge over the Cumberland River. Lebanon Pike forms the southern boundary of the damage center. The area is comprised entirely of commercial and industrial properties. Photos of typical construction in the damage center can be found in Appendix 8.F.

During the May 2010 Flood, many of the businesses were inundated. Figure 2 in Appendix 8.F illustrates the extent of the floodwaters within the damage center during the May 2010 flood.

Damage Assessments by Metro Codes indicated that all of the structures in the damage center incurred major damage. Figure 1 in Appendix 8.F summarizes the finding of the post-flood damage assessment.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Cumberland River Damage Center 6, and a summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.F.

The following alternatives were selected and were carried forward for further evaluation:

- Levee/Floodwall – Because Browns Creek bisects the damage center, two levee / floodwall systems are required. The first system will encircle the western portion of the damage center by isolating the Cumberland River to the north and Browns Creek to the east before tying into the existing railroad near Lebanon Pike. This system will be 8,200 LF and range from 0 to 13 ft. above existing grade. The second system will encircle the eastern end of the damage center by isolating Browns Creek to the west and the Cumberland River to the north before tying into the existing railroad. This levee floodwall will be 9,400 Lf and range from 0 to 14 ft. above existing grade with 4 closure structures and 2 pump stations also required.

- Floodproofing/Elevation – Elevation of commercial and industrial structures was not considered selected; however, commercial and industrial properties could benefit from floodproofing.

- Acquisition/Buyout – Typically, commercial and industrial properties are not considered for buyout; however, given the cost of the structural controls for this damage center, buyout was considered.

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

Figure 3 in Appendix 8.F identifies the location of the specific parcels that could benefit from floodproofing or acquisition. Figure 4 in Appendix 8.F identifies the location for a proposed levee and floodwall system to protect the commercial and industrial properties in the damage center. Cost opinions for the selected alternatives are summarized in Appendix 8.F.

Comparison of Alternatives

Figure 8.6 summarizes the comparison of the selected alternatives for Cumberland River Damage Center 6. The highest rated alternative in this damage center was Flood Warning/Preparedness, followed by Floodproofing/Elevation. The least preferred alternative was Levee/Floodwall, despite its excellent scores in Flood Damage Reduction Benefits and Social Considerations. However, as has been previously discussed, all of the potential economic benefits were not included in the Reconnaissance Level evaluation. The inclusion of all the economic benefits could be considered in a Feasibility Level Study to determine if the annual benefits are greater than the annual costs. Flood Warning/Preparedness rated somewhat higher than Floodproofing/Elevation in all five of the primary criteria, making it the most preferred alternative.

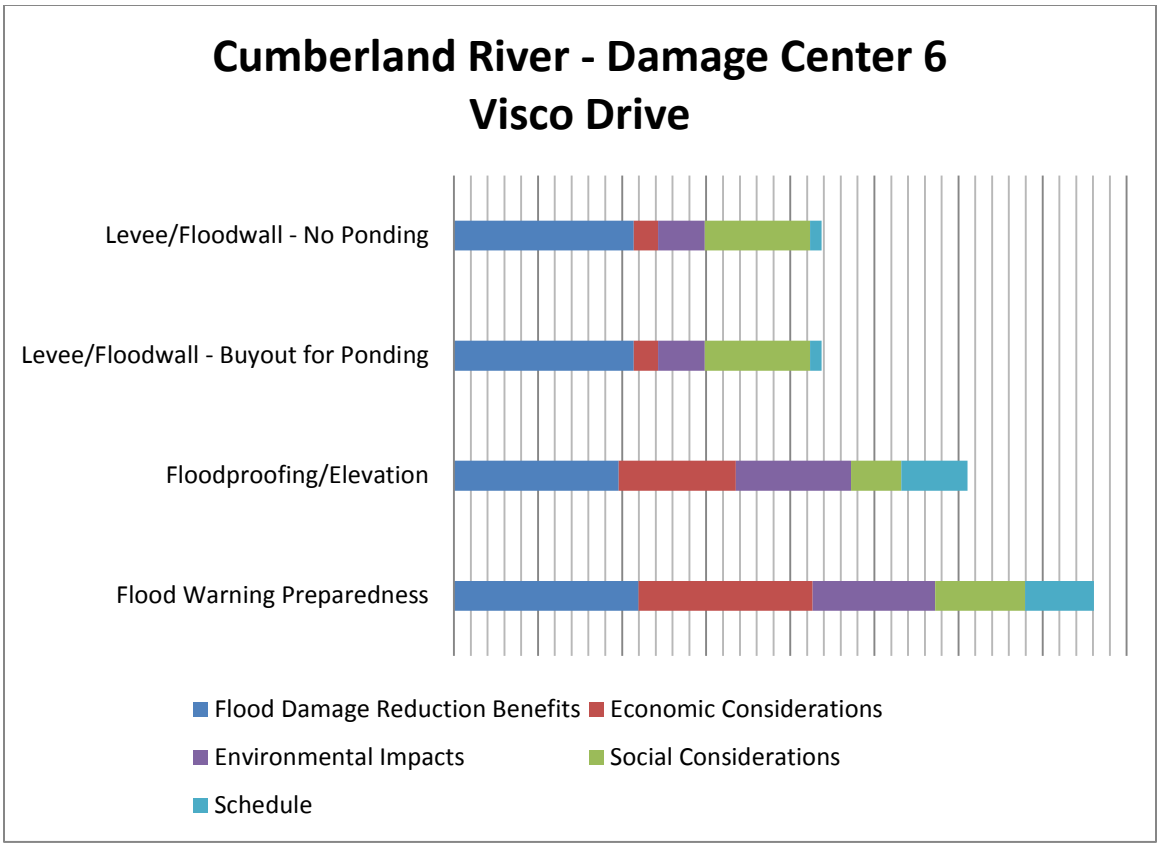


Figure 8.6: Comparison of the Viable Alternatives for Cumberland River Damage Center 6.

Table 8.6 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors.
As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.6: Evaluation Summary Cumberland River Damage Center 6.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Floodproofing/ Elevation	Good	Minimal	100 year	Average	Private	$2,845,500	$132,500	N/A	$132,500
Levee/ Floodwall (w/ buyout)	Better	Significant	500 year	Very High	Federal	$92,138,000	$4,289,100	$851,900	$5,141,000
Levee/ Floodwall (No buyout)	Better	Significant	500 year	Very High	Federal	$107,029,900	$4,982,300	$1,003,800	$5,986,100

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

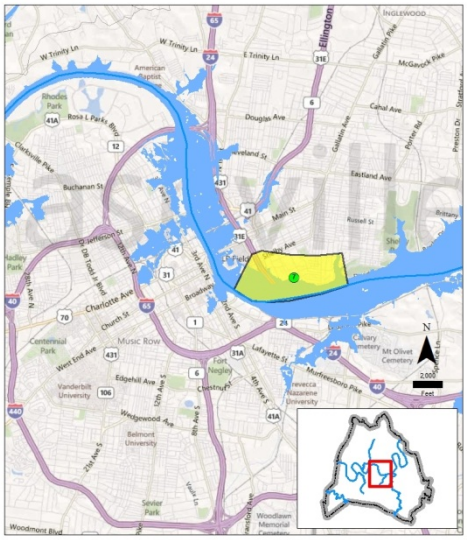
[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.1.7 Cumberland River Damage Center 7 – Davidson Street



Cumberland River Damage Center 7 is located southeast of Downtown Nashville at the confluence of Browns Creek on the right bank (looking downstream) of the Cumberland River. This damage center is across the Cumberland River from Damage Center 6. Figure 1 in Appendix 8.G illustrates the extent of the damage center. The damage center extends from Shelby Park in the east westward to the Korean Veterans Bridge over the Cumberland River. Shelby Avenue forms an approximate northern boundary of the damage center. The property between the river and Davidson Street is entirely commercial and industrial. The commercial/industrial development area extends northward in the vicinity of I-24 and in the pocket of land between I-24 and the Korean Veterans Bridge. The northeast end of the damage center in the vicinity of Shelby Park is entirely residential. Photos of typical construction in the damage center can be found in Appendix 8.G.

During the May 2010 Flood, many of the businesses were inundated. Perhaps the most prominent industry in downtown, PSC Metals, reported 6 ft. of standing water on their site. Figure 2 in Appendix 8.G illustrates the extent of the floodwaters within the damage center during the May 2010 flood.

Damage Assessments by Metro Codes indicated that all of the structures in the damage center incurred major damage. Figure 1 in Appendix 8.G summarizes the finding of the post-flood damage assessment.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Cumberland River Damage Center 7, and a summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.G.

The following alternatives were selected and were carried forward for further evaluation:

- Floodproofing/Elevation – Elevation of commercial and industrial structures was not considered; however, a number of residential properties in the eastern end of the damage center were considered for elevation. In addition, the commercial and industrial developments could benefit from floodproofing.

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time

allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

Figure 3 in Appendix 8.G identifies the location of the specific parcels that could benefit from floodproofing or acquisition. Cost opinions for the selected alternatives are summarized in Appendix 8.G.

Comparison of Alternatives

Figure 8.7 summarizes the comparison of the selected alternatives for Cumberland River Damage Center 7. Flood Warning/Preparedness was the highest rated alternative for this damage center. It rated slightly better than Floodproofing/Elevation in Economic Considerations, Flood Damage Reduction Benefits, and Social Considerations. Floodproofing/Elevation did not rate higher than Flood Warning/Preparedness in any of the five primary criteria.

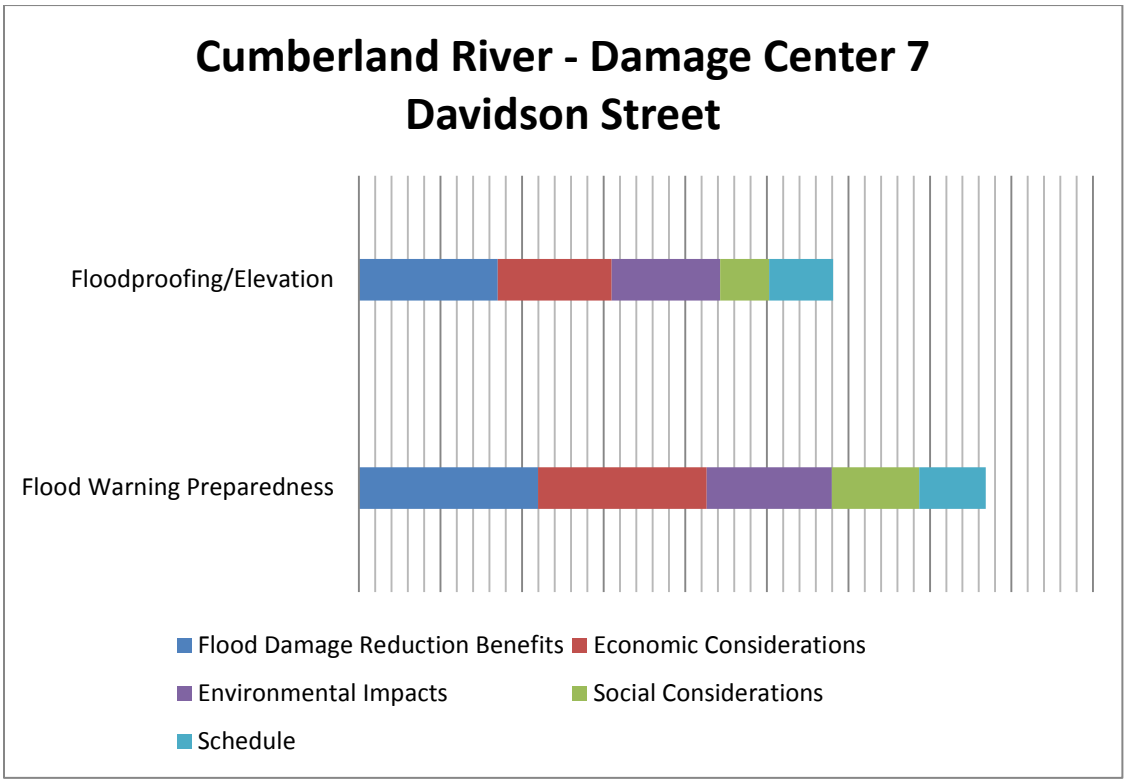


Figure 8.7: Comparison of the Viable Alternatives for Cumberland River Damage Center 7.

Table 8.7 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.7: Evaluation Summary Cumberland River Damage Center 7.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Floodproofing/ Elevation	Good	Minimal	100 year	Average	Private	$1,730,500	$80,600	N/A	$80,600

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

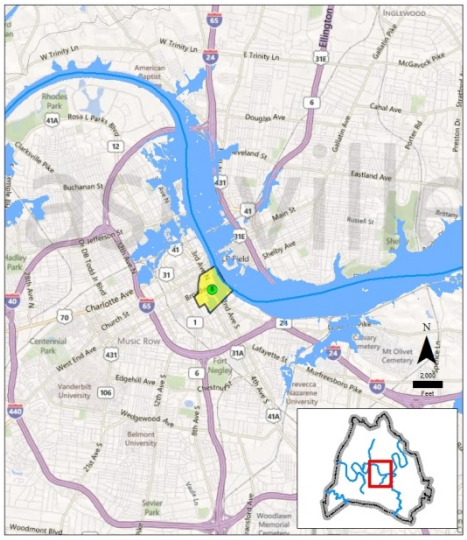
[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.1.8 Cumberland River Damage Center 8 – Broadway

Cumberland River Damage Center 8 is located in Downtown Nashville on the left bank (looking downstream) of the Cumberland River. Figure 1 in Appendix 8.H illustrates the extent of the damage center. The damage center extends along the Cumberland River roughly from the Korean Veterans Bridge northward to Church Street. The damage center extends westward along Broadway to the Bridgestone Arena. The area includes entirely commercial properties and contains a number of civic landmarks including the "Lower Broad" district, the Ryman Auditorium, the Country Music Hall of Fame, the Schermerhorn Symphony Center, and the Bridgestone Arena. Photos of typical construction in the damage center can be found in Appendix 8.H.



During the May 2010 Flood, many of the structures were inundated. Water filled subterranean utility tunnels submerging transformers and cutting off power for several blocks of the downtown business core. Floodwaters partially filled the basements of the Country Music Hall of Fame and the Schermerhorn Symphony Center, damaging artifacts and musical instruments. Parts of Lower Broad, including the Second Avenue tourist district, were flooded and without power. Bridgestone Arena took on water, mainly though subsurface percolation from floor drains, damaging locker rooms and television production facilities. Figure 2 in Appendix 8.H illustrates the extent of the floodwaters within the damage center during the May 2010 flood. Damage Assessments by Metro Codes indicated that many of the structures, especially those east of Third Avenue, incurred moderate damage. Figure 1 in Appendix 8.H summarizes the finding of the post-flood damage assessment.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Cumberland River Damage Center 8, and a summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.H.

The following alternatives were selected and were carried forward for further evaluation:

- Levee/Floodwall - A permanent levee and floodwall combined with a removable floodwall system was proposed to protect the commercial and industrial development on the left bank in Damage Center 8. The levee/floodwall will extend from the northern end of Riverfront Park, south to the Korean Veterans Bridge. A removable floodwall would extend from Riverfront Park to the Shelby Bridge (Half the levee system). The total length of this levee/floodwall system would be approximately 2,500 feet and would vary in height from 0 to 6 feet above existing grade. Two closure structures would be required at the Tennessee Central Railroad and the future Demonbreun Street extension. Storm sewer modifications, including a stormwater pump station, would be necessary behind the levee system to prevent accumulation of stormwater within the protected area. A cutoff wall would be constructed parallel to the levee from the bottom of the floodwall down to rock to limit river infiltration from the Cumberland River under the levee/floodwall.

- Floodproofing/Elevation – Elevation of commercial and industrial structures was not considered; however, all of the commercial properties in the damage center could benefit from floodproofing. Some floodproofing of commercial properties has been implemented since the May 2010 flood. For instance, the Schemerhorn installed emergency power to freight elevators and lifts for equipment transport, HVAC equipment was elevated, and a groundwater pumping system with a capacity of 20,000 gallons per minute was installed.

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

Figure 3 in Appendix 8.H identifies the location of the specific parcels that could benefit from commercial floodproofing. Figure 4 in Appendix 8.H identifies the location for a levee and floodwall system considered to protect the commercial and property in the damage center. Cost opinions for the selected alternatives are summarized in Appendix 8.H.

Comparison of Alternatives

Figure 8.8 summarizes the comparison of the selected alternatives for Cumberland River Damage Center 8. The highest rated alternative for this damage center was Flood Warning/Preparedness. It rated higher than Floodproofing/Elevation and Levee/Floodwall in all categories except Social Considerations. Levee/Floodwall rated highest in Social Considerations but lowest in all categories except Flood Damage Reduction Benefits. Therefore, Levee/Floodwall was the lowest rated. Floodproofing/Elevation did not score best in any category, leaving it as the second most preferred alternative.

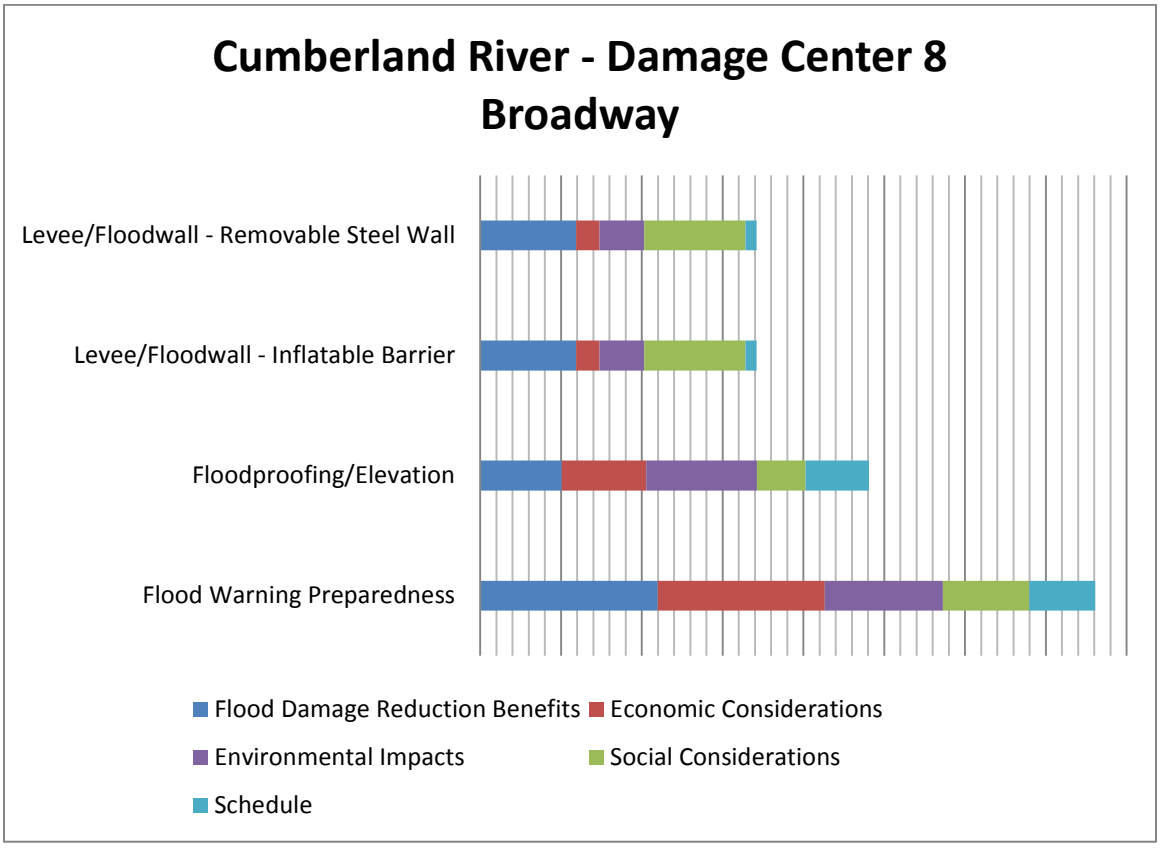


Figure 8.8: Comparison of the Viable Alternatives for Cumberland River Damage Center 8.

Table 8.8 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.8: Evaluation Summary Cumberland River Damage Center 8.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Floodproofing/ Elevation	Good	Minimal	100 year	Average	Private	$23,434,300	$1,090,900	N/A	$1,090,900
Levee/ Floodwall (Steel Wall)	Better	Significant	500 year	Very High	Federal	$87,134,100	$4,056,100	$834,400	$4,899,600
Levee/ Floodwall (Inflatable Wall)	Better	Significant	500 year	Very High	Federal	$82,818,900	$3,855,300	$795,100	$4,650,400

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.1.9 Cumberland River Damage Center 9 – Cowan Street

Cumberland River Damage Center 9 is located north of Downtown Nashville. Figure 1 in Appendix 8.I illustrates the extent of the damage center. The damage center is bounded by I-65 to the north, Second Avenue to the west, Jefferson Street to the south, and I-24 to the east. The Cumberland River runs through the middle of the damage center. The area includes entirely commercial and industrial properties. The most prominent structure along the left bank (looking downstream) of the damage center is the Central Wastewater Treatment Plant. Along the right bank, across the river from the wastewater treatment plant, is Soundchek LLC, a facility that houses musical equipment and touring gear for members of the music industry. Photos of typical construction in the damage center can be found in Appendix 8.I.

During the May 2010 Flood, many of the industries in the damage center were inundated. The Biosolids Facility at the wastewater treatment plant was inundated with approximately three feet of water in the entire facility. Significant damage to electrical and mechanical equipment in the facility caused it to be out of service for several months. Across the river to the east, Soundcheck LLC was inundated, damaging or destroying numerous vintage musical instruments, sound equipment, and touring gear. Figure 2 in Appendix 8.I illustrates the extent of the floodwaters within the damage center during the May 2010 flood.

Damage Assessments by Metro Codes indicated that all of the structures on the right bank of the damage center incurred major damage. The left bank, being slightly higher, suffered less widespread damage, although structures such as the Biosolids Facility in low-lying areas incurred significant damage. Figure 1 in Appendix 8.I summarizes the finding of the post-flood damage assessment.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Cumberland River Damage Center 9, and a summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.I.

The following alternatives were selected and were carried forward for further evaluation:

- Levee/Floodwall - Levees were considered for both the left and right bank of the Cumberland River. On the left bank, a 3,500-foot long, 12 ft. high, levee/floodwall from Van Buren Street to the bridge embankment for Interstate 65 was considered. On the right bank, a 5,800-foot long, 12 ft. high, levee/floodwall located between the Jefferson

Street bridge embankment to the Interstate 65 bridge embankment was considered. Gate access would be provided for river access on both sides of the river and for the CSX Railroad crossing near Interstate 65.

- Floodproofing/Elevation – Elevation of commercial and industrial structures was not considered; however, all of the developments in the damage center could benefit from floodproofing.

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

Figure 3 in Appendix 8.I identifies the location of the specific parcels that could benefit from industrial and commercial floodproofing. Figure 4 in Appendix 8.I identifies the location for a levee and floodwall system considered to protect the commercial and industrial property in the damage center. Cost opinions for the selected alternatives are summarized in Appendix 8.I.

Comparison of Alternatives

Figure 8.9 summarizes the comparison of the selected alternatives for Cumberland River Damage Center 9. The highest rated alternative for this damage center was Flood Warning/Preparedness. It rated higher than all other alternatives in nearly all of the primary criteria. The two Levee/Floodwall alternatives were nearly identical, differing only slightly in Economic Considerations, and were the lowest rated alternatives due to their lower ratings in every criterion but Social Considerations. Floodproofing rated neither as high as Flood warning nor as low as the Levee/Floodwall alternatives in any of the primary criteria, causing it to be the second rated alternative.

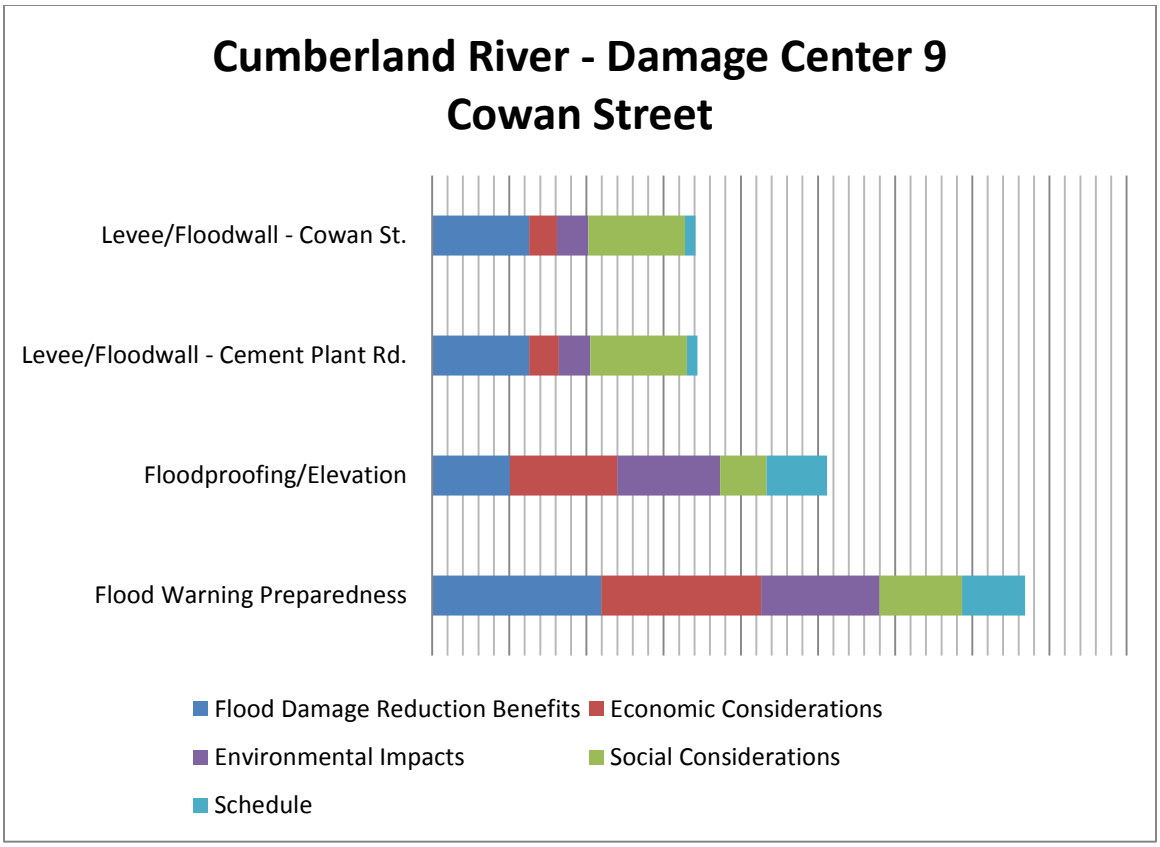


Figure 8.9: Comparison of the Viable Alternatives for Cumberland River Damage Center 9.

Table 8.9 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.9: Evaluation Summary Cumberland River Damage Center 9.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Floodproofing/ Elevation	Good	Minimal	100 year	Average	Private	$1,184,500	$55,200	N/A	$55,200
Levee/Floodwall – Cowan St.	Better	Significant	500 year	Very High	Federal	$39,625,900	$1,844,600	$512,100	$2,356,700
Levee/Floodwall – Cement Plant Rd.	Better	Significant	500 year	Very High	Federal	$34,485,900	$1,605,400	$453,200	$2,058,600

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

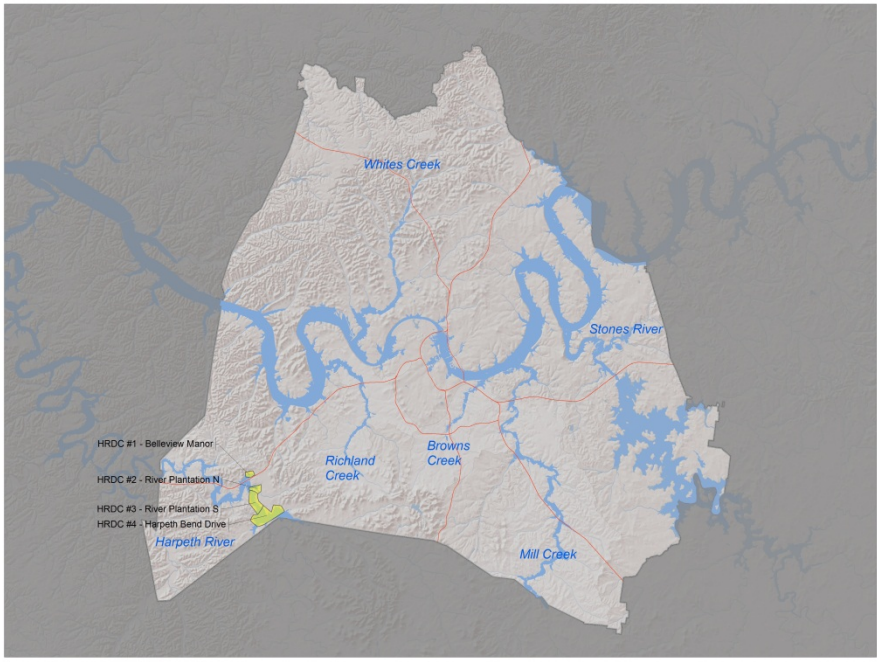
[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

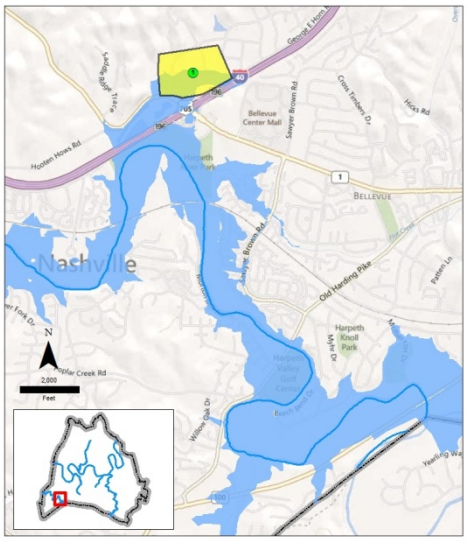
8.2 Harpeth River

Using the methodology outlined in Section 4 of this report, four damage centers were identified primarily along the right bank (looking downstream) of the Harpeth River, from Interstate 40 to the Highway 100 Bridge. In contrast to the Cumberland River, the Harpeth River is unregulated as it flows through Davidson County, and it meanders through mostly suburban residential and commercial areas. Development is fairly mature in this region, with no appreciable space for off-channel storage. In addition, while there is some available floodplain along the Harpeth River in Davidson County, channel modification is not considered for detailed evaluation due to the numerous bridges that cross the river and, consequently, interrupt the benefits of a continuous channel improvement, and due to the potential environmental impacts to the aquatic habitat caused by this measure.



8.2.1 Harpeth River Damage Center 1 – Bellevue Manor Drive

Harpeth River Damage Center 1 is north of Interstate 40 near the US Highway 70S (US 70S) intersection. Figure 1 in Appendix 8.J illustrates the extent of the damage center. Several commercial parcels are located west of US 70S, while a small office park and a residential development are situated to the east of US 70S between Interstate 40 and Harpeth Valley Rd. Photos of typical construction in the damage center can be found in Appendix 8.J.



A considerable portion of the damage center lies within the 100-yr. flood plain. During the May 2010 Flood, the commercial parcels to the west, and several of the residential properties to the east, of US 70S sustained significant damage. Both the

Shoney's Restaurant and the Belleview Theater were completely destroyed, and the theater never reopened. Figure 2 in Appendix 8.J illustrates the extent of the floodwaters within the damage center during the May 2010 flood.

Damage assessments by Metro Codes indicated that all of the commercial structures to the west side of US 70S incurred major damage. In addition, 10 of the commercial properties on Harpeth Valley Place and 12 of the residential properties on Belleview Manor Drive East of US 70S sustained major damage. The post-flood survey conducted by Metro Water Services indicated that the 12 residential structures on Belleview Manor Drive sustained damages estimated to be in excess of 50% of the structures value. Figure 1 in Appendix 8.J summarizes the finding of the post-flood damage assessment.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Harpeth River Damage Center 1, and a summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.J.

After evaluation of the alternatives with regards to site specific conditions, the following alternatives were selected for consideration and were carried forward for further evaluation:

- Levee/Floodwall - Since Interstate 40 forms a natural levee for the damage center, a gate structure added to the existing culvert under Interstate 40 would prevent Harpeth River floodwaters from backing up and entering the damage center. A pump station would be required to remove runoff from the drainage area when the gate structure is closed.

- Elevation/ Floodproofing – Elevation of commercial and industrial structures was not considered viable; however, all of the developments in the damage center could benefit from floodproofing. Residential properties could be elevated to prevent future flood damage.

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

- Brush removal – Tree and brush removal from bridge abutments and along the channel banks would allow conveyance of flood waters more efficiently, reducing flood height.

Figure 3 in Appendix 8.J identifies the location of the specific parcels that could benefit from industrial and commercial floodproofing. Figure 4 in Appendix 8.J identifies the location for a proposed levee and floodwall system to protect the properties the damage center. Cost

opinions for the selected alternatives are summarized in Appendix 8.J.

Comparison of Alternatives

Figure 8.10 summarizes the comparison of the selected alternatives for Harpeth River Damage Center 1. The highest rated alternative for this damage center is Flood Warning/Preparedness, followed by Floodproofing/Elevation, Stream Debris Removal, and Levee/Floodwall. Flood Warning/Preparedness was highest rated in every category except Social Considerations where it was second behind Levee/Floodwall. Floodproofing/Elevation rated highly in Economic Considerations, Environmental Impacts, and Schedule but rated low in the other three criteria. Stream Debris Removal rated highly in Flood Damage Reduction Benefits, Economic Considerations, and Schedule. Levee/Floodwall was the lowest rated alternative because it rated low in all but Social Considerations.

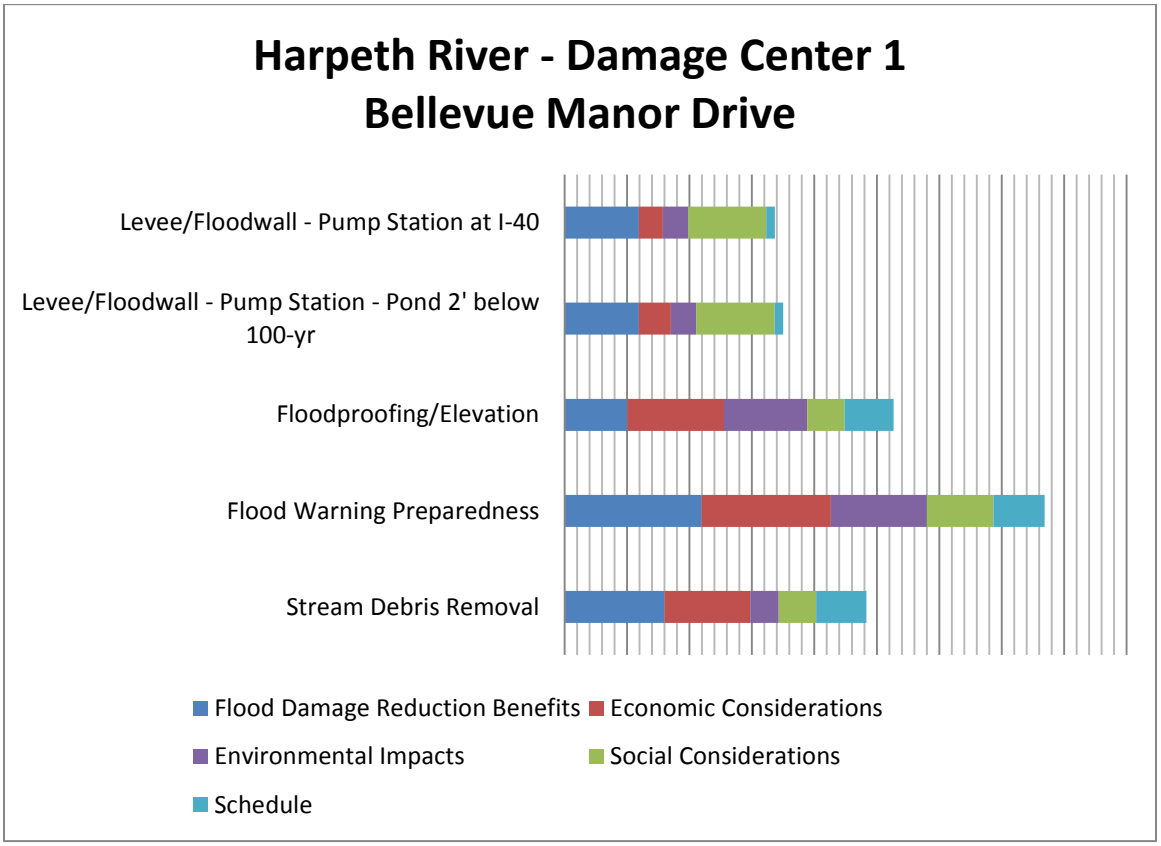


Figure 8.10: Comparison of the Selected Alternatives for Harpeth River Damage Center 1.

Table 8.10 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.10: Evaluation Summary Harpeth River Damage Center 1.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Floodproofing/ Elevation	Good	Minimal	100 year	Average	Private	$69,000	$3,200	N/A	$3,200
Levee/ Floodwall – Pump Station – 2' below 100-year	Better	Significant	500 year	Very High	Federal	$19,439,000	$904,900	$189,600	$1,094,500
Levee/ Floodwall – Pump Station at I-40	Better	Significant	500 year	Very High	Federal	$27,439,000	$1,287,000	$271,000	$1,558,000
Stream Debris Removal	Good	Minimal	N/A	Average	Local/ Private	$1,986,000	$92,000	$1,300	$93,300

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

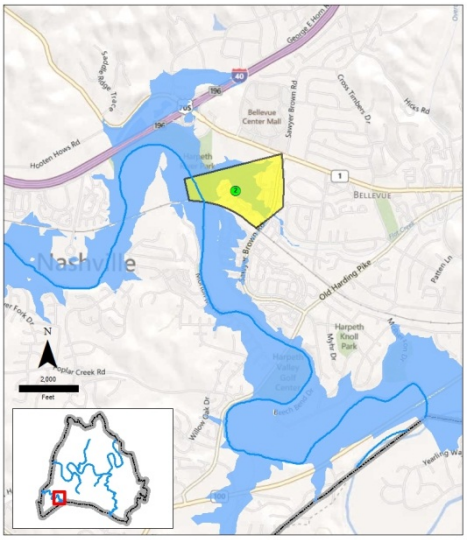
[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.2.2 Harpeth River Damage Center 2 – River Plantation North

Harpeth River Damage Center 2 is located along the right bank (looking downstream) of the Harpeth River near the confluence with Flat Creek. Figure 1 in Appendix 8.K illustrates the extent of the damage center. The damage center is bounded roughly by Flat Creek to the north, Sawyer Brown Road to the east, the CSX railroad to the south, and the Harpeth River to the west. The damage center is composed almost entirely of multifamily condominiums; the exceptions are a large municipal sewage pumping station on the western edge of the damage center and two commercial buildings in the southeast corner of the damage center along Sawyer Brown Road. Photos of typical construction in the damage center can be found in Appendix 8.K.



During the May 2010 Flood, most of the condominiums were flooded, many with 4 to 5 ft. of water. Figure 2 in Appendix 8.K illustrates the extent of the floodwaters within the damage center during the May, 2010 flood.

Damage assessments by Metro Codes indicated that all of the condominium structures west of Sawyer Brown Road incurred moderate damage, with 28 structures incurring major damage. The post-flood survey conducted by Metro Water Services indicated that 28 residential units, mainly along Flat Creek, sustained damages estimated to be in excess of 50% of their value. Figure 1 in Appendix 8.K summarizes the finding of the post-flood damage assessment.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Harpeth River Damage Center 2, and a summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.K.

After evaluation of the alternatives with regards to site specific conditions, the following alternatives were selected for consideration and were carried forward for further evaluation:

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

- Brush removal – Tree and brush removal from bridge abutments and along the channel

banks would allow conveyance of flood waters more efficiently, reducing flood height.

As is indicated on Figure 3 in Appendix 8.K, properties in this damage center were constructed to the current building code requiring the first floor elevation to be four feet above the base flood elevation. For this reason, home buyout and elevation were not considered further for this damage center. Cost opinions for the selected alternatives are summarized in Appendix 8.K.

Comparison of Alternatives

Figure 8.11 summarizes the comparison of the selected alternatives for Harpeth River Damage Center 2. The highest rated alternative for this damage center was Flood Warning/Preparedness. Flood Warning/Preparedness rated higher than Stream Debris Removal in each of the five primary criteria.

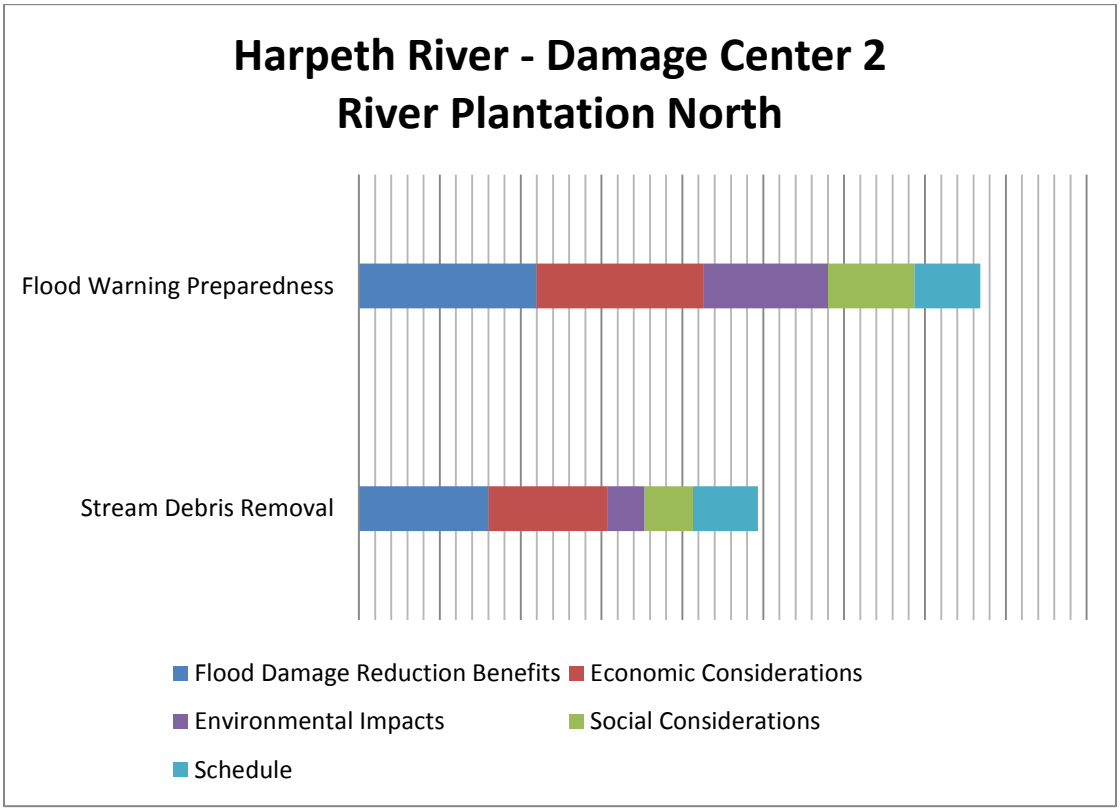


Figure 8.11: Comparison of the Selected Alternatives for Harpeth River Damage Center 2.

Table 8.11 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.11: Evaluation Summary Harpeth River Damage Center 2.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Stream Debris Removal	Good	Minimal	N/A	Average	Local/ Private	$549,000	$25,600	$300	$25,900

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

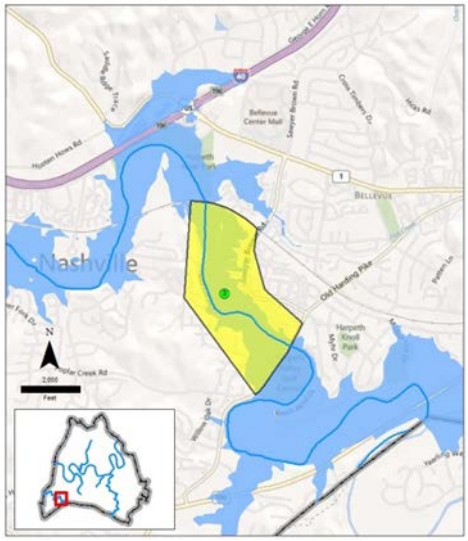
[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.2.3 Harpeth River Damage Center 3 – River Plantation South



Harpeth River Damage Center 3 is located along the right and left banks (looking downstream) of the Harpeth River near the confluence with Flat Creek. Figure 1 in Appendix 8.L illustrates the extent of the damage center. The right bank of the damage center is bounded roughly by Sawyer Brown Road to the east, the CSX railroad to the north, and Old Harding Road to the south. The left bank of the damage center is limited principally to Morton Mill Road as it parallels the Harpeth River. The right bank of the damage center is composed almost entirely of duplex condominiums; the left bank properties are single family homes on moderately sized lots. Photos of typical construction in the damage center can be found in Appendix 8.L.

During the May 2010 Flood, most of the condominiums east of the Harpeth and west of Sawyer Brown Road were flooded with up to 5 ft. of water. Homes on Morton Mill sustained similar damage. Figure 2 in Appendix 8.L illustrates the extent of the floodwaters within the damage center during the May 2010 flood.

Damage assessments by Metro Codes indicated that more than 200 of the condominium units west of Sawyer Brown Road incurred moderate damage, with 13 structures sustaining major damage. On the left bank, more than 80 structures incurred moderate damage, while 6 sustained major damage. The post-flood survey conducted by Metro Water Services indicated that 1 residential condominium on the right bank sustained damages estimated to be in excess of 50% of its value, while 5 structures (two on the right bank and three on the left bank) sustained damages estimated to be between 40% and 50% of their value. Over 150 additional structures on both sides of the river incurred damages that were estimated to be less than 40% of their value. Figure 1 in Appendix 8.L summarizes the findings of the post-flood damage assessment.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Harpeth River Damage Center 3, and a summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.L.

After evaluation of the alternatives with regards to site specific conditions, the following alternatives were selected for consideration and were carried forward for further evaluation:

- Levee/Floodwall – A 5,800 ft. levee constructed on the right bank of the Harpeth River in

Damage Center 3 could be built to provide protection to the 500 yr. flood. The structure would range from 6 to 10 ft. high. A pump station would be required to remove runoff from the drainage within the protected area during flood situations.

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.
- Brush removal – Tree and brush removal from bridge abutments and along the channel banks would allow conveyance of flood waters more efficiently, reducing flood height.

As is indicated on Figure 3 in Appendix 8.L, properties in this damage center were constructed to the current building code requiring the first floor elevation to be four feet above the base flood elevation. For this reason, home buyout and elevation were not considered further for this damage center. Figure 4 in Appendix 8.L identifies the location for a proposed levee and floodwall system to protect the residential property in the damage center. Cost opinions for the selected alternatives are summarized in Appendix 8.L.

Comparison of Alternatives

Figure 8.12 summarizes the comparison of the selected alternatives for Harpeth River Damage Center 3. The highest rated alternative for this damage center is Flood Warning/Preparedness, followed by Stream Debris Removal and Levee/Floodwall. Flood Warning/Preparedness rated highest in every category except Social Considerations where it ranked second behind Levee/Floodwall. Stream Debris Removal rated highly in Flood Damage Reduction Benefits, Economic Considerations, and Schedule. Levee/Floodwall rated highest in Social Consideration and Flood Damage Reduction Benefits. However, it was still the lowest rated alternative.

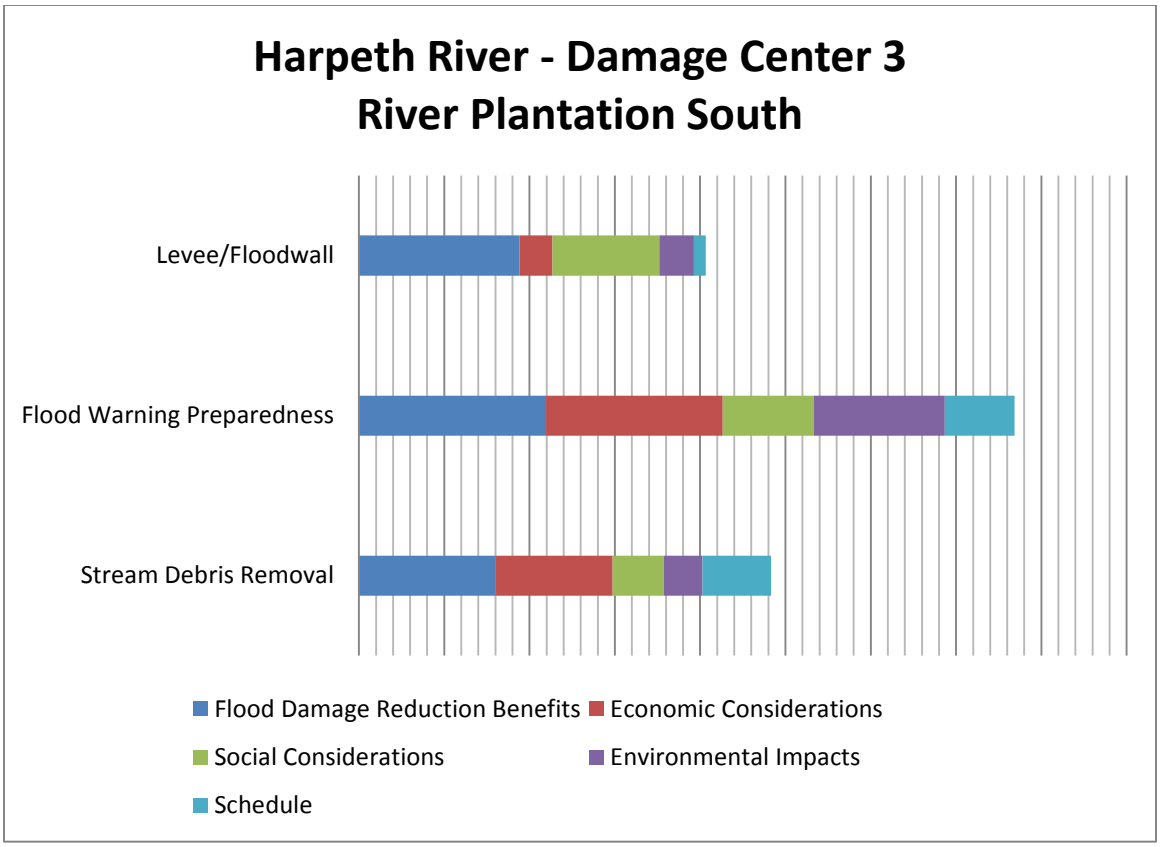


Figure 8.12: Comparison of the Selected Alternatives for Harpeth River Damage Center 3.

Table 8.12 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.12: Evaluation Summary Harpeth River Damage Center 3.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Levee	Better	Significant	500 year	Very High	Federal	$28,144,400	$1,310,200	$311,100	$1,621,300
Stream Debris Removal	Good	Minimal	N/A	Average	Local/ Private	$3,623,400	$168,700	$1,700	$170,400

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

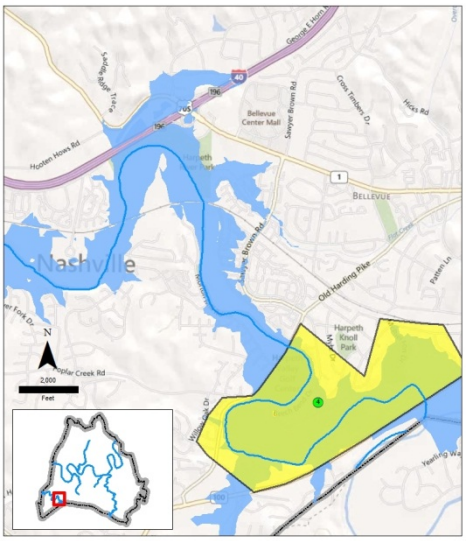
[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.2.4 Harpeth River Damage Center 4 – Harpeth Bend Drive

Harpeth River Damage Center 4 is located along the right and left banks (looking downstream) of the Harpeth River upstream of Harpeth River Damage Center 3. Figure 1 in Appendix 8.M illustrates the extent of the damage center. The damage center is roughly bounded by the bridges for Highway 100 and Old Harding Road, with the CSX railroad forming an approximate eastern boundary. The right bank of the damage center is composed almost entirely of single family homes on small lots. The left bank properties are single family homes on large lots. Sports fields and a golf center are located in the floodplain. Photos of typical construction in the damage center can be found in Appendix 8.M.



During the May 2010 Flood, most of the homes along Beech Bend Drive and Harpeth Bend Drive were flooded with up to 9 ft. of water. Homes at the intersection of McPherson Drive and Harpeth Bend Drive were also flooded up to 9 feet. YouTube videos show submerged cars and floodwaters up to the roofline of homes along McPherson Drive (http://www.youtube.com/watch?v=NmtbyPlDc9I). Figure 2 in Appendix 8.M illustrates the extent of the floodwaters within the damage center during the May, 2010 flood.

Damage assessments by Metro Codes indicated that most of the homes along Beech Bend Drive and Harpeth Bend Drive west of Silo Court incurred major damage, as did homes near the McPherson Drive and Harpeth Bend intersection. Seven homes on the left bank near an unnamed drainage way also incurred major damage. The post-flood survey conducted by Metro Water Services indicated that 49 residential units on the right bank sustained damages estimated to be in excess of 50% of their value, more than 80 homes incurred damages that were estimated to be between 40 and 50% of their value, and more than 40 incurred damages estimated to be less than 40% of their value. Figure 1 in Appendix 8.M summarizes the finding of the post-flood damage assessment.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Harpeth River Damage Center 4, and a summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.M.

After evaluation of the alternatives with regards to site specific conditions, the following alternatives were selected for consideration and were carried forward for further evaluation:

- Levee/Floodwall - This alternative requires approximately 6,900 linear feet of levee or

floodwall around the Harpeth Bend Peninsula in order to protect all of the houses on Beech Bend Drive, Footpath Terrace, and Harpeth Bend Drive. In order to adequately protect residents, the top of this levee/floodwall would need to be approximately six feet tall, and would likely occupy a large portion of the residents' backyards. To protect the homes on McPherson Drive and Harpeth Bend Drive, a 1,600 ft. ring levee could be installed in the floodplain and the TVA right of way. Pump stations would be required to remove runoff from the within the protected area during flood situations.

- Floodproofing/Elevation –Most residential properties are built with first floor elevations higher than one foot above the 100-yr. flood elevation, and thus are not considered for elevation. Commercial properties would benefit from floodproofing.

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

- Brush removal – Tree and brush removal from bridge abutments and along the channel banks would allow conveyance of flood waters more efficiently, reducing flood height.

Figure 3 in Appendix 8.M identifies the location of the specific parcels that could benefit from elevation or home buyout. Figure 4 in Appendix 8.M identifies the location for a proposed levee system to protect the residential properties in the damage center. Cost opinions for the selected alternatives are summarized in Appendix 8.M.

Comparison of Alternatives

Figure 8.13 summarizes the comparison of the selected alternatives for Harpeth River Damage Center 4. This damage center's highest rated alternatives were, in order: Flood Warning/Preparedness, Acquisition/Buyout, Floodproofing/Elevation, Stream Debris Removal, and Levee/Floodwall. Flood Warning/Preparedness rated highest in every category except Social Considerations. Acquisition/Buyout was rated slightly lower than Flood Warning/Preparedness in all categories except Environmental Impacts, in which the two rated equally well. Floodproofing/Elevation rated slightly lower than Acquisition/Buyout in all categories except Schedule. Stream Debris Removal rated lower than Floodproofing/Elevation in all categories except Schedule. Levee / Floodwall rated the lowest of all alternatives in every category except Social Considerations, causing it to be the lowest rated alternative.

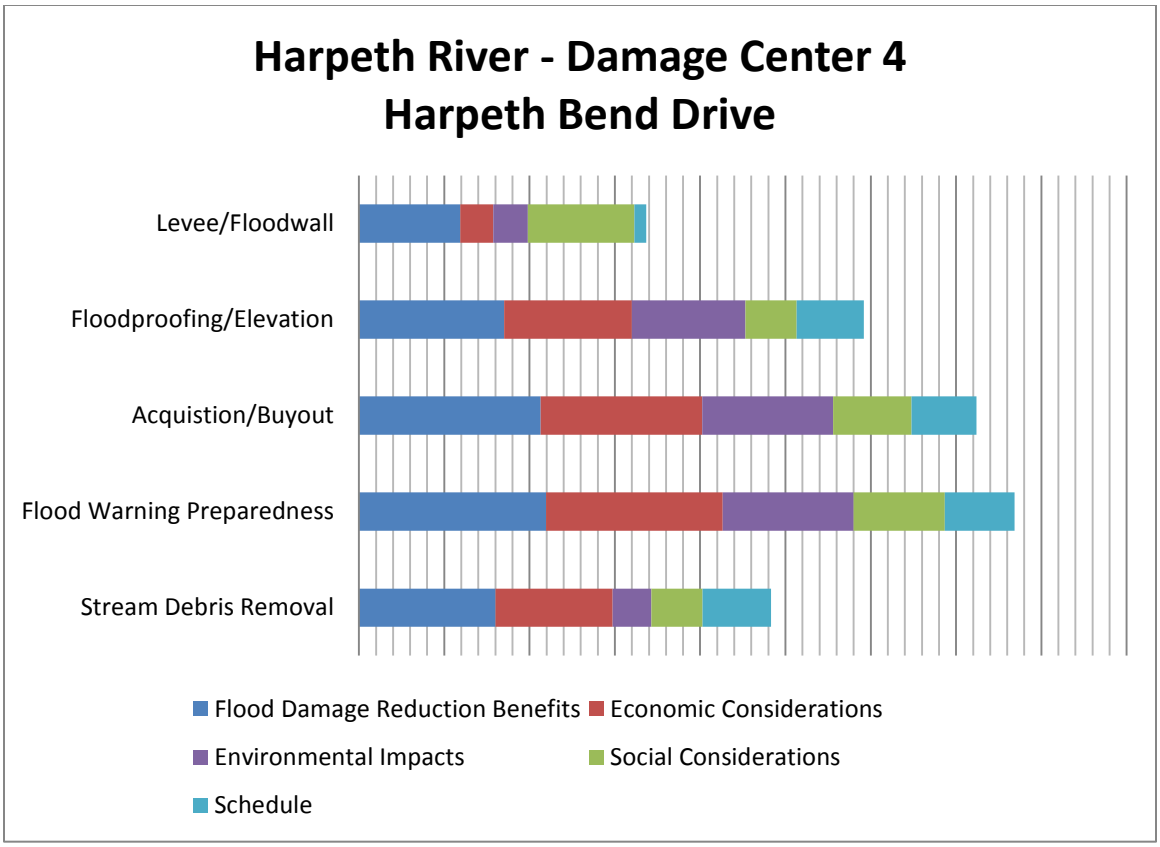


Figure 8.13: Comparison of the Selected Alternatives for Harpeth River Damage Center 4.

Table 8.13 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.13: Evaluation Summary Harpeth River Damage Center 4.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Acquisition/ Buyout	Best	Minimal	100 year	Average	Local/ Federal	$2,975,300	$138,500	$10,000	$148,500
Floodproofing/ Elevation	Good	Minimal	100 year	Average	Private	$695,000	$32,400	N/A	$32,400
Levee	Better	Significant	500 year	Very High	Federal	$23,273,800	$1,083,400	$284,900	$1,368,300
Stream Debris Removal	Good	Minimal	N/A	Average	Local/ Private	$4,941,000	$230,000	$3,100	$233,100

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

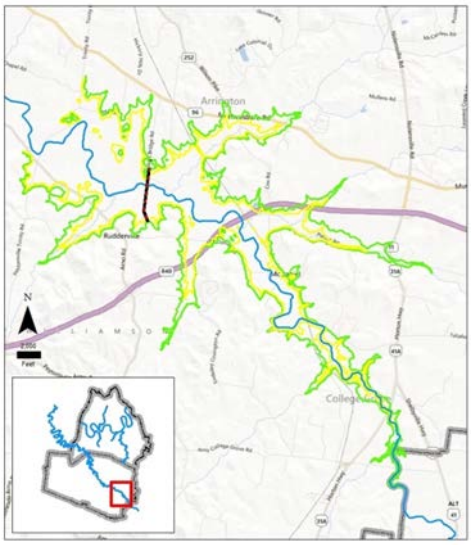
8.2.5 Harpeth River Regional Alternatives

In addition to the damage center-specific alternatives considered in the following sections, two "regional" alternatives were considered for the Harpeth River drainage basin. These alternatives differed from the alternatives considered in previous sections in that their implementation would, from a flooding standpoint, benefit multiple damage centers on the Harpeth River.

Regional Reservoir

The first regional alternative considered was the construction of a dry reservoir on the Harpeth River in eastern Williamson County. A dry reservoir would be used for storm water detention, with a flow control structure that would allow the basin to drain slowly and reduce the intensity of flood peak flows through the lower reaches of the watershed. Based on topographical analysis of land in Davidson and Williamson County, a potential site was identified in central Williamson County where an impoundment could be constructed.

The proposed site is located in the Arrington Community of Williamson County near the Williamson County/Rutherford County line. A 4,800 linear ft. (maximum height of 30 ft.) earthen impoundment with a concrete discharge structure (See Section 7) would be constructed south of Murfreesboro Pike (SR-96) between Arno Road and Lampkins Bridge Road. When impounded, water would back up past SR-840 to College Grove near the US-41A / US-31A intersection. The impoundment would detain 106 square miles of drainage area.



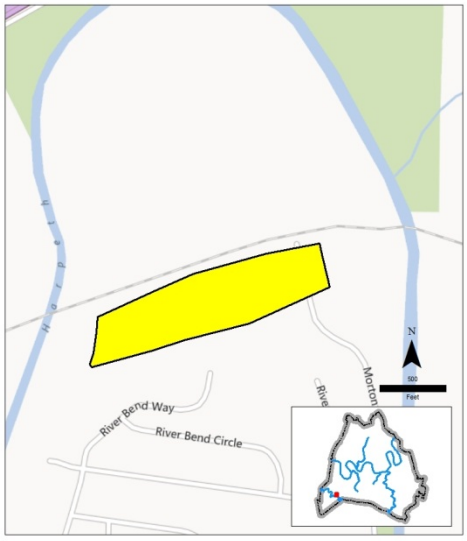
The Davidson County Flood Insurance Study (FIS) tabulates peak discharges for various return interval storms at locations along the Harpeth River. These flows are summarized in Table 8.14 below. Comparing upstream (Harpeth River at the confluence of Arrington Creek near the proposed reservoirs) and downstream (Belleview gage) peak flows during the 100-yr. and 500-yr. storm, the FIS suggests that over 40% of the peak flow in the Harpeth River occurs in the upstream reaches, even though the drainage area above the proposed impoundment on the Harpeth River represents only 26% of the total drainage area at the Belleview gage. Therefore, detaining this peak flow and slowly releasing in into the Harpeth River would reduce peak flows in the downstream reaches, which would also reduce downstream flood stages.

Table 8.14: Drainage area and Peak Discharges at Select Locations on Harpeth River.

Location	Drainage area (Acres)	100-yr. flow (cfs)	500-yr. flow (cfs)
Belleview gage	408	38,200	51,600
Arrington Creek	106	15,800	21,200
Impounded drainage area and percent of peak flow (% of Belleview gage)	26%	41.4%	41.0%

Regional Figure 1 in Appendix 8.N illustrates two potential elevations for the maximum storage in the dry reservoir. At elevation 690, the basin could detain approximately 19,600 ac-ft., which is approximately 3.5-in. of rain over the 106 square mile drainage area. At elevation 700 ft., the dry reservoir could detain approximately 44,800 ac-ft., which is approximately 7.9 in. of rain over the drainage area. If the 500-yr. rainfall event is 9.38 in. over 24-hr., then the lower elevation reservoir would detain enough rainfall so that the effective release from the reservoir would be approximately the 10-yr., 24-hr. storm (5.88 in released compared to 5.12 in for the 10-yr., 24-hr. event). Similarly, the higher elevation reservoir would detain enough rainfall so that the effective release from the reservoir was less than the 1-yr., 24-hr. event. (1.48 in. released compared to 3.08 in. for the 1-yr., 24-hr. event). Computer modeling, which is beyond the scope of this study, should be used to derive better estimates of the impact of this alternative on downstream flood stages.

Diversion



The second regional alternative considered was the construction of a diversion channel in the bend of the Harpeth River immediately below Harpeth River Damage Center 2. The CSX railroad crosses the river at two points in that bend, leading to approximately 6 feet of headloss during extreme (500-yr. or greater) floods. A diversion was proposed to cut across the bend upstream of the first bridge. The diversion channel proposed was approximately 250 ft. wide, 2,700 ft. long, and the elevation of the channel was coincident with the 100-yr. flood elevation. The diversion would remove the constrictions caused by the railroad bridges at high flow without the need to relocate the bridges themselves. Computer modeling, which is beyond the scope of this study, should be used to derive better estimates of the impact of this alternative on flood stages upstream and downstream of the diversion.

A summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.N. Regional Figure 1 in Appendix 8.N identifies the location of the reservoir

alternative. Regional Figure 2 in Appendix 8.N identifies the location of the diversion alternative. Cost opinions for these alternatives are summarized in Appendix 8.N.

Table 8.15 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.15: Evaluation Summary Harpeth River Regional Solution.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Diversion	Better	Significant	100 year	Very High	Federal	$29,203,100	$1,359,400	$245,500	$1,604,900
Reservoir	Better	Significant	100 year	Very High	Federal	$30,808,300	$1,434,200	$67,900	$1,502,100

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

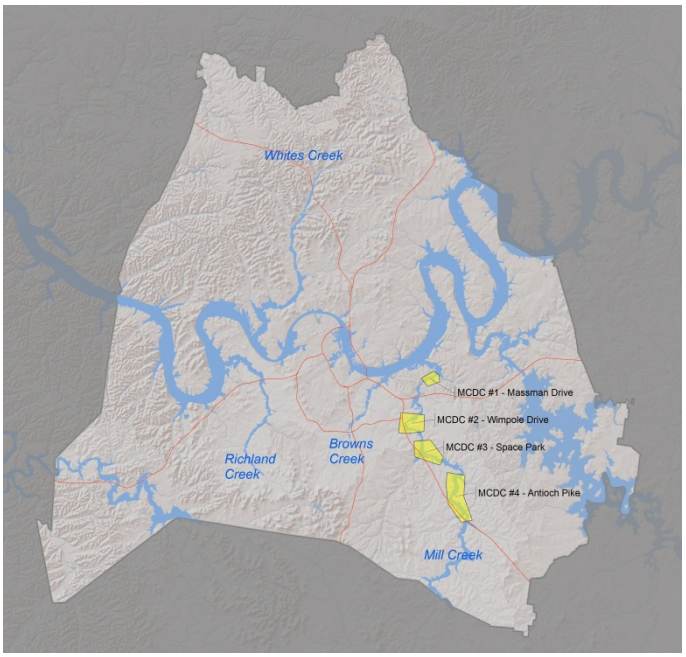
[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

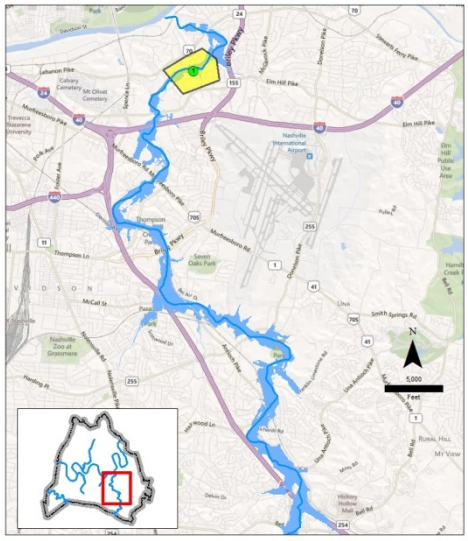
8.3 Mill Creek

Using the methodology outlined in Section 4 of this report, four damage centers were identified along the banks of Mill Creek, between its confluence with the Cumberland River and the Davidson County Line to the south. Like the Harpeth River, Mill Creek is unregulated as it flows through Davidson County, and it meanders through mostly suburban residential and commercial/industrial areas. Development is fairly mature in this region, and some areas have a long history of flooding.



8.3.1 Mill Creek Damage Center 1 – Massman Drive

Mill Creek Damage Center 1 is located in Southeast Davidson County. Figure 1 in Appendix 8.O illustrates the extent of the damage center. The damage center is roughly bounded by Lebanon Pike to the north and west, Briley Parkway to the east, and Elm Hill Pike to the south. The right bank (looking downstream) of the damage center is composed almost entirely of commercial warehouse properties, including Gibson Guitars and United Parcel Service. The eastern right bank contains a small residential area with single family homes. Photos of typical construction in the damage center can be found in Appendix 8.O.



During the May 2010 Flood, the warehouses north of Massman Drive were inundated. In addition, several of the residential properties in the area were flooded. Figure 2 in Appendix 8.O illustrates the extent of the floodwaters within the damage center during the May, 2010 flood.

Damage Assessments by Metro Codes indicated that the warehouses incurred major damage, as did homes near the Sanborn Drive and Bismark Drive intersection. The post-flood survey conducted by Metro Water Services indicated that three residential units on the right bank

sustained damages estimated to be between 40% and 50% of their value, and four others incurred damages estimated at less than 40% of their value. Figure 1 in Appendix 8.O summarizes the finding of the post-flood damage assessment.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Mill Creek Damage Center 1, and a summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.O.

After evaluation of the alternatives with regards to site specific conditions, the following alternatives were selected for consideration and were carried forward for further evaluation:

- Floodproofing/Elevation –Most residential properties are built well above the 100-yr. flood elevation, and thus are not considered for elevation. A single home is considered for elevation. Commercial properties would benefit from floodproofing.

- Acquisition/Buyout – This alternative includes the consideration of buyout of the residences in the Bismarck Drive and Quinn Court areas that received significant damage. Commercial buyout is not considered.

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

- Debris Removal – Removal of accumulated debris along bridge abutments would result in lower headlosses and more efficient movement of water through the damage center.

Figure 3 in Appendix 8.O identifies the location of the specific parcels that could benefit from commercial floodproofing, residential elevation or home buyout. Cost opinions for the selected alternatives are summarized in Appendix 8.O.

Comparison of Alternatives

Figure 8.14 summarizes the comparison of the selected alternatives for Mill Creek Damage Center 1. The highest rated alternative for this damage center was Acquisition Buyout, followed by Flood Warning Preparedness, Floodproofing/Elevation, and Stream Debris Removal. Acquisition/Buyout only rated higher than Flood Warning/Preparedness in the Flood Damage Reduction Benefit criteria but that difference was enough to cause Acquisition/Buyout to be the highest rated alternative. Floodproofing/Elevation was rated slightly higher than Stream Debris Removal in Economic Considerations and Environmental Impacts. Stream Debris Removal rated higher than Floodproofing/Elevation in Schedule and Flood Damage Reduction Benefits. Overall, Floodproofing/Elevation rated higher than Stream Debris Removal.

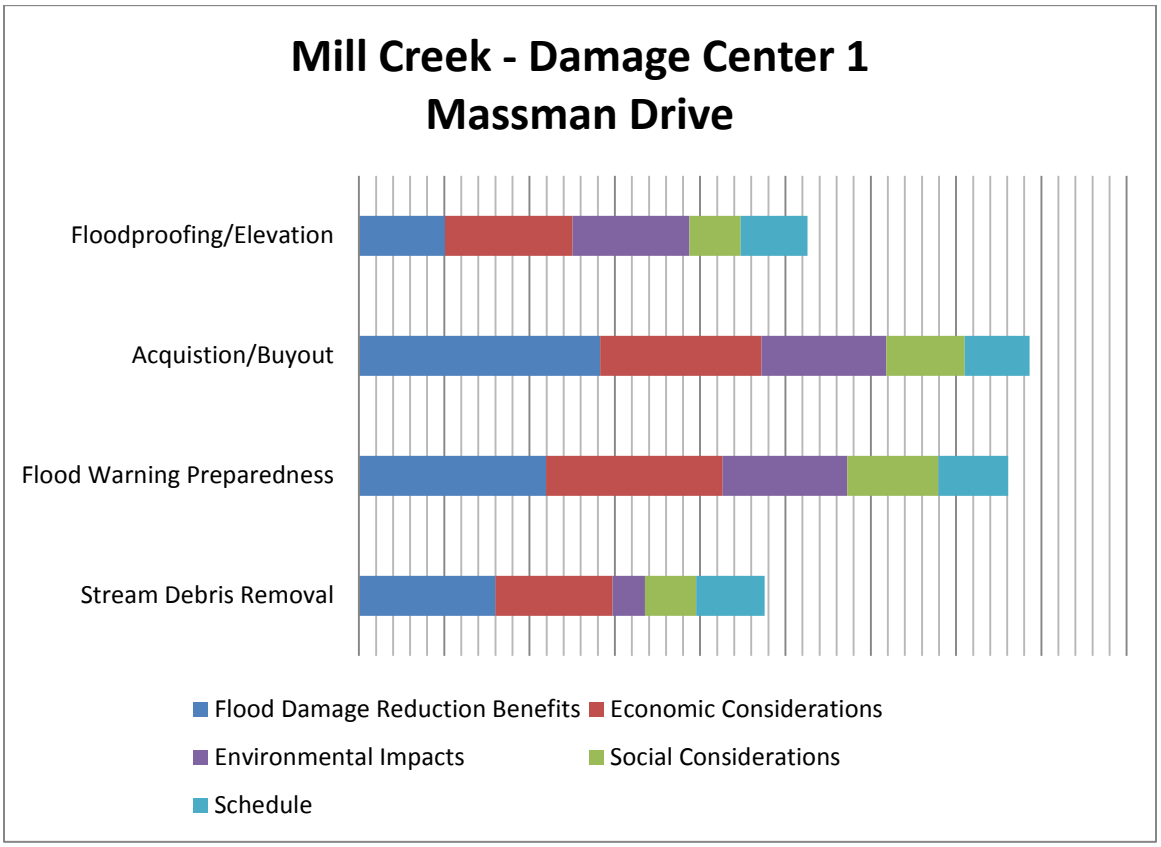


Figure 8.14: Comparison of the Viable Alternatives for Mill Creek Damage Center 1.

Table 8.16 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.16: Evaluation Summary Mill Creek Damage Center 1.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Acquisition/ Buyout	Best	Minimal	100 year	Average	Local/ Federal	$1,137,500	$1,562,600	$6,400	$1,581,900
Floodproofing/ Elevation	Good	Minimal	100 year	Average	Private	$768,000	$35,800	N/A	$35,800
Stream Debris Removal	Good	Minimal	N/A	Average	Local/ Private	$2,031,300	$94,600	$1000	$95,600

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

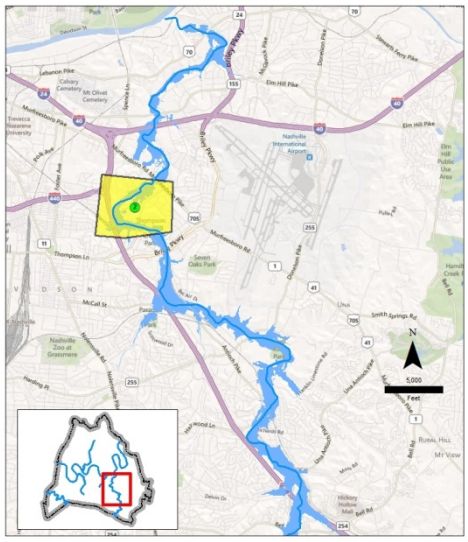
[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.3.2 Mill Creek Damage Center 2 – Wimpole Drive



Mill Creek Damage Center 2 is located in southeast Davidson County. Figure 1 in Appendix 8.P illustrates the extent of the damage center. The damage center is roughly bounded by I-24 to the west, Thompson Lane to the south and east, and Murfreesboro Road to the north and east. The right bank of the damage center is composed almost entirely of single family homes. Photos of typical construction in the damage center can be found in Appendix 8.P.

During the May 2010 Flood, residences along Wimpole Drive were flooded, particularly near the two intersections with Thompson Lane. In addition, some commercial property suffered flood damage in the area of Murfreesboro Road. Figure 2 in Appendix 8.P illustrates the extent of the floodwaters within the damage center during the May, 2010 flood.

Damage assessments by Metro Codes indicated that the warehouses incurred moderate damage, while the homes on Wimpole Drive generally sustained major damage. The post-flood survey conducted by Metro Water Services indicated that 17 residential units sustained damages estimated to be in excess of 50% of their value, while four homes incurred damages estimated to be between 40% and 50% of their value, and 47 others incurred damages estimated to be less than 40% of their value. Figure 1 in Appendix 8.P summarizes the finding of the post-flood damage assessment.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Mill Creek Damage Center 2, and a summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.P.

After evaluation of the alternatives with regards to site specific conditions, the following alternatives were selected for consideration and were carried forward for further evaluation:

- Bridge Improvements – Modifications of the bridges at Thompson Lane and Murfreesboro Road were considered since evaluation of the published FEMA profiles downstream of and through the Wimpole Drive study area indicated measureable losses for the 100- and 500-year floods. The Murfreesboro Road bridge was not considered for further study due to recent improvements made to the bridge.

- Channel Modifications – Channel Modifications through the Wimpole Drive damage area were considered independently and in connection with bridge improvements.

- Floodproofing/Elevation –Sixteen homes along Wimpole Drive were considered for elevation. Commercial properties near Murfreesboro Road would also benefit from floodproofing.

- Acquisition/Buyout – This alternative includes consideration of buyout of 29 residences on Wimpole Drive that received significant damage. Commercial buyout is not considered.

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

- Debris Removal – Removal of accumulated debris along bridge abutments would result in lower headlosses and more efficient movement of water through the damage center.

Figure 3 in Appendix 8.P identifies the location of the specific parcels that could benefit from residential elevation or home buyout. Figure 4 in Appendix 8.P identifies the location of bridge modifications and channel modifications considered in this damage center. Cost opinions for the selected alternatives are summarized in Appendix 8.P.

Comparison of Alternatives

Figure 8.15 summarizes the comparison of the selected alternatives for Mill Creek Damage Center 2. This damage center's highest rated alternatives were, in order: Acquisition/Buyout, Flood Warning/Preparedness, Floodproofing Elevation, Channel Modification, Stream Debris Removal, and Bridge Improvement. The only criterion in which Acquisition/Buyout rated highest were Flood Damage Reduction Benefits and Environmental Impacts. However, the alternative's strong performance in the other criteria resulted in it being the highest rated alternative. Flood Warning/Preparedness was rated slightly lower than Acquisition/Buyout, rating highest in all four criteria other than Flood Damage Reduction Benefits. Floodproofing/Elevation rated well in all categories except Social Consideration, in which it was lowest rated. Channel Modification rated low in Schedule, Economic Consideration, and Environmental Impacts. Stream Debris Removal rated low in Schedule and Economic Considerations, and rated relatively low in the other three criteria. Bridge Improvement was the lowest rated alternative. Its low rating came in Flood Damage Reduction Benefits, Economic Considerations, and Schedule.

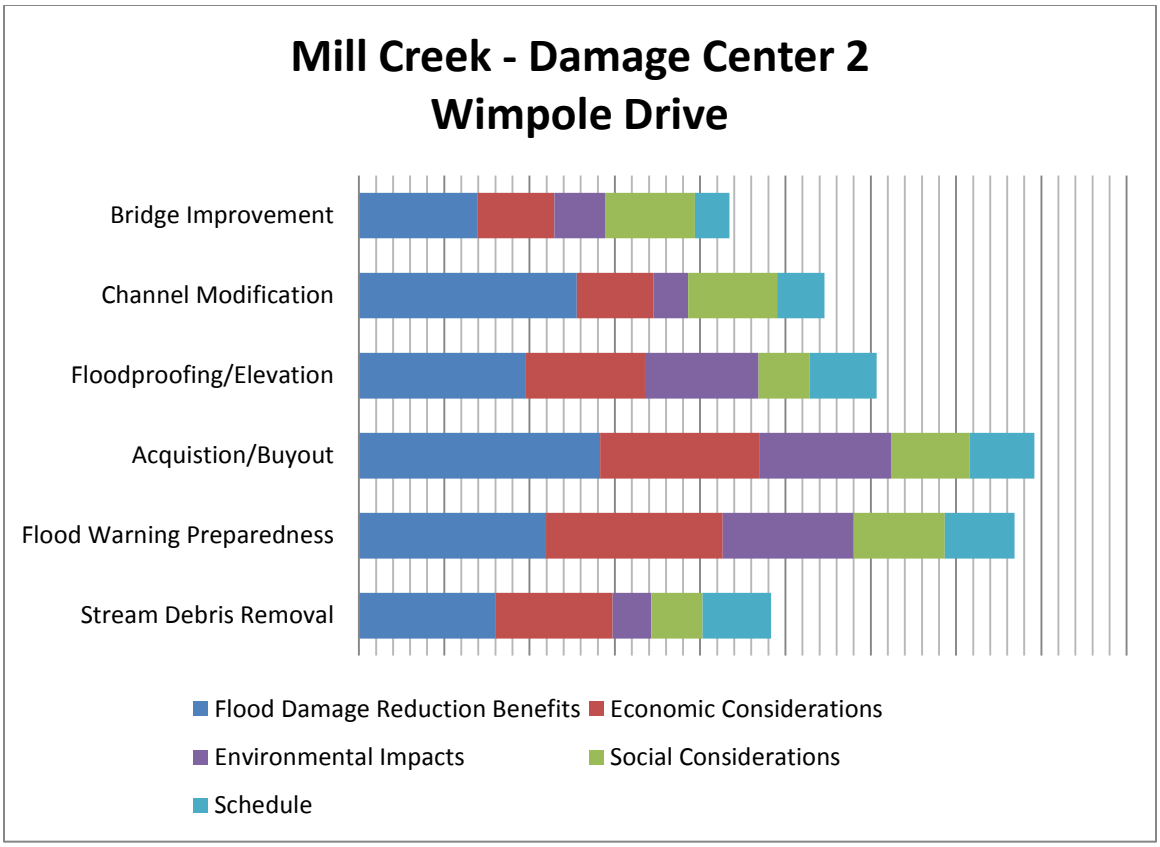


Figure 8.15: Comparison of the Viable Alternatives for Mill Creek Damage Center 2.

Table 8.17 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.17: Evaluation Summary Mill Creek Damage Center 2.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Acquisition/ Buyout	Best	Minimal	100 year	Average	Local/ Federal	$10,356,400	$53,000	$25,700	$59,400
Floodproofing/ Elevation	Good	Minimal	100 year	Average	Private	$1,018,400	$47,400	N/A	$47,400
Channel Modification	Good	Significant	100 year	High	Federal	$2,607,000	$121,400	$20,700	$142,100
Bridge Improvement	Good	Significant	100 year	High	State	$3,901,500	$181,700	$24,300	$206,000
Stream Debris Removal	Good	Minimal	N/A	Average	Local/ Private	$5,490,000	$255,600	$2,500	$258,100

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

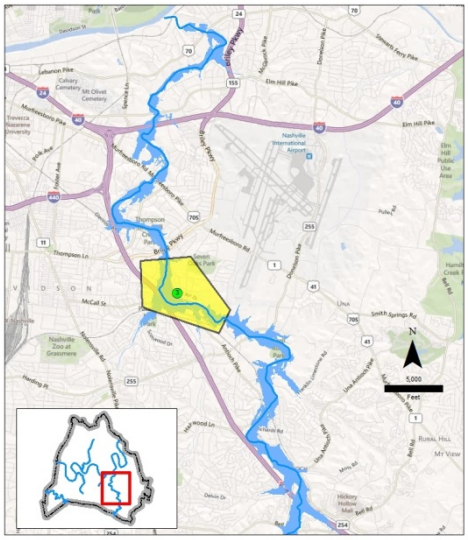
[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.3.3 Mill Creek Damage Center 3 – Space Park



Mill Creek Damage Center 3 is located in southeast Davidson County at the confluence of Sevenmile Creek. Figure 1 in Appendix 8.Q illustrates the extent of the damage center. The damage center is roughly bounded by I-24 to the west, Briley Parkway to the north Antioch Pike to the south, and Nashville International Airport to the east. The right bank (looking downstream) of the damage center, where the bulk of the damage was located, is composed almost entirely of commercial warehouse properties. To the north, downstream of Sevenmile Creek and upstream of Briley Parkway, there are a number of residential properties on Currey Road and Drummond Drive. Photos of typical construction in the damage center can be found in Appendix 8.Q.

During the May 2010 Flood, the warehouses along Space Park South Drive were flooded, as were some residential properties near Briley Parkway. Figure 2 in Appendix 8.Q illustrates the extent of the floodwaters within the damage center during the May 2010 flood.

Damage Assessments by Metro Codes indicated that the warehouses on the right bank incurred major damage, while warehouses on the left bank sustained moderate damage. The post-flood survey conducted by Metro Water Services indicated that two residential properties on Antioch Pike sustained damages estimated to be greater than 50% of the property value, while one home each on Antioch Pike and Drummond Drive incurred damages estimated to be between 40% and 50% of their value. Sixteen others structures in the damage center sustained damages estimated to be less than 40% of their value. Figure 1 in Appendix 8.Q summarizes the finding of the post-flood damage assessment.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Mill Creek Damage Center 3, and a summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.Q.

After evaluation of the alternatives with regards to site specific conditions, the following alternatives were selected for consideration and were carried forward for further evaluation:

- Bridge Replacement – A number of bridges cross Mill Creek both within and immediately downstream of Damage Center 3. Inspection of the Davidson County Flood Insurance Study indicated that modifying one or more of these bridges may have a beneficial impact on flow through the damage center. Improvements were considered

at the following bridges or combinations of bridges: (1) Briley Parkway; (2) Briley Parkway and CSX; (3) CSX and Space Park; and (4) Briley Parkway, CSX, and Space Park. Bridge improvements in conjunction with channel improvements were also considered. (See below.)

- Channel Modification – Channel Modification was considered alone and in conjunction with bridge improvements. Floodplain fill downstream of the confluence with Sevenmile Creek cold be removed to improve the hydraulics and increase the efficiency of flow through the Damage Center. In addition, performing these channel modifications in conjunction with bridge improvements to both the CSX and Briley Parkway Bridges should be considered to reduce flooding.

- Floodproofing/Elevation –Homes on Finley and Drummond Drive were considered for elevation. Commercial properties near Space Park South Drive would also benefit from floodproofing.

- Acquisition/Buyout – This alternative includes the consideration of buyout of residences on Finley Drive that received significant damage. Commercial buyout is not considered.

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

- Debris Removal – Removal of accumulated debris along bridge abutments would result in lower headlosses and more efficient movement of water through the damage center.

Figure 3 in Appendix 8.Q identifies the location of the specific parcels that could benefit from residential elevation or home buyout. Figure 4 in Appendix 8.Q identifies the location of the bridges which are considered for modification and the location of the proposed channel modifications. Cost opinions for the selected alternatives are summarized in Appendix 8.Q.

Comparison of Alternatives

Figure 8.16 summarizes the comparison of the selected alternatives for Mill Creek Damage Center 3. Flood Warning/Preparedness and Acquisition/Buyout rated highest among the all the alternatives. Although some of the Bridge Improvement alternatives rated higher on Flood Damage Reduction Benefits and some of the Social Considerations, Flood Warning/Preparedness and Acquisition/Buyout rated higher in the other criteria. The Bridge Improvement and Channel Modification alternative received high ratings in Flood Damage Reduction Benefits and Social Considerations and poor ratings in Schedule, Economic Considerations, and Environmental Impacts. Floodproofing/Elevation rated highly in Economic

Considerations, Environmental Impacts and Schedule. Stream Debris Removal rated relatively well in Flood Damage Reduction Benefits, Economic Considerations and Schedule.

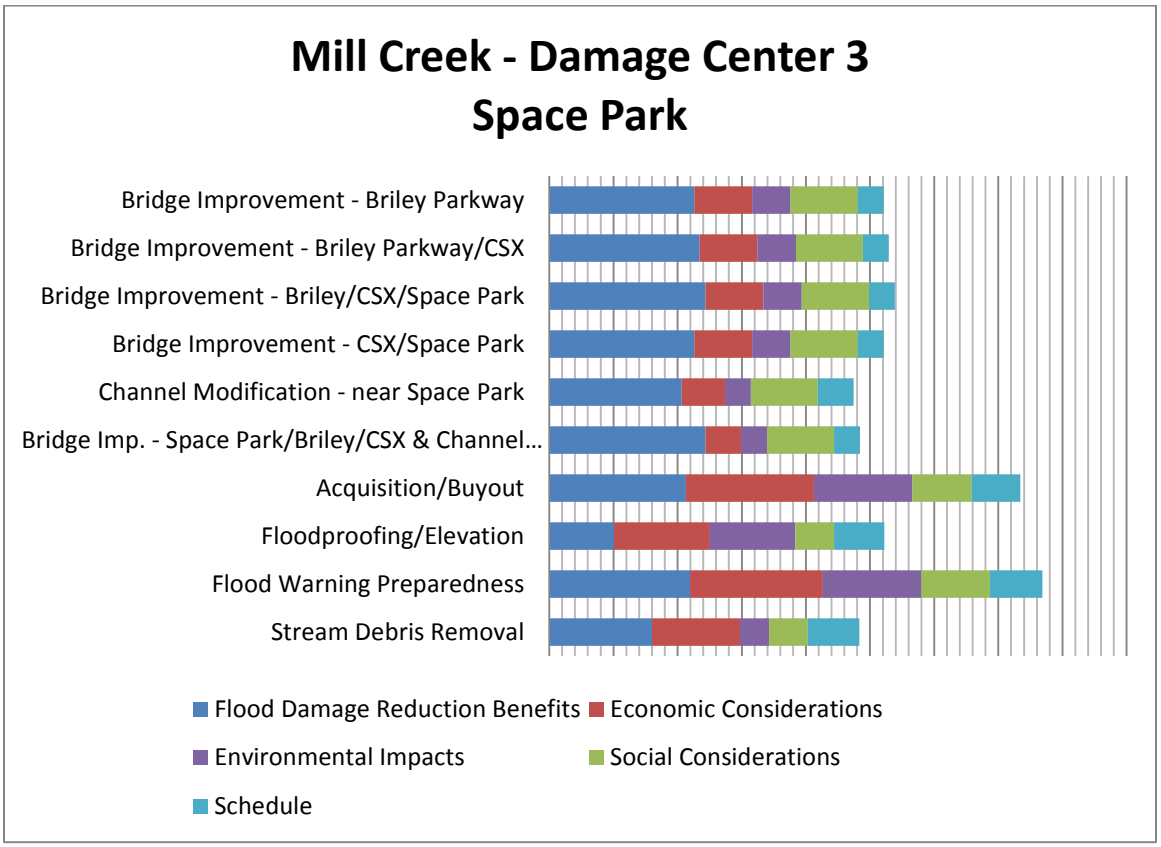


Figure 8.16: Comparison of the Viable Alternatives for Mill Creek Damage Center 3.

Table 8.18 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.18: Evaluation Summary Mill Creek Damage Center 3.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Acquisition/Buyout	Best	Minimal	100 year	Average	Local/ Federal	$964,100	$44,900	$3,000	$47,900
Floodproofing/ Elevation	Good	Minimal	100 year	Average	Private	$194,200	$9,100	N/A	$9,100
Bridge Improvement (Briley Parkway)	Good	Significant	100 year	High	State	$2,265,000	$105,500	$15,000	$120,500
Bridge Improvement (Briley Parkway/ CSX)	Good	Significant	100 year	High	State	$5,500,000	$256,100	$35,800	$291,900
Bridge Improvement (CSX/Space Park)	Good	Significant	100 year	High	State	$6,196,500	$288,500	$39,100	$327,500
Bridge Improvement (Briley/CSX/Space Park)	Good	Significant	100 year	High	State	$8,462,000	$393,900	$54,000	$447,900
Bridge Improvement (Briley/CSX/Space Park) & Channel Modification	Good	Significant	100 year	High	State/ Federal	$13,446,000	$625,900	$68,800	$694,700
Channel Modification	Good	Significant	100 year	High	Federal	$4,984,000	$232,000	$14,700	$246,700
Stream Debris Removal	Good	Minimal	N/A	Average	Local/ Private	$5,490,000	$255,600	$2,500	$258,100

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

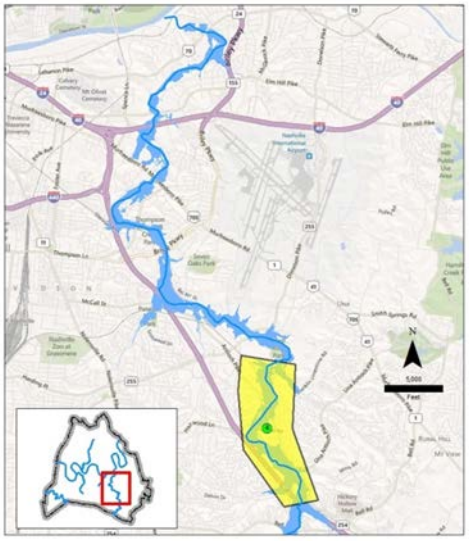
[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.3.4 Mill Creek Damage Center 4 – Antioch Pike

Mill Creek Damage Center 4 is located in southeastern Davidson County. Figure 1 in Appendix 8.R illustrates the extent of the damage center. The damage center is located east of I-24 between approximately Blue Hole Road to the south and approximately Franklin Limestone Road to the north. As it meanders through the damage center, Mill Creek is bordered by mostly commercial and light industrial development, with a few pockets of residential parcels. Photos of typical construction in the damage center can be found in Appendix 8.R.



During the May 2010 flood, the warehouses in the vicinity of Franklin Limestone Road and the mobile homes north of Richards Road were flooded, as were some residential properties in the southern part of the damage center on Antioch Pike and Benzing Road. Figure 2 in Appendix 8.R illustrates the extent of the floodwaters within the damage center during the May 2010 flood.

Damage assessments by Metro Codes indicated that some of the warehouses and trailer parks in the northern end of the damage center and some of the residential and commercial properties along the creek incurred major damage. The post-flood survey conducted by Metro Water Services indicated that nine residential properties sustained damages estimated to be in excess of 50% of their value, 11 properties incurred damages estimated between 40% and 50% of their value, and 29 structures incurred damages estimated to be less than 40% of their value. Figure 1 in Appendix 8.R summarizes the finding of the post-flood damage assessment.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Mill Creek Damage Center 4, and a summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.R.

After evaluation of the alternatives with regards to site specific conditions, the following alternatives were selected for consideration and were carried forward for further evaluation:

- Bridge Modification with Channel Modification – Modification or removal of bridges or combinations of bridges at Franklin Limestone Road, the abandoned railroad bridge at Mill Creek River Mile 10.9, CSX Railroad, and Antioch Pike were considered to improve reduce the head losses in the damage center. Two segments of channel above and below the abandoned railroad bridge at MCRM 10.9 were considered for modification in conjunction with bridge modifications to improve the hydraulic efficiency of Mill Creek

through the damage center.

- Acquisition/Buyout – This alternative includes the consideration of buyout of residences on Antioch Pike and Benzing Drive that received significant damage. Commercial buyout is not considered.

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

- Debris Removal – Removal of accumulated debris along bridge abutments would result in lower headlosses and more efficient movement of water through the damage center.

Figure 3 in Appendix 8.R identifies the location of the specific parcels that could benefit from home buyout. Figure 4 in Appendix 8.R identifies the location of the bridges that are considered for modification as well as the areas proposed for channel modification in conjunction with bridge modification. Cost opinions for the selected alternatives are summarized in Appendix 8.R.

Comparison of Alternatives

Figure 8.17 summarizes the comparison of the selected alternatives for Mill Creek Damage Center 4. The highest rated alternative for this damage center was Flood Warning/Preparedness. It rated higher than all other alternatives in all criteria. Acquisition/Buyout rated slightly lower than Flood Warning/Preparedness in all criteria. Of the Bridge Improvement/Channel Modification alternatives, the alternative at the Abandoned Railroad rated the highest due to slightly better ratings in Economic Considerations and Flood Damage Reduction Benefits. These three alternatives rated higher than Stream Debris Removal, due to the ratings that Stream Debris Removal received in Flood Damage Reduction Benefits, Environmental Impacts, and Social Considerations.

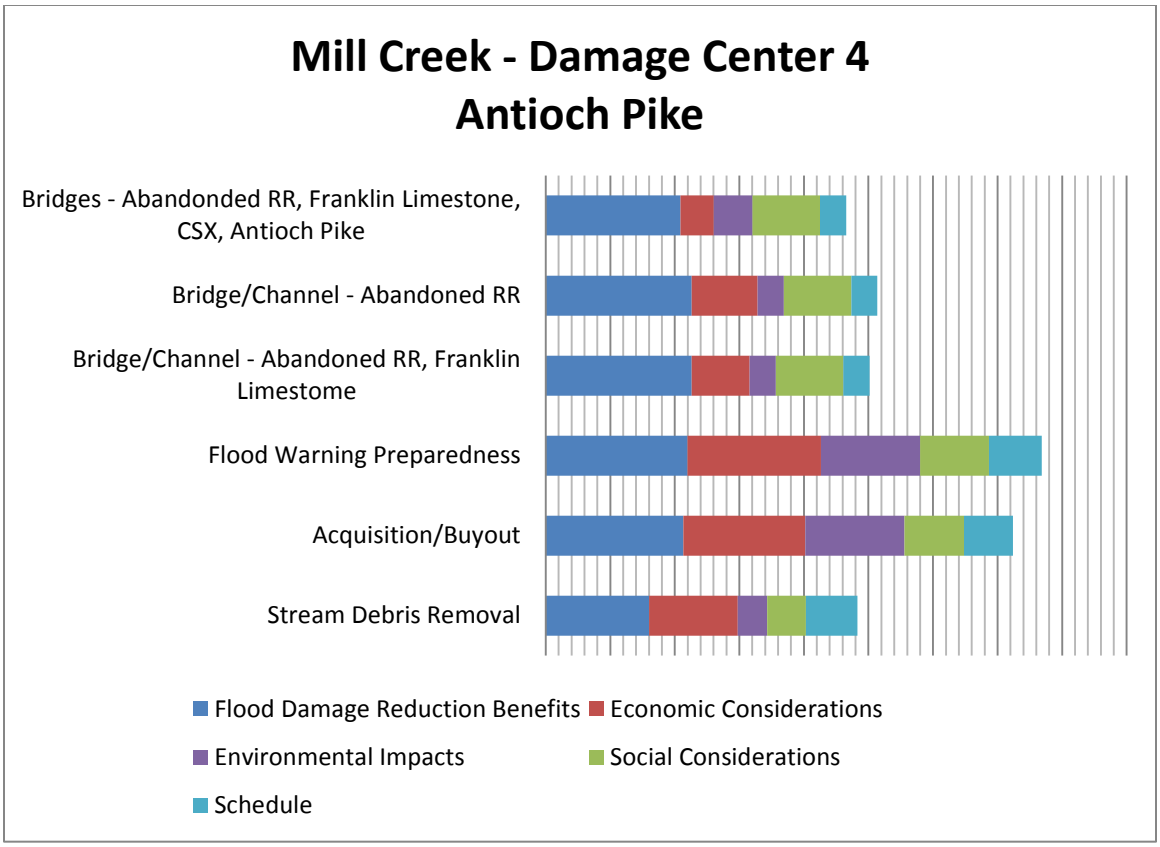


Figure 8.17: Comparison of the Viable Alternatives for Mill Creek Damage Center 4.

Table 8.19 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.19: Evaluation Summary Mill Creek Damage Center Number 4.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Acquisition/Buyout	Best	Minimal	100 year	Average	Local/ Federal	$2,126,000	$99,000	$3,500	$102,00
Bridge Improvement (Abandoned Railroad) & Channel Modification	Good	Significant	100 year	High	State/ Federal	$498,500	$23,205	$2,700	$25,905
Bridge Improvement (Railroad/Franklin Limestone) & Channel Modification	Good	Significant	100 year	High	State/ Federal	$6,419,100	$298,800	$40,900	$339,700
Bridge Improvement (RR/Franklin Limestone/ CSX/Antioch Pike)	Good	Significant	100 year	High	State	$12,667,000	$589,700	$80,900	$670,600
Stream Debris Removal	Good	Minimal	N/A	Average	Local/ Private	$8,784,000	$408,900	$4,000	$412,900

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

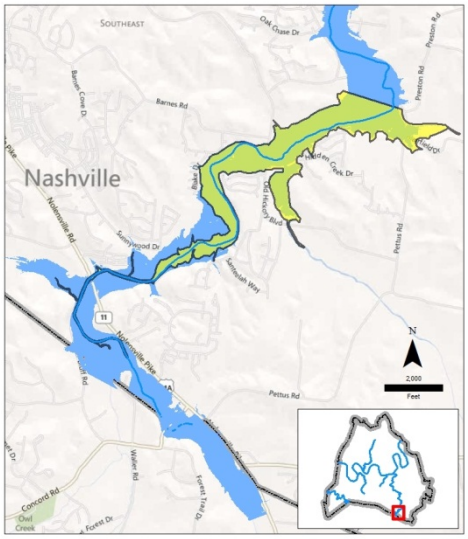
[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.3.5 Mill Creek Regional Alternatives

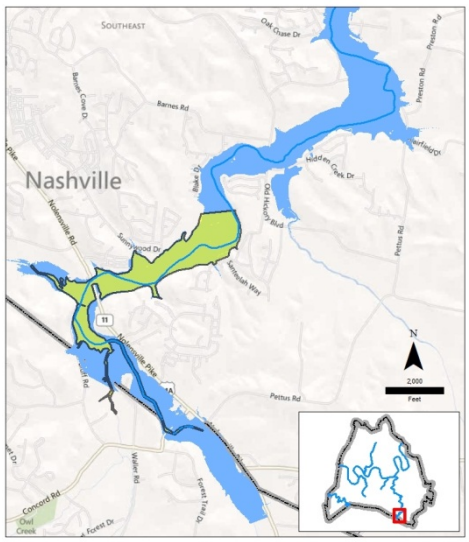
In addition to the damage center-specific alternatives considered in the following sections, two "regional" alternatives were considered for the Mill Creek drainage basin. These alternatives differed from the alternatives considered in previous sections in that their implementation would, from a flooding standpoint, benefit all damage centers located downstream of the proposed solution, not strictly a single damage center.



Regional Reservoirs

The first regional alternative considered was a reservoir built near the Davidson County line at Mill Creek River Mile 16.4, approximately 0.2 miles upstream from Pettus Road. The dry dam reservoir would include an approximately 2,000-LF earthen embankment and a concrete discharge structure (See Section 7 for further description.) Dry dams typically contain no gates or turbines, and are intended to allow the channel to flow freely during normal conditions. During periods of intense rainfall that would otherwise cause floods, the dam holds back excess water, releasing it downstream at a controlled rate. This reservoir would detain a 50.8-square mile drainage area and, at the 500-yr. event, would inundate 347 acres.

A second reservoir formed from a 1,350-LF earthen embankment and discharge structure at Mill Creek River Mile 18.0, approximately 0.75 miles upstream from Old Hickory Boulevard, was also considered. Like the structure at Pettus Road, the Old Hickory Boulevard reservoir would include a dry dam to allow free flow to pass during normal flow conditions, and during peak events the discharge structure would allow attenuated flows to pass through the embankment to reduce the magnitude of downstream peaks. The reservoir would detain a 43.0-square mile drainage area and, at the 500-yr. storm, would inundate 310 acres.



Regional Figures 1 and 2 in Appendix 8.S illustrates the location of these regional alternatives. Cost opinions for these alternatives are summarized in Appendix 8.S.

The Davidson County Flood Insurance Study (FIS) tabulates peak discharges for various return interval

storms at locations along Mill Creek. These flows are summarized in Table 8.20 below. Comparing upstream (MCRM 16.65 near the proposed reservoirs) and downstream (Thompson Lane near Massman Drive) peak flows during the 100-yr. and 500-yr. storm, the FIS suggests that over 50% of the peak flow in Mill Creek occurs in the upstream reaches. In addition, the drainage area above the proposed Old Hickory Blvd. impoundment on Mill Creek represents approximately 50% of the total drainage area at Thompson Lane. Therefore, these reservoirs have the potential to significantly reduce peak flows in the downstream reaches.

Table 8.20: Drainage Area and Peak Discharges at Select Locations on Mill Creek.

Location	Drainage area (Acres)	100-yr. flow (cfs)	500-yr. flow (cfs)
Thompson Lane	92.7	29,700	45,550
MCRM 16.65	43.0	25,194	37,355

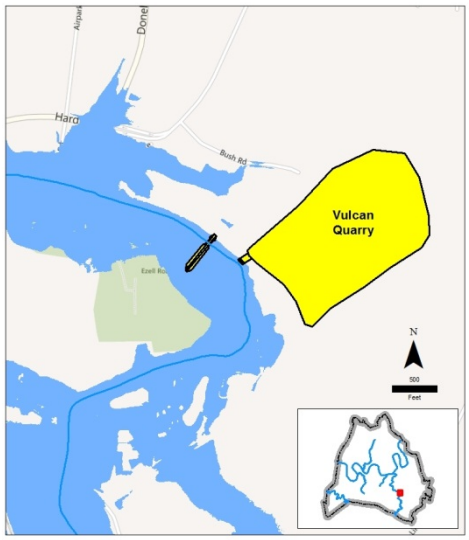
Modeling results for these two reservoirs is summarized in Table 8.21 below. As the table indicates, peak flows are reduced ranging from 16% to 24% depending on the size of the storm for the project at MCRM 16.4. Peak flows at MCRM 18.0 are reduced between 16% and 33% depending on the size of the storm.

Table 8.21: Impact of Regional Reservoirs on Peak Flows in Mill Creek.

	Storm Frequency (yr)	Existing Flow (cfs)	Downstream Flow With Project (cfs)	Downstream Flow Reduction (%)
Mill Creek at RM 16.4	2	9,000	7,500	17%
	10	16,500	13,000	21%
	25	21,000	16,000	24%
	50	24,000	19,000	21%
	100	28,000	22,000	21%
	500	37,000	31,000	16%
Mill Creek at 18.0	2	9,000	6,500	28%
	10	16,500	11,000	33%
	25	21,000	16,000	24%
	50	24,000	19,000	21%
	100	28,000	22,000	21%
	500	37,000	31,000	16%

Regional Off-Channel Storage

The second regional alternative considered for the Mill Creek drainage basin was Off Channel Storage in the Vulcan Quarry. Mill Creek passes within a few hundred feet of the western edge of the Vulcan Quarry off Franklin Limestone Road. The quarry has a volume of approximately 5,000 ac-ft. (1.63 billion gallons) which could be used to attenuate peak flows from extreme storms and reduce flooding in downstream reaches. The 100-yr. and 500-yr. peak flows at river mile 10.3 are approximately 25,000 cubic feet per second (cfs) and 38,000 cfs, respectively. At 13,000 cfs, it would take over 4.5 hours to fill the quarry. The reduction in flow at Mill Creek River Mile 10.3 could be an effective means of reducing downstream flood elevations.



The alternative would require the construction of a flow diversion structure and channel or tunnel to connect the stream and quarry during extreme flow events. A summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.S. Regional Figure 3 in Appendix 8.S illustrates the location of the diversion channel and off-site storage. Cost opinions for these alternatives are summarized in Appendix 8.S.

Comparison of Alternatives

Figure 8.18 provides a comparison of the regional alternatives for Mill Creek. The highest rated alternative for regional consideration was Off Channel Storage. This alternative rated slightly higher than the two reservoir alternatives in Flood Damage Reduction Benefits, Environmental Impacts, and Schedule. However, it is important to note that the costs included for the quarry option do not include the market value of the property related to the existing quarry operation. The actual costs of an easement/acquisition of the property would require discussions with the property owner which would be warranted in a subsequent Feasibility Study. The two reservoir alternatives received identical scores in all of the criteria.

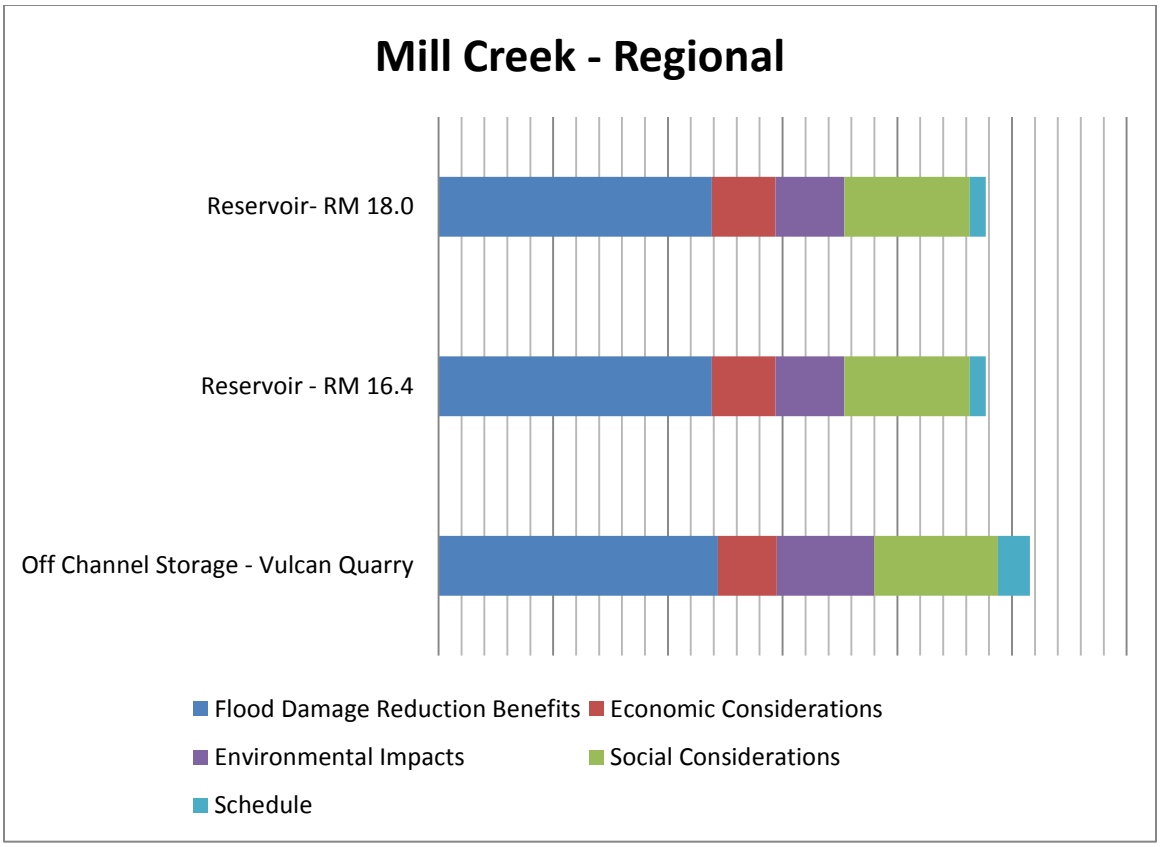


Figure 8.18: Comparison of the Regional Alternatives for Mill Creek.

Table 8.22 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.22: Evaluation Summary Mill Creek Regional Solutions.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Reservoir – RM 16.4	Better	Significant	100 year	Very high	Federal	$33,567,000	$1,562,600	$19,300	$1,581,900
Reservoir – RM 18.0	Better	Significant	100 year	Very high	Federal	$17,605,300	$819,600	$17,000	$836,600
Off Channel Storage – Vulcan Quarry	Better	Significant	100 year	Very high	Federal	$21,173,000	$985,600	$162,800	$1,148,400

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

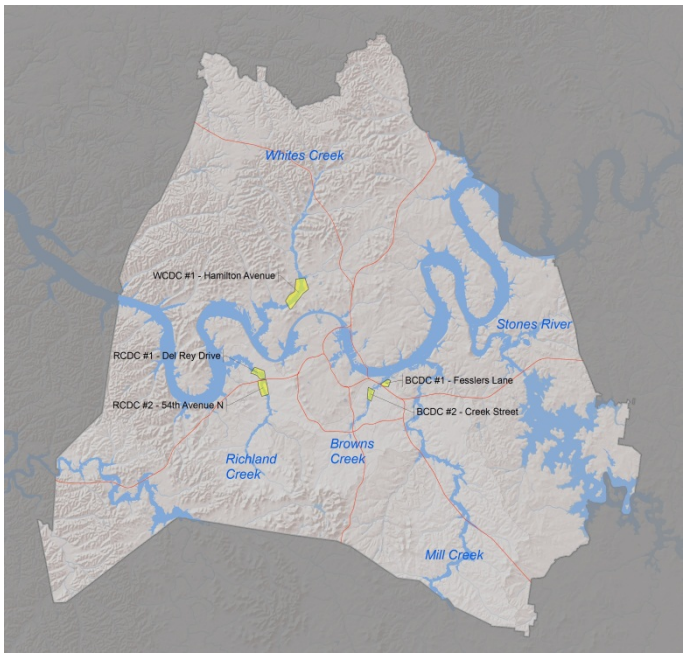
[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.4 Browns, Richland, Whites Creeks

Using the methodology outlined in Section 4 of this report, a total of five damage centers were identified along the lower reaches of Browns Creek in south central Davidson County; along the lower reaches of Richland Creek, in southwest Davidson County; and along Whites Creek near the confluence with Ewing Creek.



8.4.1 Browns Creek Damage Center 1 – Fesslers Lane

Browns Creek Damage Center 1 is located immediately upstream of Lebanon Pike (adjacent to Cumberland River Damage Center 6) in south central Davidson County. Figure 1 in Appendix 8.T illustrates the extent of the damage center. The damage center falls along the right bank (looking downstream) of Browns Creek bounded by Lebanon Pike to the north, Interstate 40 to the south, and Calvery Cemetery to the east. Land use in the damage center is entirely commercial and industrial, with warehousing and intermodal facilities the prominent businesses. Photos of typical construction in the damage center can be found in Appendix 8.T.

Aerial photographs taken on May 3, 2010 indicate sporadic flooding of some of the structures and parking lots in the lower elevations of the damage center, especially along Lebanon Pike. Properties along Fesslers Lane near I-40 appear suitably elevated to avoid floodwaters. No videos were found to document the extent of the flood in the damage center. Figure 2 in Appendix 8.T illustrates the extent of the floodwaters within the damage center during the May, 2010 flood.

Damage Assessments by Metro Codes indicated that most of the properties in the damage center incurred major damage. Figure 1 in Appendix 8.T summarizes the finding of the post-flood damage assessment.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Browns Creek Damage Center 1, and a summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.T.

After evaluation of the alternatives with regards to site specific conditions, the following alternatives were selected for consideration and were carried forward for further evaluation:

- Floodproofing/Elevation – Elevation of commercial and industrial structures was not considered viable; however, all of the developments in the damage center could benefit from floodproofing.

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

Figure 3 in Appendix 8.T identifies the location of the specific parcels that could benefit from commercial floodproofing. Cost opinions for the selected alternatives are summarized in Appendix 8.T.

Comparison of Alternatives

Figure 8.19 summarizes the comparison of the selected alternatives for Browns Creek Damage Center 1. The highest rated alternative in this damage center was Flood Warning/Preparedness. It rated higher than Floodproofing/Elevation in all five of the criteria.

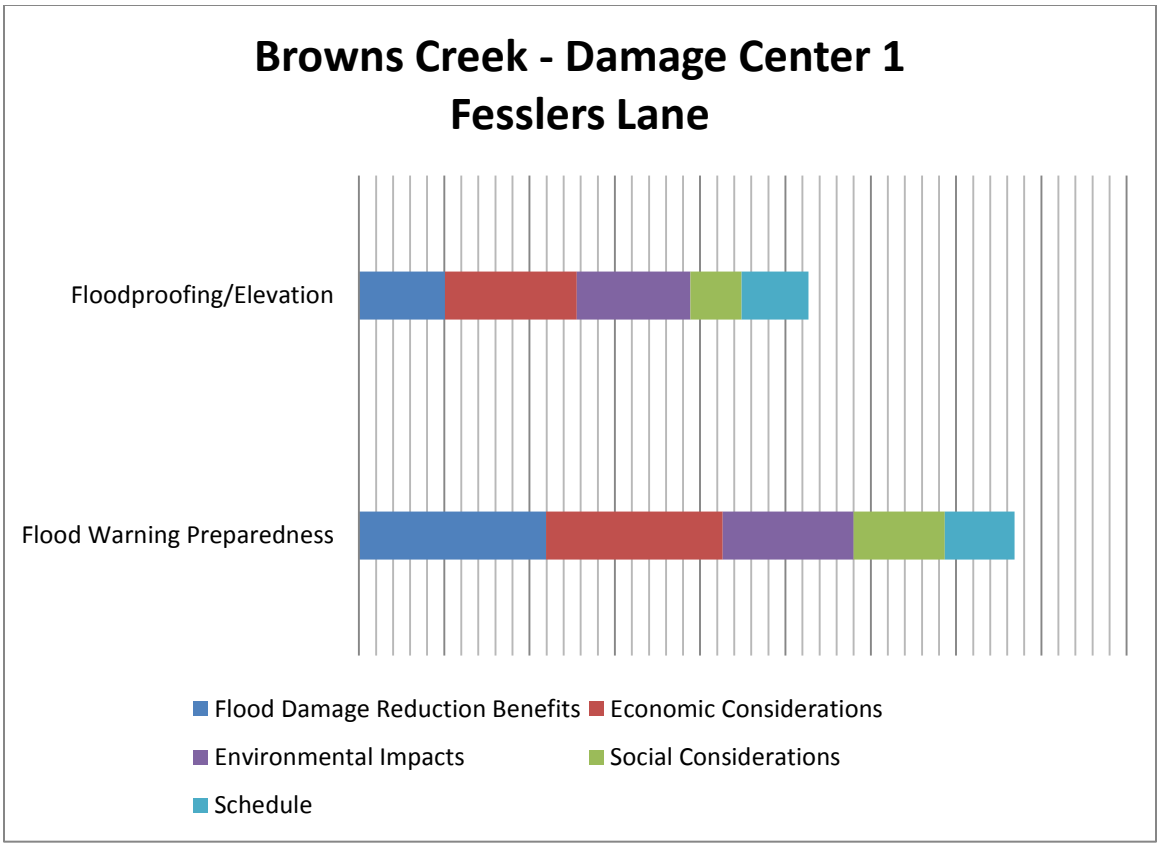


Figure 8.19: Comparison of the Viable Alternatives for Browns Creek Damage Center 1.

Table 8.23 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.23: Evaluation Summary Browns Creek Damage Center 1.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Floodproofing/ Elevation	Good	Minimal	100 year	Average	Private	$30,000	$1,400	N/A	$1,400

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.4.2 Browns Creek Damage Center 2 – Trimble Bottoms

Browns Creek Damage Center 2 is located immediately upstream of Murfreesboro Pike (Lafayette Street) in south central Davidson County. Figure 1 in Appendix 8.U illustrates the extent of the damage center. The damage center falls mainly along the left bank (looking downstream) of Browns Creek in an area known as Trimble Bottoms, bounded by Lafayette Street to the north, CSX railroad to the south and east, and Lewis Street to the west. Land use in the damage center is almost entirely commercial and industrial, with a few residential structures on the western end of the damage center, west of Lewis Street. Photos of typical construction in the damage center can be found in Appendix 8.U.

The area has a history of flooding, and a number of the parcels lack any development (open lots) or have previously been bought out by Metro. Eighteen of the parcels in the area are deemed "Repetitive Loss Structures" indicating a history of flood damage claims. Aerial photographs taken on May 3, 2010 (Figure 2 in Appendix 8.U) provide a poor indication of the degree of flooding in the area due to receding floodwaters; however, the remaining debris and sediment on the exposed roadways suggests flooding extended from Browns Creek to Lewis Street to the west, and that the industrial areas in the northern and southern ends of the damage center were inundated with creek water. No videos were found to document the extent of the flood in the damage center.

Damage assessments by Metro Codes indicated that eight of the properties in the damage center sustained major damage, while 17 of the parcels sustained moderate damage. The post-flood damage assessment conducted by Metro Water Services identified three structures that incurred damages estimated to be in excess of 50% of their value, three structures incurred damages estimated between 40 and 50% of their value, and three structures sustained damages estimated to be less than 40% of their value. Figure 1 in Appendix 8.U summarizes the findings of the post-flood damage assessment.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Browns Creek Damage Center 2, and a summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.U.

After evaluation of the alternatives with regards to site specific conditions, the following alternatives were selected for consideration and were carried forward for further evaluation:

- Bridge Modification / Replacement - The Lafayette Street bridge (US 41) forms a significant constriction in the floodway and floodplain and leads to considerable backwater effects upstream of Lafayette Street. Widening of this segment of the creek would reduce flooding in the Trimble Bottoms area, but at considerable cost.

- Channel Modification - A fifty foot wide channel along the existing floodplain adjacent to the creek should be investigated to move floodwaters thorough the damage center.

- Bridge Improvement/Channel Modification – This alternative combines the actions taken by the previous two alternatives.

- Floodproofing/Elevation – Elevation of commercial and industrial structures was not considered viable; however, all of the commercial developments in the damage center could benefit from floodproofing.

- Acquisition/Buyout – There are a few residential structures in the damage center that were considered for acquisition.

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

Figure 3 in Appendix 8.U identifies the location of the specific parcels that could benefit from industrial and commercial floodproofing or home buyout. Figure 4 in Appendix 8.U identifies the location for a proposed channel widening and the location of bridge modifications to protect the commercial, industrial, and residential properties in the damage center. Cost opinions for the selected alternatives are summarized in Appendix 8.U.

Comparison of Alternatives

Figure 8.20 summarizes the comparison of the viable alternatives for Browns Creek Damage Center 2. The highest rated alternative in this damage center was Acquisition / Buyout, followed by Flood Warning/Preparedness, Floodproofing/Elevation, Channel Modification, Bridge Improvement and Channel Modification/Bridge Improvement. Acquisition/Buyout rated highest in only Flood Damage Reduction Benefits, but that score was enough to make it the highest rated alternative overall. Flood Warning/Preparedness rated highest in Schedule, Economic Considerations, and Social Considerations. Floodproofing/Elevation rated poorly in Social Considerations. Of the Bridge Improvement and Channel Modification alternatives, Channel Modification was the highest rated due to its high scores in Economic Considerations and Flood Damage Reduction Benefits.

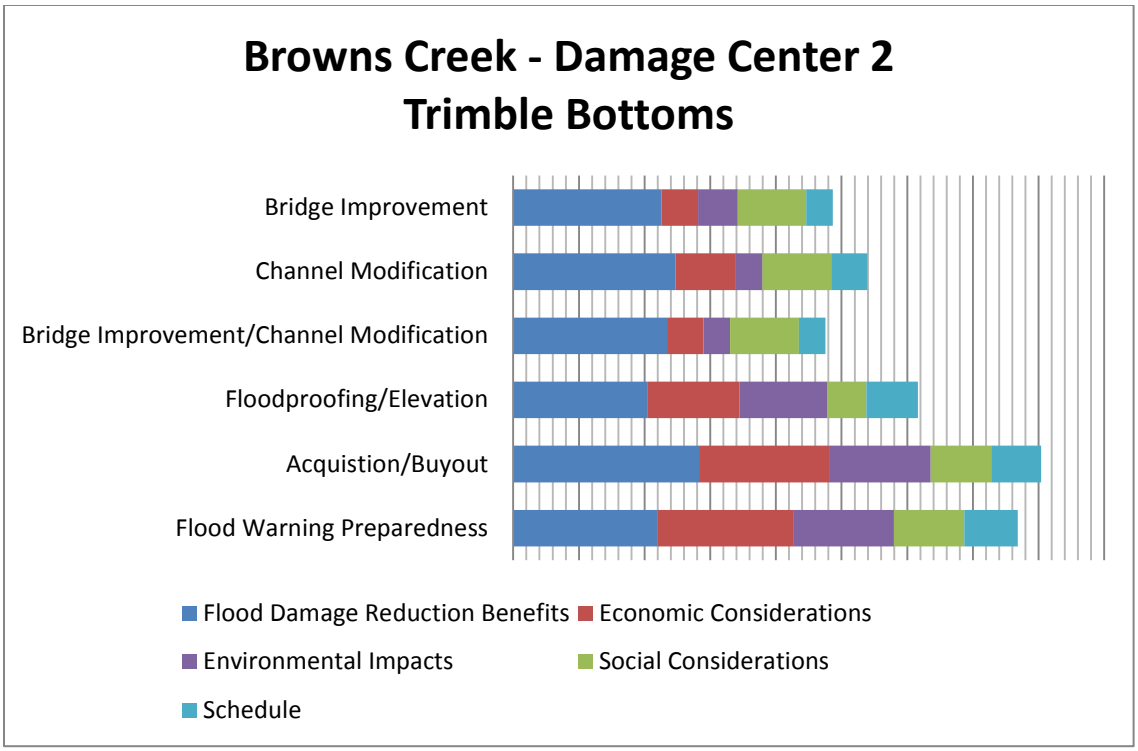


Figure 8.20: Comparison of the Viable Alternatives for Browns Creek Damage Center 2.

Table 8.24 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.24: Evaluation Summary Browns Creek Damage Center 2.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Acquisition/ Buyout	Best	Minimal	100 year*	Average	Local/ Federal	$376,800	$17,600	$1,000	$18,600
Floodproofing/ Elevation	Good	Minimal	100 year	Average	Private	$1,212,400	$56,500	N/A	$56,500
Bridge Improvement	Good	Significant	100 year	High	State	$10,691,100	$497,700	$59,800	$557,500
Channel Modification	Good	Significant	100 year	High	Federal	$1,069,400	$49,800	$5,700	$55,500
Bridge Improvement & Channel Modification	Good	Significant	100 year	High	State/ Federal	$11,760,300	$547,500	$65,400	$612,900

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.4.3 Richland Creek Damage Center 1 – Delray Drive

Richland Creek Damage Center 1 is located in southwest Davidson County immediately north of Interstate 40. Figure 1 in Appendix 8.V illustrates the extent of the damage center. The damage center is bounded by Briley Parkway to the west, Morrow Road to the east, and West Park to the north. The damage center is almost entirely residential, with cottage-style single family homes on small lots. Photos of typical construction in the damage center can be found in Appendix 8.V.

During the May 2010 flood, flooding was extensive in this damage center. Damage assessments by Metro Codes indicated that 172 of the properties in the damage center sustained major damage, while 44 of the parcels sustained moderate damage. Aerial photographs taken on May 3, 2010 (Figure 2 in Appendix 8.V) provide an indication of the degree of flooding in the area. The post-flood damage assessment conducted by Metro Water Services identified 51 structures with damages estimated to be greater than 50% of their value, 73 structures which sustained damages estimated between 40 and 50% of their total value, and 115 structures which incurred damages estimated to be less than 40% of their value. Figure 1 in Appendix 8.V summarizes the finding of the post-flood damage assessment.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Richland Creek Damage Center 1, and a summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.V.

After evaluation of the alternatives with regards to site specific conditions, the following alternatives were selected for consideration and were carried forward for further evaluation:

- Channel Modification - A fifty foot wide channel along the existing floodplain adjacent to the creek should be investigated to move floodwaters thorough the damage center.

- Acquisition/Buyout – Numerous residential properties along Morrow Road, Delray Drive, Conch, Drive, Conway Street, and Hite Street, along with homes on 57th Avenue N. and Winn Street were considered for acquisition.

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time

allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

Figure 3 in Appendix 8.V identifies the location of the specific parcels that could benefit from residential elevation or home buyout. Figure 4 in Appendix 8.V identifies the location for proposed channel widening to mover water more efficiently through the damage center. Cost opinions for the selected alternatives are summarized in Appendix 8.V.

Comparison of Alternatives

Figure 8.21 summarizes the comparison of the selected alternatives for Richland Creek Damage Center 1. The highest rated alternative in this damage center was Acquisition/Buyout, followed by Flood Warning/Preparedness, and Channel Modification. Acquisition/Buyout rated highest only in Flood Damage Reduction Benefits, but that was sufficient to make it the highest rated alternative overall. Flood Warning/Preparedness rated highest in Schedule, Economic Considerations, and Social Considerations. Channel Modification rated relatively low in Schedule, Economic Considerations, and Environmental Impacts causing it to be the lowest rated alternative.

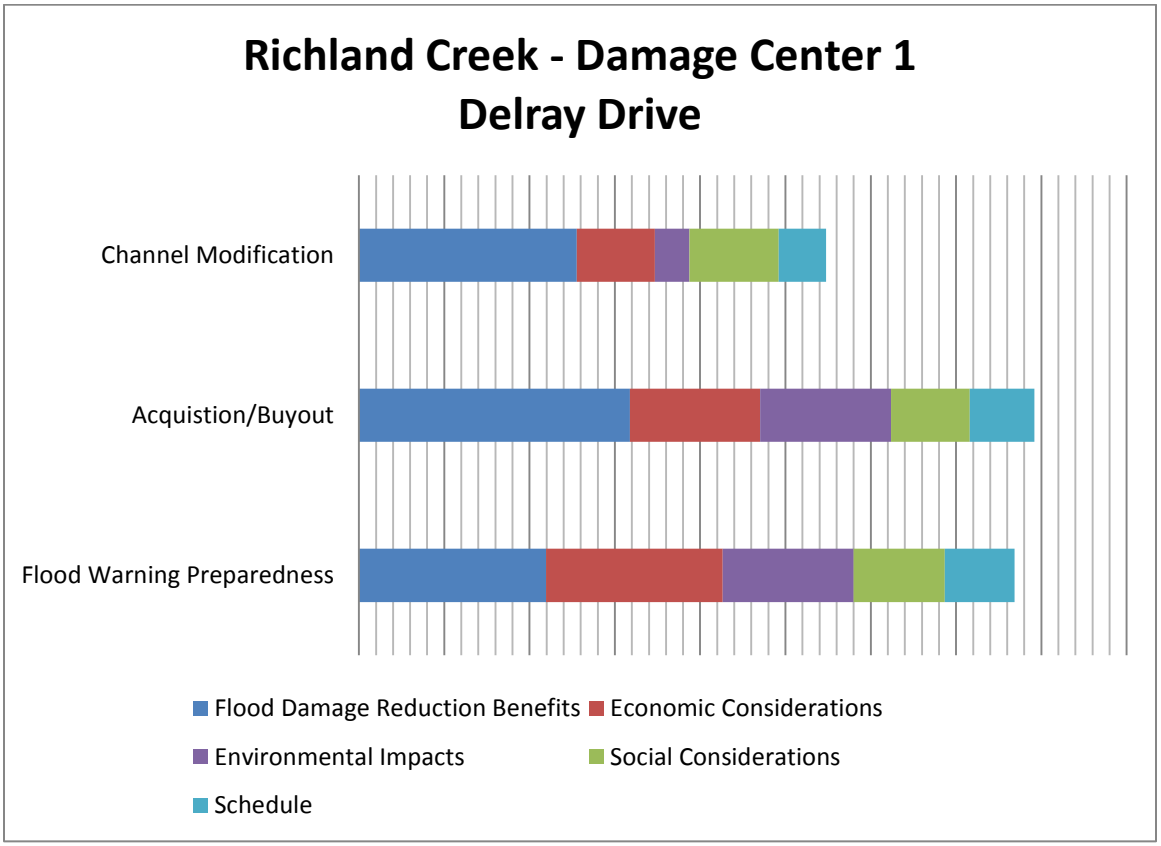


Figure 8.21: Comparison of the Viable Alternatives for Richland Creek Damage Center 1.

Table 8.25 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation

complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.25: Evaluation Summary Richland Creek Damage Center 1.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Acquisition/ Buyout	Best	Minimal	100 year	Average	Local/ Federal	$14,301,300	$665,800	$17,200	$683,000
Channel Modification	Good	Significant	100 year	High	Federal	$1,230,700	$57,300	$8,500	$65,800

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.4.4 Richland Creek Damage Center 2 – Charlotte Pike

Richland Creek Damage Center 2 is located in southwest Davidson County immediately south of Interstate 40. Figure 1 in Appendix 8.W illustrates the extent of the damage center. The damage center is bounded by I-40 and White Bridge Road to the west, 54th avenue to the east, and McCabe Golf Course to the south. The damage center contains a commercial district in the northern end, extending along White Bridge Road to the west and is primarily residential to the south, with a mix of scottage-style single family homes on small lots. Photos of typical construction in the damage center can be found in Appendix 8.W.

During the May, 2010 flood, the commercial area was inundated with Richland Creek floodwaters. Several commercial establishments in the strip mall that borders the left bank of the creek were significantly damaged. Video taken by security cameras at the time of the flood (http://www.youtube.com/watch?v=iGXww36_R9c) show floodwaters in excess of 4 ft. in the buildings. Aerial photographs taken on May 3, 2010 (Figure 2 in Appendix 8.W) provide a poor indication of the degree of flooding in the area due to receding floodwaters at the time of the photo and low hanging clouds; however, the remaining debris and sediment on the exposed roadways and parking lots suggests flooding extended from the creek to Morrow Road to the east, and half way to White Bridge Road to the west, encompassing an area that roughly corresponds to the 500-yr. flood plain. To the south, residential areas along Meadow Crest Lane and Bon Aire Circle sustained heavy damage, with parcels along 54th Avenue incurring more moderate flooding.

Damage assessments by Metro Codes indicated that all of the commercial properties along Charlotte Pike in the north end of the damage center sustained major damage. The post-flood damage assessment conducted by Metro Water Services revealed the worst residential flooding occurred to the south along Meadow Crest Lane, with five homes sustaining damages estimated to be in excess of 50% of their value and several more incurring damages estimated to be 40% or less of their value. Figure 1 in Appendix 8.W summarizes the finding of the post-flood damage assessment.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Richland Creek Damage Center 2, and a summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.W.

After evaluation of the alternatives with regards to site specific conditions, the following

alternatives were selected for consideration and were carried forward for further evaluation:

- Channel Modification - A fifty foot wide channel along the existing floodplain adjacent to the creek should be investigated to move floodwaters thorough the damage center.

- Floodproofing/Elevation – Elevation of commercial and industrial structures was not considered viable; however, all of the commercial developments in the damage center could benefit from floodproofing.

- Acquisition Buyout – Residential Properties along Meadowcrest, 53rd Ave N., and 54th Ave N. were considered for acquisition.

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

Figure 3 in Appendix 8.W identifies the location of the specific parcels that could benefit from industrial or commercial floodproofing, residential elevation or home buyout. Figure 4 in Appendix 8.W identifies the location for proposed channel widening to mover water more efficiently through the damage center. Cost opinions for the selected alternatives are summarized in Appendix 8.W.

Comparison of Alternatives

Figure 8.22 summarizes the comparison of the selected alternatives for Richland Creek Damage Center 2. The highest rated alternative in this damage center was Acquisition/Buyout, followed by Flood Warning/Preparedness, Floodproofing/Elevation, and Channel Modification. Acquisition/Buyout only rated highest in Flood Damage Reduction Benefits, but that rating was enough to make it the highest rated alternative overall. Flood Warning/Preparedness rated highest in Schedule, Economic Considerations, and Social Considerations. Floodproofing/Elevation rated lowest in Social Considerations and Flood Damage Reduction Benefits, but was still rated higher than Channel Modification. Channel Modification rated poorly in Schedule, Economic Considerations, and Environmental Impacts causing it to be the lowest rated alternative.

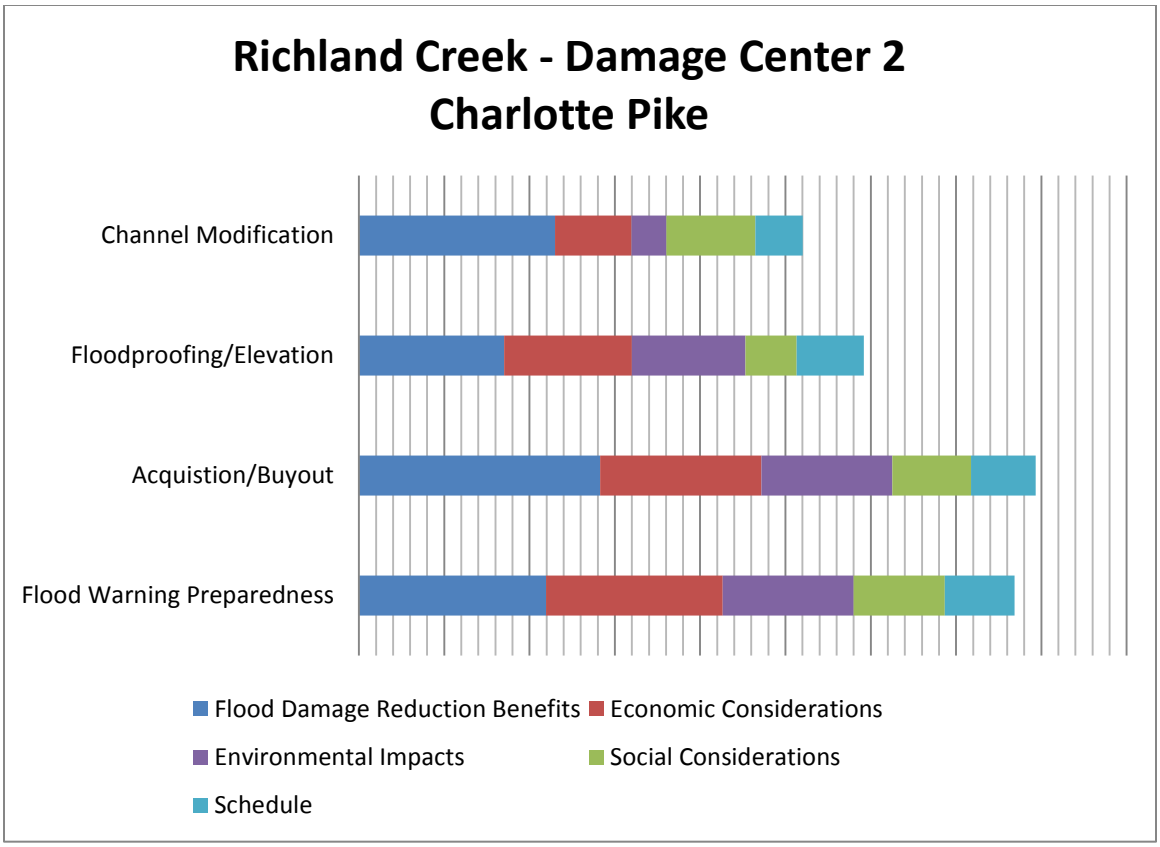


Figure 8.22: Comparison of the Viable Alternatives for Richland Creek Damage Center 2.

Table 8.26 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.26: Evaluation Summary Richland Creek Damage Center Number 2.

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Floodproofing/ Elevation	Good	Minimal	100 year	Average	Private	$405,100	$18,900	N/A	$18,900
Acquisition/ Buyout	Best	Minimal	100 year	Average	Local/ Federal	$3,360,600	$156,500	$3,500	$160,000
Channel Modification	Good	Significant	100 year	High	Federal	$2,739,200	$127,600	$17,100	$144,600

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

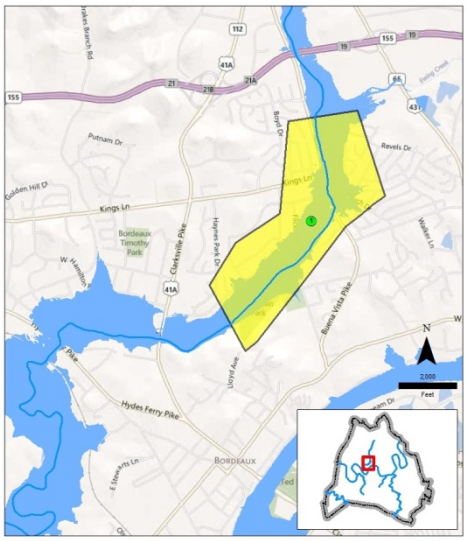
[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

8.4.5 Whites Creek Damage Center 1 – West Hamilton Road

Whites Creek Damage Center 1 is located in northern Davidson County in the Bordeaux area immediately below the confluence with Ewing Creek. Figure 1 in Appendix 8.X illustrates the extent of the damage center. The damage center is situated in an area that is roughly bounded by Whites Creek Pike to the East, Clarksville Pike to the west, Trinity Lane to the south, and Briley Parkway to the north. West Hamilton Road and Buena Vista Pike follow the creek as it bisects the damage center. The damage center is mostly residential, with single family homes on small lots. Photos of typical construction in the damage center can be found in Appendix 8.X.



During the May, 2010 flood, the properties along West Hamilton Road and Buena Vista Pike were severely damaged. Video taken at the time of the flood (http://www.youtube.com/watch?v=BgW6LmnTooQ) shows floodwaters up to the roofline of several homes, and roadways under feet of water. Aerial photographs taken on May 3, 2010 (Figure 2 in Appendix 8.X) provide a poor indication of the degree of flooding in the area due to receding floodwaters at the time of the photo.

Damage assessments by Metro Codes indicated that over 90 of the residential properties along Buena Vista Pike and West Hamilton Road sustained major damage, while over 40 sustained moderate damage. The post-flood damage assessment conducted by Metro Water Services indicated 26 homes sustained damages estimated to be greater than 50% of their value, 63 homes sustained damages estimated between 40 -50% of their value, and 82 incurred damages estimated to be less than 40% of their value. Figure 1 in Appendix 8.X summarizes the finding of the post-flood damage assessment.

Summary of Alternatives Evaluated

Eleven alternatives were considered for Whites Creek Damage Center 1, and a summary of the alternative screening assessment is found in the Alternatives Matrix in Appendix 8.X.

After evaluation of the alternatives with regards to site specific conditions, the following alternatives were selected for consideration and were carried forward for further evaluation:

- Bridge Replacement with Channel Modification - During the 100-year flood event, a two foot increase in headwater occurs at both Tucker Road and Buena Vista Pike. Multiple permutations of improving the two bridges and modifying the channel were examined as alternatives

- Channel Modification - Channel modification included widening the channel by as much as 50 feet to reduce the 100-year flood elevations between one and four feet. Multiple permutations of improving the two bridges and modifying the channel were examined as alternatives

- Floodproofing/Elevation – Elevation of commercial and industrial structures was not considered viable; however, all of the commercial developments in the damage center could benefit from floodproofing. No residential properties were considered for elevation.

- Acquisition/Buyout – Numerous residential properties along West Hamilton Drive, including Tucker Road, Flicker Drive, Buena Vista Pike, Hummingbird Drive, Mallard Drive, Kings Lane and Crouch Drive were considered for acquisition. In addition, homes along Crouch Drive, including Rowan Drive, Augusta Drive, and Atwell Drive were considered for buyout.

- Flood Warning/Preparedness – Flood warning is highly beneficial for public safety as it provided flood forecast and flood inundation predictions that allow for evacuation of citizens in harm's way in advance of the flood inundation. Adequate warning time allows equipment to be moved out of predicted inundation zones and homes and commercial facilities to be prepare for flooding to minimize the extent of flood damage.

Figure 3 in Appendix 8.X identifies the location of the specific parcels that could benefit from industrial or commercial floodproofing or home buyout. Figure 4 in Appendix 8.X identifies the location for proposed channel widening and bridge modification to move water more efficiently through the damage center. Cost opinions for the selected alternatives are summarized in Appendix 8.X.

Comparison of Alternatives

Figure 8.23 summarizes the comparison of the selected alternatives for Whites Creek Damage Center 1. The highest rated alternatives for Whites Creek were Acquisition / Buyout and Flood Warning/Preparedness. Acquisition/Buyout was rated highest due to its high score in Flood Damage Reduction Benefits. Flood Warning/Preparedness rated higher in Schedule, Economic Considerations, and Social Considerations. Floodproofing Elevation rated poorly in Social Considerations and Flood Damage Reduction Benefits. Of all of the Channel Modification/Bridge Improvement combinations, Channel Modification alone was the only alternative to rate higher than Floodproofing/Elevation. This was due to the relatively high rating for Channel Modification in Flood Damage Reduction Benefits and Social Considerations. All of the other combinations of Channel Modification and Bridge Improvement were the lowest rated alternatives due to their low ratings in Environmental Impacts, Economic Considerations, and Schedule.

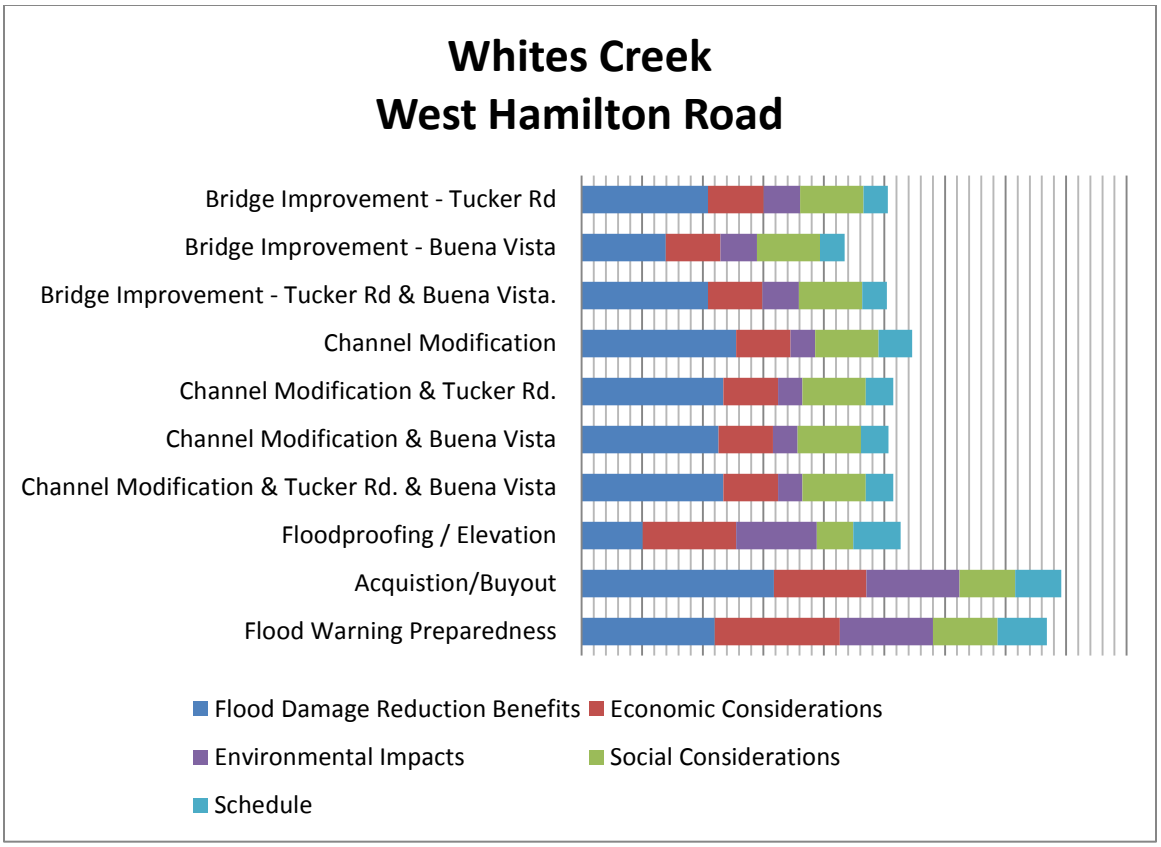


Figure 8.23: Comparison of the Viable Alternatives for Whites Creek Damage Center 1.

Table 8.27 provides a comparison of each of the evaluated alternatives in terms of important qualitative (public safety, environmental impact, level of protection, and implementation complexity) and quantitative (capital and operations and maintenance costs) factors. As noted in Section 7.2, all of the potential economic benefits were not required for the Reconnaissance Level evaluation. A Feasibility Study is required to better define the annual benefits of the flood damage reduction solutions and to provide the additional evaluation of alternative necessary to identify solutions that qualify for federal funding.

Table 8.27: Evaluation Summary Whites Creek Damage Center

Alternative	Public Safety[1]	Adverse Environmental Impacts[2]	Level of Protection[3]	Implementation Complexity[4]	Potential Funding Source[5]	Total Capital Cost[6]	Annual Capital Cost[7]	Annual O&M Cost[8]	Annual Capital & O&M Costs[9]
Flood Warning	Best	None	1,000 year	Average	Local/ Federal	$270,000	$12,600	$135,000	$147,600
Acquisition/Buyout	Best	Minimal	100 year*	Average	Local/ Federal	$28,876,000	$1,344,200	$73,900	$1,418,100
Floodproofing/Elevation	Good	Minimal	100 year	Average	Private	$21,900	$1,000	N/A	$1,000
Bridge Improvement (Tucker Rd.)	Good	Significant	100 year	High	State	$1,517,500	$70,700	$9,300	$80,000
Bridge Improvement (Buena Vista)	Good	Significant	100 year	High	State	$3,198,800	$148,900	$17,700	$166,600
Bridge Improvement (Tucker Rd. & Buena Vista)	Good	Significant	100 year	High	State	$4,716,300	$219,600	$27,000	$246,600
Channel Modifications	Good	Significant	100 year	High	Federal	$2,747,800	$127,900	$15,700	$143,600
Bridge Improvement (Tucker Rd.) & Channel Modification	Good	Significant	100 year	High	State/ Federal	$4,265,300	$198,600	$25,000	$223,600
Bridge Improvement (Buena Vista) & Channel Modification	Good	Significant	100 year	High	State/ Federal	$5,946,600	$276,800	$33,400	$310,200
Bridge Improvement (Tucker Rd. & Buena Vista) & Channel Modification	Good	Significant	100 year	High	State/ Federal	$7,464,100	$347,500	$42,700	$370,200

The classification of the criteria listed in this table are based on the qualitative assessment of the rating curves in Appendix 7.C

[1] 'Good' indicates a marginal impact on Public Safety while 'Better' and 'Best' represent incremental improvements to Public Safety

[2] 'None' indicates a relatively beneficial impact. 'Minimal' indicates a benign impact. 'Significant' indicates moderate to substantial environmental impacts

[3] Alternatives were designed to provide flood protection up to one of three flood elevations: 100 year, 500 year, or 1000 year

[4] 'Average' represents a relatively simple implementation. 'High' indicates a greater degree of complexity. 'Very High' indicates a complex implementation

[5] Four different Potential Funding Sources are considered: 'Federal', 'State', 'Local', and 'Private'

[6] Total Capital Cost is the Estimated Construction Cost Opinion for the Alternative

[7] Annual Capital Cost is the annualized cost of the Total Capital Cost based on a 50 year service life and 4% interest rate

[8] Annual O&M Cost is the estimated annual cost to operate and/or maintain an Alternative

[9] Annual Capital & O&M Costs is the sum of the Annual Capital Cost and Annual O&M Cost

9.0 Ongoing Metro Flood Damage Reduction Programs

9.1 Metro Water Services Awareness of Flood Events (SAFE) Program

One of the many flood response efforts undertaken by Metro Government following the flood of May 2010 was the creation of a new comprehensive flood warning system. This system is termed the Situational Awareness for Flooding Events, or the Nashville SAFE Program for short. Primary responsibility for the SAFE program rests with Metro Water Services (MWS). In the creation of the SAFE Program, MWS collaborated with the Metro Office of Emergency Management (OEM), Metro Nashville Police Department (MNPD), Metro Planning Department (Planning), Metro ITS (ITS), the U.S. Army Corps of Engineers (USACE), the U.S. Geological Survey (USGS), and the National Weather Service (NWS).

The SAFE Program was developed to assist emergency personnel in making prudent decisions in anticipation of and during flood events for public safety. This collaborative effort included the development and maintenance of a flood warning system utilizing GIS tools, numerical models, real-time and forecasted data, communications and coordination between agencies, decision support tools, and targeted response actions. The result is a flood warning system that specifically satisfies the needs of local emergency managers, is well-understood by all, and is cost-effective to stakeholders.

Watershed Advisory Guides

Watershed Advisory Guides, or WAGs as they are commonly known, were created for the six (6) primary watersheds in Davidson County; Browns Creek, Richland Creek, Whites Creek, Mill Creek, Harpeth River, and Cumberland River. WAGs are reference manuals that combine flood modeling, inundation mapping, and GIS data into a myriad of watershed-specific flood impact assessments, grouped into 11 “Action Levels”. The WAGs provide MWS, OEM, and Planning with the decision support needed to determine and prioritize flood response actions at each Action Level:

- Evacuation or Closure of Neighborhood Housing, Public Places, or Critical Facilities
- Closure of Bridges or Roads
- Sandbag Staging at Strategic Locations
- Sandbagging Shorelines

WAGs also contain graphical depictions of watersheds and stream profiles such that emergency managers can visually see the impacts of flooding, as well as tables indicating the predicted timing between Action Levels. Data contained in the WAGs is also used as input to the Nashville SAFE online mapping tool, which was developed by Planning as part of this collaborative effort.

Watershed Advisors

Having primary responsibility for the Nashville SAFE Program, MWS selected experienced and professional staff members to serve the role of Watershed Advisors. Watershed Advisors are

trained scientists and engineers whose purpose is to analyze current and predicted stream conditions and make recommendations to OEM at the Emergency Operations Center (EOC) during a flood event in an attempt to minimize potential human loss or injury and property damage from flooding. Emergency procedures and standards of practice for Watershed Advisors, called Job Action Sheets, were developed in order to ensure that Advisors get a full understanding of the interrelationships between data and are able to interpret it, in real time, while collaborating with NWS, USGS, USACE, and OEM personnel. Watershed Advisors have been trained through multiple in-service training sessions and table-top exercises.

Emergency Support Coordination

MWS provides additional flood warning support and emergency management coordination with OEM, NWS, and Planning during activations of the EOC. MWS staff, or their designees, is stationed at the EOC during flood events to assist in the real-time development of emergency action plans, customized specifically for the imminent flood event.

Education and Outreach

MWS, in conjunction with OEM and Planning, developed a workflow to effectively communicate Action Level impacts to Metro Nashville Police Department (MNPD) Officers in the field using Action Level Maps, accessible on the Officer's mobile data terminals. To educate Officers on the many uses of Action Level Maps, a training video was developed and implemented as part of the required training curriculum throughout MNPD.

Remote Sensing Data Integration

MWS continues to improve the accuracy and effectiveness of the Nashville SAFE Program through the integration of additional remote sensing data. Currently, remote sensing data at 18 rain gages, river stage data from the Dry Creek Weir, and video collected by mobile webcams are being integrated into the Nashville SAFE Program online mapping tool.

9.2 Nashville Emergency Response Viewing Engine (NERVE)

In an effort to communicate information from the SAFE Program during a flood event, Metro has developed NERVE which is a one-stop on-line interactive mapping site designed to provide timely information related to real-time natural or man-made emergencies in Nashville. As an emergency arises, the web site will provide information about road closures, evacuation areas or routes, shelters and relief centers. Citizens can use the site to see what is happening around them and to find a path to their destination which avoids closed roads or other obstructions. The local media will also utilize NERVE as a source for communicating with the public regarding recommended evacuations and road closures.

The web site address is http://maps.nashville.gov/NERVE. An image of the web site is included below.

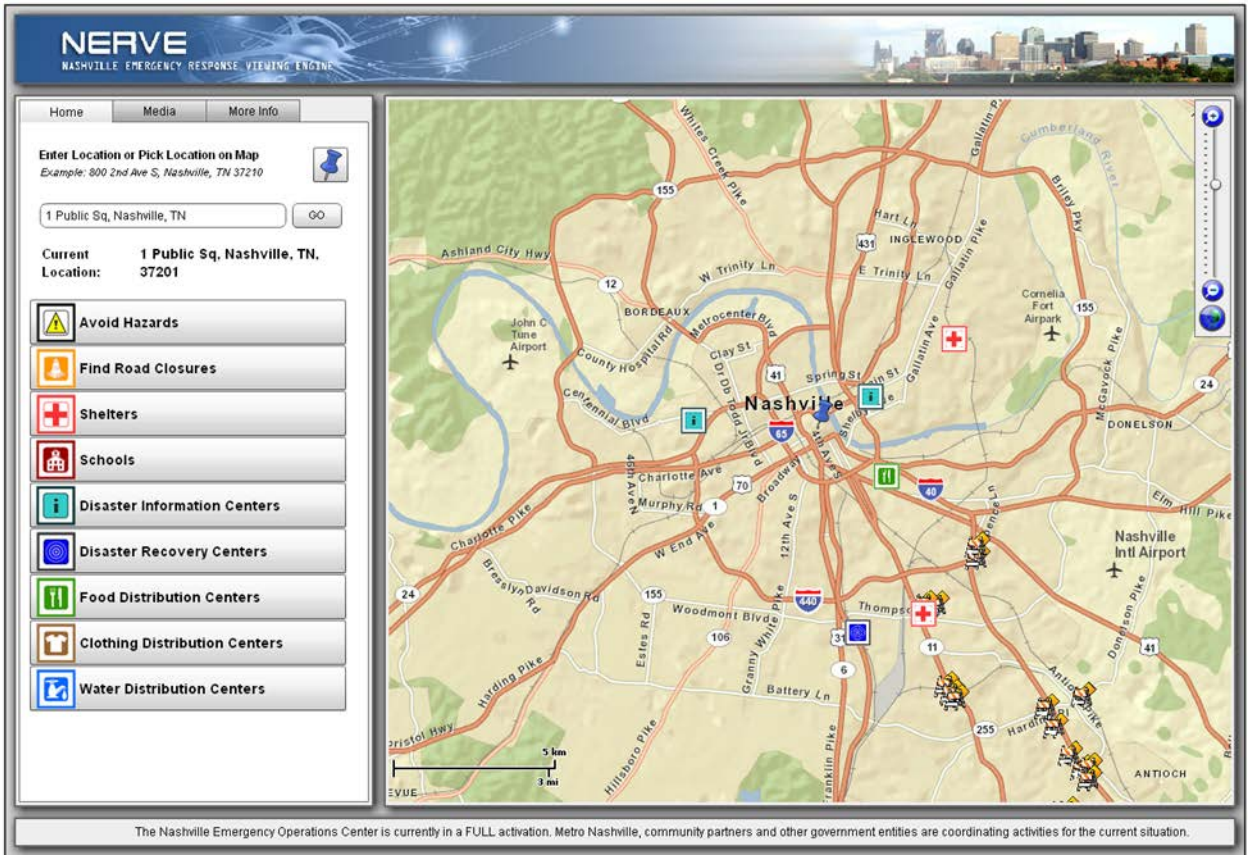


Figure 9.1: Nashville Emergency Response Viewing Engine Webpage.

9.3 Metro Water Services Home Buyout Program

Acquisition of properties that are susceptible to extreme flooding on a frequent basis has been a part of the Metro Nashville flood mitigation strategy for more than 30 years. The Home Buyout Program is a program used by MWS to reduce damage and losses caused by flooding along the Cumberland River and associated tributaries where a structural flood damage reduction project, such as widening the channel or constructing a stormwater detention basin, is not considered to be cost effective or beneficial. When elevation or modification of a building located in a special flood hazard area is not practical, purchase and removal may be the most effective and efficient way to prevent future losses.

Prior to the flood of May 2010, Metro Nashville had acquired and removed more than 50 residential structures from local floodplains and floodways since the 1970's. Following the May 2010 flood, this mitigation strategy has become more formalized and more focused. Known currently as the Home Buyout Program, this flood mitigation strategy is a key component of floodplain management efforts by Metro Water Services. Through the Home Buyout Program, MWS has identified more than 300 residential structures for acquisition and has completed the purchase and removal of more than 170 of these structures.

Prioritization of Structures for Acquisition

The Home Buyout Program incorporates administrative policies to manage the program as a logical, fair program based upon potential flood risk and actual flood loss. Due to the limits of available federal funding, buyout projects must be prioritized. Flood prone parcels are prioritized by measurable and unbiased criteria:

1. Actual Damages. Actual damages are determined using data from the May 2010 flood and other previous events, as available, which indicates structures have actually incurred damage due to flooding. Data used include:
   - NFIP Flood Insurance Claims
   - FEMA Repetitive Loss Properties
   - May 2010 Flood Event Damage Assessments
   - Substantial Damage

2. Potential Damages. Potential damages are determined by one or more overlays of digital data which indicate that a structure (building) has the potential to flood based on available flood hazard mapping and related data. Data used include:
   - FEMA Flood Insurance Study (FIS)
   - FEMA Digital Flood Insurance Rate Map (DFIRM)
   - Previous MWS Basin Plans and Flood Studies
   - Previous USACE Studies
   - MWS identified Repetitive Loss Areas
   - Elevation Certificates
   - Soil Stability

3. Special Considerations. Special considerations are indicators that a site or area may need protection from flooding regardless of historic actual damages incurred or identified potential damages. The following special considerations are used:
   - NFIP Insurance
   - Building Use
   - Variances to Floodplain Management Regulation
   - Contiguous with other Flood Control or Open Space Projects
   - Historical Significance

A scoring system using these criteria is used to determine which properties are best suited for the buyout program and to rank each property.

A prioritized list of eligible properties for acquisition is maintained and continually updated as additional information becomes available. These properties are ready candidates for acquisition when funding, either federal or local, becomes available.

Home Buyout Program Funding

Home Buyout Programs are recognized by the Federal Emergency Management Agency (FEMA) and the Tennessee Emergency Management Agency (TEMA) as a viable and common flood mitigation strategy. FEMA supports Home Buyout Programs financially through grant programs. Home Buyout Programs ultimately result in reduced costs for the National Flood Insurance Program (NFIP) by removing from the insurance pool those structures that are most likely to incur flood damages and file resultant flood insurance claims. For qualifying structures, FEMA grants cover 75% of the cost of acquisition and removal.

9.4 Metro Water Services Treatment Plant Mitigation Measures

The May 2010 severely impacted two of Metro's three wastewater treatment plants (Dry Creek WWTP and Central WWTP) and one of Metro's two water treatment plants (K.R. Harrington WTP). Metro's second water treatment plant (Omohundro WTP) remained in service throughout the flood but came to within inches of being flooded.

Shortly after the floodwaters receded, Metro Water Services commenced with flood related response work at all their facilities. FEMA's Public Acceptance Program assists communities with the costs of flood damage repairs to return the facilities back to their pre-flood condition and improve their resiliency against future flood disasters. As a part of this program, Metro Water Services has submitted Hazard Mitigation Proposals (HMPs) to FEMA for each of the impacted treatment facilities. The HMPs are currently under review and consideration by FEMA. The following paragraphs provide a general description of the HMPs for each of the facilities.

9.4.1 Dry Creek WWTP

The Dry Creek Wastewater Treatment Plant (WWTP) receives wastewater from northeastern Davidson County and portions of Sumner County. It is located in Madison, Tennessee on the north bank of the Cumberland River near the Rivergate Mall. The facility has a rated capacity of 24 million gallons per day (MGD) and serves a population of over 112,000 people.

Floodwaters eclipsed the protective berm around the plant and flooded the site. A majority of the buildings on the site were flooded. Flood damage at the WWTP was extensive, estimated at approximately $20 million. The facility was out of service for two months following the flood.

A Hazard Mitigation Proposal (HMP) was prepared for the Metro Water Services' Dry Creek Wastewater Treatment Plant (DCWWTP). To avoid flood damage this extensive in the future, the HMP examined different alternatives to mitigate future damage. Both a perimeter flood wall and localized/limited flood protection measures were evaluated. The localized/ limited protection measures considered included raising equipment, dry floodproofing of structures, wet flood proofing of structures, and walls and gates around individual buildings. The perimeter flood wall consists of a combination earthen berms, sheet-pipe walls, and flood gates to protect the treatment plant from flood waters.

Based on the complexity of protecting the processes, the difficulty in access these localized protection measures would require, the anticipated cost of these mitigation measures, and the fact that these localized mitigation measures would not prevent a future loss of service, but only a more rapid return to service, localized/ limited flood protection measures were deemed infeasible.

The proposed mitigation measure is a perimeter flood wall. The opinion of probable construction cost for the proposed perimeter wall is $9.2 million.

9.4.2 Central WWTP Biosolids Facility

The Central WWTP Biosolids Facility treats all the solids generated in the wastewater treatment process for the Central WWTP and the Whites Creek WWTP. It is located just north of downtown Nashville on the west bank of the Cumberland River. The facility has a capacity to treat 138 dry tons of solids per day and serves a population of approximately 590,000 people.

The facility was inundated with approximately 3 feet of flood water in all the buildings causing extensive damage and the facility to be out of service for over a month. The estimated flood damages at the plant were approximately $8 million.

A Hazard Mitigation Proposal (HMP) was prepared for the Metro Water Services' Central WWTP Biosolids Facility. During initial planning of mitigation alternatives, both a perimeter flood wall and localized/ limited flood protection measures were evaluated. The localized/ limited protection measures considered included raising equipment, dry flood proofing, wet flood proofing, and walls and gates around individual buildings. Based on the complexity of protecting the processes, the difficulty in access these localized protection measures would require, the anticipated cost of these mitigation measures, and the fact that these localized mitigation measures would not prevent a future loss of service, but only a more rapid return to service, localized/ limited flood protection measures were deemed infeasible.

It was determined that three items will work best to mitigate flood damage in the future: a perimeter sheet piling flood wall approximately 5' high with flood gates, two internal stormwater pump stations, and electrical supply protection. A perimeter flood wall around the entire Biosolids Facility will prevent flood waters from entering the site, alleviating future flooding. This mitigation measure provides full protection of all structures and equipment on site up to the protection elevation. The opinion of probable cost of the proposed mitigation measure is $4.7 million.

9.4.3 K.R. Harrington WTP

The K.R. Harrington WTP is one of two water plants that serves the majority of Metro Nashville and Davidson County. The facility has a nominal capacity of 60 MGD and serves a population of approximately 582,000 people. The plant is located on the Cumberland River near the confluence of the Stones River.

The K.R. Harrington WTP was shut down on May 2, 2010 when flood waters were projected to rise above the on-site electrical substation and emergency power generators. The WTP was submerged by flood waters and required complete rehabilitation to allow operation of the WTP within federal and state guidelines. The WTP was not functional until June 1, 2010, and then only at a limited capacity.

HMPs were prepared separately for the Generator Building and Hot House, Solids Building, Raw Water Pumping Station, Maintenance Building and the Filter Building.

The Generator Building and Hot House suffered extensive damage during the May 2010 flood. This portion of the plant was out of service for 7 days. The lower floor level of the Hot House was a major contributor to allowing the entire plant to be shut down. Flood waters entered the Hot House and flowed through conduit to other areas of the plant. To mitigate flood damage in the future, the HMP recommends building a new Generator Building and Hot House at a higher elevation.

The damage associated with the Solids Building was primarily in the loss of pumps and mixers which were not submersible. The HMP proposes replacing all existing pumps and mixers with submersible types.

During the May 2010 flood, the Raw Water Pumping Station suffered damage due to sluice gates not properly closing. This allowed the water levels inside the pump station to equalize with the flood level of the river, which submerged the electrical equipment of the pump station. The HMP recommends raising the equipment (pumps, chemical feeders, and electrical panels) inside the pump station, rather than raise the pump station entirely. This would keep the pump station in service for flood levels up to the 500-year flood elevation + 2 feet.

The Filter Building suffered damage to pumps, electrical control panels, and chemical feeds systems from the May 2010 flood. The best solution determined through the HMP was to dry floodproof the critical components of the building. Dry floodproofing includes: a small concrete barrier around the filters, sealing exterior doors, and raising the electrical panels and HVAC ducts. Also proposed was installing submersible backwash and clearwell transfer pumps, installing sump pumps, and ordering extra high service pumps (due to an 18 month lag between ordering and delivering) to have on hand.

The opinion of cost for the proposed mitigation measures at the K.R. Harrington WTP is approximately $18.5 million.

9.4.4 Omohundro WTP

The Omohundro WTP is located on the banks of the Cumberland River across from Shelby Park. The George Reyer Pumping Station houses the low services and high service pumps to

Omohundro and has continuously supplied drinking water to the Nashville population for more than 100 years.

The Omohundro WTP remained in operation during the May 2010 flood although the raw water intakes and the George Reyer Pumping Station were submerged in whole or in part. Significant emergency protective measures had to be taken so that Metro could provide water to Nashville. These measures were within 0.14 feet of failing. Had these emergency measures not been deployed, approximately 582,000 customers would have lost water for fire protection and potable use.

The Omohundro WTP receives raw water from the George Reyer Pumping Station (GRPS) which receives raw water from two intakes: Intake #4 and Intake #2. During the May 2010 flood Intake #4 was submerged and, therefore, the intake was out of service. The GRPS was constructed in the 1800's with hand carved stone. During the May 2010 flood, leaks were plugged by plant operators and sand bags were stacked by prisoners. These efforts helped maintain water supply to Davidson County for the time after the flood, because the K.R. Harrington plant was out of service. The HMP suggests floodproofing the GRPS's stone walls with grout and to raise the building of Intake #4 to an elevation equal to the 500-year flood + 2 feet.

Access to the Omohundro WTP was also considered with an HMP. The HMP proposed raising the road to the plant to an elevation equal to the 500-year flood + 2 feet. This would prevent the plant from shutting down for several days in the event of a major flood.

The opinion of cost for the proposed mitigation measures at the Omohundro WTP is approximately $7.2 million.

9.5 National Flood Insurance Program

Floods cause more damage in the United States than any other natural hazard. Each year, floods cause $4 billion dollars in damage and kill 150 people. Many people do not realize that flood damage is NOT covered by standard homeowner's insurance policies. Since 1968, the National Flood Insurance Program (NFIP) has provided federally backed flood insurance to communities participating in the NFIP. Metropolitan Nashville and Davidson County joined the NFIP program in 1982, therefore, insurance is available for ALL properties in Davidson County. Metro Water Services annually notifies property owners in the 100-year floodplain about the importance of obtaining flood insurance. Flood insurance can be purchased through any licensed property insurance agent or broker. All agents must charge the same rates. The rates will not change if a damage claim is filed; the rates are set on a national basis. The purchase of flood insurance is mandatory as a condition of receiving any federally related financial assistance such as loans through the Federal Housing Administration, the Veterans Administration, or the Small Business Administration for properties in the floodplain. It has been estimated that only one out of four properties susceptible to flooding is insured. Therefore, a large number of homes and businesses in Davidson County are not protected from

the financially devastating effects of a flood. Just because a property has not flooded in the past does not mean that it will not flood in the future. Property owners should not wait for the next flood to buy insurance protection. Owners of property located in the 100-year floodplain are encouraged to obtain flood insurance coverage for both the structure and its contents. There is a thirty (30) day waiting period before National Flood Insurance coverage takes effect. Property owners can contact their insurance agent for more information on rates and coverage.

10.0 Funding Analysis

A number of federal, state, and county programs are available to assist with the funding of flood damage reduction projects. Table 10.1 categorizes these programs by federal, state, and local administration, classifies each on the basis of type of support (capital, planning, data collection), and summarizes the program and its potential applicability to the alternatives evaluated in the UFPP. Appendix 10 provides a more detailed summary of these programs and includes contact information, eligibility requirements, including deadlines, and required matching funds, and an estimate of average funding amount.

Note that government assistance programs are ever-evolving, particularly in the funding levels and application requirements. Existing programs may not be suitable, or adequate, for a given project at the time of implementation. Consequently, additional programs may become available in the future.

This section of the report is designed to be used as a primary tool to identify potential funding sources, or pairing of funding sources, for implementation of flood damage reduction projects.

Table 10.1: Potential Funding Sources.

DEPARTMENT	AGENCY/ BUREAU/ OFFICE	PROGRAM	TYPE OF SUPPORT	DESCRIPTION	POTENTIALLY ELIGIBLE UFPP PROJECT
FEDERAL PROGRAMS					
U.S. DEPARTMENT OF AGRICULTURE (USDA)	Natural Resources Conservation Service (NRCS)	Watershed Protection and Flood Prevention Program	Capital; Planning	Works through local government sponsors and helps participants solve natural resource and related economic problems regarding watersheds. Projects include watershed protection, flood prevention, erosion and sediment control, water supply, water quality, fish and wildlife habitat enhancement, wetland creation and restoration and public recreation in watersheds of 250,000 or fewer acres.	• Reservoirs • Off-Channel Storage/Reservoir • Diversion • Bridge Replacement/Improvement • Channel Modification • Levee/Floodwall • Tree and Brush Removal
U.S. DEPARTMENT OF AGRICULTURE (USDA)	Natural Resources Conservation Service (NRCS)	Watershed Surveys and Planning	Planning; Technical	Supports surveys and studies of river basins as a basis for the development of coordinated water resource programs with Federal and State partners for floodplain management studies and flood insurance studies. Intent of the Watershed Survey and Planning program is to identify solutions that use conservation practices, including nonstructural measures, to solve problems related to watershed management.	
U.S. DEPARTMENT OF AGRICULTURE (USDA)	Natural Resources Conservation Service (NRCS)	Emergency Watershed Protection Program	Planning; Technical	Supports emergency measures, including the purchase of floodplain easements, for runoff retardation and soil erosion prevention to safeguard lives and property from floods, drought and the products of erosion on any watershed whenever fire, flood or any other natural occurrence is causing or has caused a sudden impairment of the watershed. NRCS may purchase Emergency Water Protection easements on floodplain lands that have been impaired within the last twelve (12) months or that have a history of repeated flooding (i.e., flooded at least two (2) times during the past ten (10) years).	• Channel Modification
U.S. DEPARTMENT OF COMMERCE (DOC)	NOAA / National Weather Service (NWS)	Automated Flood Warning System (AFWS)	Capital	Supports the creation, renovation or enhancement of rain and stream gauge networks that are locally operated and maintained with non-NOAA resources. NOAA funds are used primarily to buy equipment and secondarily to obtain specialized, short-term expertise to assist in design and implementation. Information collected and disseminated from these networks is used by local communities to increase their lead time for disaster preparedness and by NOAA for its forecasts and warnings. Approximately $500,000 will be available each fiscal year subject to the availability of funds. Proposals up to $100,000 may be submitted with an anticipated five (5) to 10 awards granted each year.	• Flood Warning/Preparedness
U.S. DEPARTMENT OF DEFENSE (DOD)	U.S. Army Corps of Engineers (USACE)	Small Flood Control Projects	Capital	Section 205 of the 1948 Flood Control Act authorizes construction of small flood control projects, including levees, channel enlargement, realignments, obstruction removal, and bank stabilization. An important requirement attached to this assistance is that each project must be a complete solution to the problem and must not commit the federal government to additional improvements to insure effective operation.	• Reservoirs • Off-Channel Storage/Reservoir • Diversion • Channel Modification • Levee/Floodwall
U.S. DEPARTMENT OF DEFENSE (DOD)	U.S. Army Corps of Engineers (USACE)	Snagging and Clearing for Flood Control	Technical, Planning, Capital	Section 208 of the Flood Control Act of 1954, as amended, provides authority for the Corps of Engineers to make improvements for the purposes of flood control. Examples of typical projects include removing accumulated snags and other debris, and clearing and straightening stream channels for flood control. Each project is limited to a Federal cost of not more than $500,000. The Federal cost limitation includes all project-related costs for feasibility studies, planning, engineering, and construction.	• Bridge Replacement / Improvement • Tree and Brush Removal

U.S. DEPARTMENT OF DEFENSE (DOD)	U.S. Army Corps of Engineers (USACE)	Protection of Essential Highways, Highway Bridge Approaches, and Public Works	Technical, Planning, Capital	To provide bank protection of highways, highway bridges, essential public works, churches, hospitals, schools, and other nonprofit public services endangered by flood-caused erosion.	• Bridge Replacement / Improvement • Tree and Brush Removal
U.S. DEPARTMENT OF DEFENSE (DOD)	U.S. Army Corps of Engineers (USACE)	Emergency Bank Protection	Capital	Section 14 of the 1946 Flood Control Act provides for emergency streambank protection to prevent damage to highways, bridge approaches, municipal water supply systems, sewage disposal plants, and other essential public works facilities.	• Channel Modification
U.S. DEPARTMENT OF THE INTERIOR (DOI)	U.S. GEOLOGICAL SURVEY	Cooperative Water Program	Data	The Mission of the USGS Cooperative Water Program is to provide reliable, impartial, and timely information needed to understand the Nation's water resources through a program of shared efforts and funding with State, Tribal, and local partners to enable decision makers to wisely manage the Nation's water resources.	• Flood Warning System
			FEDERALLY FUNDED STATE PROGRAMS AND STATE PROGRAMS		
U.S. DEPARTMENT OF HOMELAND SECURITY (DHS)	Federal Emergency Management Agency (FEMA) And Tennessee Emergency Management Agency (TEMA)	Hazard Mitigation Grant Program	Capital; Planning	Provides funding to implement long-term hazard mitigation measures after a major disaster declaration. The key purpose is to ensure that the opportunity to take critical mitigation measures to reduce the risk of loss of life and property from future disasters is not lost during the reconstruction process following a disaster. The State, through TEMA, administers this federal program.	• Reservoirs • Off-Channel Storage/Reservoir • Diversion • Bridge Replacement/Improvement • Channel Modification • Levee/Floodwall • Floodproofing/Elevation • Acquisition/Buy-Out
U.S. DEPARTMENT OF HOMELAND SECURITY (DHS)	Federal Emergency Management Agency (FEMA) And Tennessee Emergency Management Agency (TEMA)	Pre-Disaster Mitigation	Capital; Planning	Provides a consistent source of funding to State, tribal and local governments for pre-disaster mitigation planning and projects primarily addressing natural hazards. Funding these plans and projects reduces overall risks to populations and structures and also reduces reliance on funding from actual disaster declarations. The State, through TEMA, administers this federal program.	• Reservoirs • Off-Channel Storage/Reservoir • Diversion • Bridge Replacement/Improvement • Channel Modification • Levee/Floodwall • Floodproofing/Elevation • Acquisition/Buy-Out
U.S. DEPARTMENT OF HOMELAND SECURITY (DHS)	Federal Emergency Management Agency (FEMA) And Tennessee Emergency Management Agency (TEMA)	Flood Mitigation Assistance / Repetitive Flood Claims / Severe Repetitive Loss	Capital; Planning	Helps States and communities plan and carry out activities designed to reduce the risk of flood damage to structures covered under contracts for flood insurance. Planning grants are available to prepare Flood Mitigation Plans. Only communities participating in the National Flood Insurance Program (NFIP) with approved Flood Mitigation Plans can apply for Flood Mitigation Assistance (FMA) Project grants to implement measures to reduce flood losses, such as elevation, acquisition or relocation of NFIP-insured structures. States are encouraged to prioritize FMA funds for applications that include repetitive loss properties; these include structures with two (2) or more losses each with a claim of at least $1,000 within any 10-year period since 1978. Technical Assistance Grants for the State to help administer the FMA program and activities. Up to 10 percent of project grants may be awarded to States for FMA Technical Assistance Grants.	• Reservoirs • Off-Channel Storage/Reservoir • Diversion • Bridge Replacement/Improvement • Channel Modification • Levee/Floodwall • Floodproofing/Elevation • Acquisition/Buy-Out

				The State, through TEMA, administers this federal program.	
U.S. DEPARTMENT OF TRANSPORTATION (DOT)	Federal Highway Administration And Tennessee Department of Transportation	Highway Planning and Construction	Capital	Provides funding to States for improving the condition of their highway bridges through replacement, rehabilitation and systematic preventative maintenance. Funding allocated by metropolitan planning organizations and regional planning entities through Transportation Improvement Plans (TIPs). The State, through TDOT, administers this federal program.	• Bridge Replacement / Improvement
U.S. DEPARTMENT OF HOUSING & URBAN DEVELOPMENT (HUD)	Community Planning and Development	Entitlement Communities	Capital	Provides funding to carry out a wide range of community development activities directed toward revitalizing neighborhoods, economic development, and providing improved community facilities and services. The State, through Tennessee Economic and Community Development (ECD), administers this federal program.	• Acquisition/Buy-Out
U.S. DEPARTMENT OF HOUSING & URBAN DEVELOPMENT (HUD)	Community Planning and Development	Disaster Recovery Assistance	Capital	HUD provides flexible grants to help cities, counties, and States recover from Presidentially declared disasters, especially in low-income areas, subject to availability of supplemental appropriations. The State, through Tennessee Economic and Community Development (ECD), administers this federal program.	• Acquisition/Buy-Out
TENNESSEE DEPARTMENT OF ENVIRONMENT & CONSERVATION (TDEC)	Recreation Educational Services Division	Land & Water Conservation Fund (LWCF)	Capital	The LWCF program provides matching grants to states and through the state to local governments and state agencies that provide recreation and parks, for the acquisition and development of public outdoor recreation areas and facilities.	• Acquisition/Buy-Out
TENNESSEE DEPARTMENT OF ENVIRONMENT & CONSERVATION (TDEC)	Recreation Educational Services Division	Local Parks and Recreation Fund (LPRF)	Capital	The LPRF is to provide grants to all eligible local governmental entities for the purchase of lands for parks, natural areas, greenways, and for the purchase of land for recreation facilities.	• Acquisition/Buy-Out
TENNESSEE DEPARTMENT OF ENVIRONMENT & CONSERVATION (TDEC)	Recreation Educational Services Division	Natural Resources Trust Fund (NRTF)	Capital	Grants from the NRTF may be awarded to all eligible local governmental entities and state agencies for outdoor recreation, historical or archaeological sites, the acquisition of lands, waters, or interests in lands and waters.	• Acquisition/Buy-Out
TENNESSEE DEPARTMENT OF ENVIRONMENT & CONSERVATION (TDEC)	Recreation Educational Services Division	Recreation Trails Program (RTP)	Capital	The Recreational Trails Program (RTP) is a federal funded, state administered grant program. The RTP provides grant funding for land acquisition for trails, trail maintenance, trail construction, trail rehabilitation and for trail head support facilities.	• Acquisition/Buy-Out

COUNTY PROGRAMS					
METROPOLITAN NASHVILLE-DAVIDSON COUNTY	Metro Water Services	Capital Improvements Budget and Program	Capital; Planning	Capital improvement plan for Metro Water Services, which will upgrade Nashville's aging water infrastructure to meet increased demands on the system and stricter federal regulations.	• Reservoirs • Off-Channel Storage/Reservoir • Diversion • Bridge Replacement/Improvement • Channel Modification • Levee/Floodwall • Floodproofing/Elevation • Acquisition/Buy-Out