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Technical Memorandum

To: *City of Franklin IWRP Team*

From: *CDM*

Date: *July 27, 2011*

Subject: *Integrated Water Resources Plan - Ecological Restoration and Stream Enhancement Technical Analysis*

As part of the Integrated Water Resources Plan (IWRP) for the City of Franklin (City), Camp Dresser & McKee (CDM) has researched available information provided by the City and other local agencies to identify opportunities within the Harpeth River watershed for stream restoration, bank stabilization, and riparian buffer enhancement. In addition, CDM has developed planning level cost estimates for identified improvements and quantified, to the extent practicable, the relative benefits that may be expected from these projects. The following sections summarize the data evaluated for this effort as well as the cost vs benefit analysis performed. The results of this study will be used for comparison with other improvement alternatives being evaluated as a part of the Integrated Water Resources Plan.

1.0 Introduction

Preservation and protection of the Harpeth River (the River) is a key priority identified by both the City and the Stakeholders participating in the Phase I process of the IWRP project. Specifically, the Stakeholders in the Phase I process established objectives related to Water Quality and Ecological Health and Improved Access and Aesthetics of the river. Because there are areas of the Harpeth River that are degraded by runoff from both urban and agricultural areas, there are opportunities to implement BMPs such as stream restoration, bank stabilization, and riparian restoration projects along the River and its tributaries. The costs and benefits of these options will be evaluated within a planning level computer model (STELLA) developed for the IWRP project. The ability to quantify the ultimate benefits to the River and watershed for each project option is key to the analysis and selection of improvement options that will be included in the final Integrated Water Resources Plan.

The Harpeth River is a dynamic, natural system responding to the watershed development and channel alterations imposed upon it over centuries of agriculture and recent urbanization. Bank

erosion and degraded wildlife habitat in the River are symptoms of the history and current conditions of the watershed. Stream restoration in and around the City of Franklin can be expected to alleviate some of the localized sediment burden and improve channel conditions, but cannot remedy the hydrologic flow regime or sediment regime from the entire watershed.

2.0 Study Scope

The Harpeth River begins in Rutherford County and extends northwest through 4 counties before converging with the Cumberland River in Cheatham County, for a total watershed area of 863 square miles (TDEC, 2002). The River receives runoff from approximately 169 square miles (sq. mi.) before entering the City. The City encompasses approximately 23 sq. mi. and is almost entirely in the Harpeth River watershed, with 13.7 river miles running through the City. This evaluation focuses on the main stem and tributaries of the River within the City's municipal limits, as well as some of the upstream reaches extending beyond the City limits. A mechanism to promote better agricultural practices in the watershed upstream of the City is being sought by the Harpeth River Watershed Association (HRWA) (personal communication with Michael Cain, April 2011).

The primary objectives of this planning level study are to identify candidate stream restoration, bank stabilization, and riparian restoration projects along the River, develop conceptual opinions of probable cost, and describe and quantify potential benefits associated with the identified projects.

3.0 Data Collection

Existing data and information regarding the conditions of the main stem and tributaries of the River in and upstream of the City were reviewed as part of this evaluation. Studies conducted by the HRWA, visual assessment information data provided by the City, geographical information survey (GIS) data, and available stormwater and watershed master plan reports were used to identify potential stream channel restoration, bank stabilization, and riparian restoration projects.

Habitat conditions in the River have been described as poor, due to low dissolved oxygen, high sediment embeddedness, and a lack of habitat heterogeneity (HRWA, 2006). In 2002, the EPA published a Total Maximum Daily Load (TMDL) Modeling Study Report (EPA, 2002a) and Siltation and Habitat Alteration TMDL (EPA, 2002b). The same year, the Tennessee Department of Environment and Conservation (TDEC) compiled a listing of all impaired stream in the state (referred to as the 303(d) list, which included the Harpeth River. In addition, TDEC published a Watershed Plan to address impairments associated with the 303(d) listings of the River and several of its tributaries (TDEC, 2002). As of 2010, the River remains on the 303(d) list as shown in Table 1 for low dissolved oxygen and loss of biological integrity.

Studies conducted by the HRWA describe the extent of degraded physical, chemical, and biological conditions in the River and their potential sources. Multiple HRWA studies attempt to quantify the effects of erosion and sedimentation throughout the River and were used to estimate the benefits of candidate projects on the water quality and habitat conditions in the Harpeth River.

Table 1 - Harpeth River 2010 303(d) Listings for Williamson County

Waterbody ID	Miles/Acres Impaired	Cause	Pollutant Source	Comments
TN0513020 4016 –1000	6.8	Low dissolved oxygen, Phosphorus	Municipal Point Source Discharges from MS4 area	Category 4a. EPA approved DO and nutrient TMDLs for the known pollutants.
TN0513020 4016 – 4000	7.5	Low Dissolved Oxygen, Loss of biological integrity due to siltation	Pasture Grazing	Category 4a. EPA approved DO and siltation TMDLs for the known pollutants.
TN0513020 4016 – 3000	9.0	Low Dissolved Oxygen, Loss of biological integrity due to siltation	Pasture Grazing	Category 4a. EPA approved DO and siltation TMDLs for the known pollutants.

(TDEC, 2010 Final 303(d) List)

In 2007, the HRWA conducted both a sediment study (HRWA and CRC) and a bank erosion study (HRWA, 2007a) on the Harpeth River. The sediment study, conducted jointly by HRWA and the Cumberland River Coalition, indicated a high suspended sediment loading from the watershed. The bank erosion study showed that severe bank erosion is occurring along the main stem of the River and is considered a major sediment load contributor. The erosion study does not, however, indicate the extent of the erosion except at particular locations along the River, all of which are downstream of the City. Due to inherent variability in bed and bank erosion rates, neither the HRWA sediment study, nor the Harpeth River TMDL (EPA, 2002) studies could quantify the portion of the sediment loading originating from streambank erosion. Steep banks, utility crossings, and a lack of riparian vegetation were identified as the leading causes of bank erosion along the River (HRWA, 2007).

Results of the visual assessment of the streams in and immediately upstream of the City, conducted by the City, provided locations and estimated lengths of stream currently experiencing

erosion or other issues. The survey results were provided by the City in a Geographic Information System (GIS) shapefile with assessment categories for erosion being either common or occasional along the banks. Results of this general survey were used to estimate the extent of potential stream stabilization projects necessary in the study area. A detailed evaluation of each potential project reach is needed prior to further planning and implementation in accordance with the criteria set forth by the City's Harpeth River Watershed Initiative (Franklin, 2007). Data were translated into potential stream restoration and stabilization lengths for the watersheds where more detailed master plan reports were not available. Sites identified with occasional erosion were considered to require bank stabilization and those where erosion was common were assigned a restoration need. These tributary areas identified from the visual assessment are shown in **Figure 1**.

A review of the 2009 aerial photography, in GIS, revealed areas where extensive erosion is occurring along the main stem of the River and where riparian vegetation is lacking within the study area. Figure 1 shows the areas of erosion identified from the aerials and highlights the stream reaches with significantly less than 50 feet of developed riparian vegetation.

Information regarding currently planned projects was obtained through the Sharps Branch Stormwater Master Plan (CDM, 2002), and the Harpeth low head dam removal project presentation (Beaver Creek Hydrology, 2010). Sharps Branch is budgeted for restoration/stabilization, according to the fiscal year 2011-2015 Capital Improvement Plan (CIP) Stormwater Projects.

4.0 Stream Enhancement Measures

Various degrees and methods of stream enhancement are available for implementing improvements to the River and tributaries in and immediately upstream of the City to address 303(d) list impairments for low dissolved oxygen and loss of biological integrity for siltation. These treatment types are:

1. Stream restoration
2. Bank stabilization
3. Riparian restoration
4. Cattle exclusion

Full **stream restoration** is defined for this evaluation as returning pre-disturbance hydrologic functionality, where a shallow stream is interconnected with the floodplain, groundwater, and wetlands, maximizing recharge, organics and nutrient retention, and ecological functionality. Lesser forms of stream restoration feasible in developed areas (natural channel design) are defined by modifications performed within a stream channel to restore the functional conveyance and sediment transport, reduce bank erosion, and improve habitat conditions (Rosgen, 2006).

Bank stabilization may consist of any combination or singular treatment of bank shaping to achieve stable slopes or the application of biotechnical techniques for promoting riparian vegetation to hold soils in place and provide structural stability (USDA 2002). **Riparian restoration** is defined as the planting of native riparian vegetation on stable banks to provide a minimum buffer zone of 60 feet from the top of the banks in accordance with City ordinance. **Cattle exclusion** involves the installation of physical barriers that exclude cattle access to adjacent water bodies.

To evaluate the benefits of the types of stream enhancement, the stated objectives of the IWRP have been categorized into three broad groups; water quantity, water quality, and wildlife habitat. Water quality is defined broadly by metrics which quantify nutrient loadings and TSS and further by dissolved oxygen and temperature. Water quantity is defined by base flow and frequency, magnitude, and duration of runoff event flows. Wildlife habitat is dependent on the actual physical habitat space and conditions suitable for survival of native species including macroinvertebrates and fish.

The water quantity, water quality, and wildlife habitat improvement benefits of the various stream enhancement methods can be measured by several metrics. To allow comparison between stream enhancement methods for the purposes of this IWRP, each stream enhancement method is assigned a high/medium/low rating based on the general influence of the applicable metrics on improvements in each area. Performance of the stream enhancement methods for each metric category is compared in Table 2.

Table 2 - Stream Enhancement Benefits

Type of Riparian Improvement	Unit Cost (per Linear Foot)	Water Quantity	Water Quality	Wildlife Habitat
Full Stream Restoration	$400 - $1,000	High	High	High
Natural Channel Design	$400 - $1,000	Low	Medium	Medium
Bank Stabilization	$400	Medium	Low	Medium
Riparian Restoration	$100	Low	Low	Medium
Cattle Exclusion	$4	Low	High	Medium

Full stream restoration can achieve high benefits in water quantity, water quality, and wildlife habitat because it maximizes the natural ability of the stream system to retain and infiltrate water, retain and treat pollutants, and create diverse self sustaining ecosystems. In-channel modifications using natural channel design techniques are capable of improving local habitat conditions by reducing embeddedness and providing riffle pool sequences and improving water

quality by reducing sediment inputs to stream channel from eroding banks, but cannot improve the runoff conditions of the watershed. Bank stabilization improves water quality by reducing the sediment inputs to the stream channels and the associated nutrients. Riparian restoration improves habitat conditions with roots and contribution of organic materials, and may provide shade to reduce water temperatures. Cattle exclusion has a major impact on water quality as it eliminates direct nutrient and fecal coliform releases and halts trampling damage to streambanks promoting erosion. Cattle exclusion also shares the benefits associated with riparian restoration since it allows revegetation of the banks.

5.0 Improvement Options and Locations

CDM evaluated the most feasible and cost effective options applicable to the Harpeth River and tributaries. The applicable treatment type depends on the runoff conditions, surrounding land uses, type and degree of degradation, and other factors. Due to the incised condition of the main stem of the River in the City, full stream restoration is not feasible without increasing flooding and would be extremely costly. Full stream restoration on the tributaries is only feasible where flooding of adjacent structures or roadways is not an issue along remaining undeveloped corridors. Bank stabilization is recommended where excessive erosion is occurring but alone cannot remedy the altered flow regime and sediment influx creating the degraded conditions throughout the River. Therefore, riparian buffer restoration is recommended as the least expensive and most beneficial broadly applicable treatment. Streambank stabilization can be expected to alleviate some of the localized sediment burden where vegetation is not providing sufficient stabilization, but cannot remedy the hydrologic flow regime or sediment regime from the entire watershed. Low impact development techniques, full stream restoration, reforestation, and stormwater and agricultural BMPs should be implemented throughout the watershed to the extent feasible to retain water, sediment, and nutrients on the land before they enter the River. A reach scale evaluation is recommended to evaluate the most appropriate stream enhancement option for each section of the River and tributaries.

The HRWA's Headwaters of the Harpeth River Water Quality and Habitat Study indicated that stream bank stabilization is necessary for about 10% of upstream banks in Williamson and Rutherford Counties (HRWA, 2007). This would be about 32 miles of the approximately 317 miles of stream in the headwaters, at an estimated cost of $8.5 Million for bioengineered bank stabilization ($50/linear foot [LF] cedar revetments, and mulch socks). HRWA also reported in that document that "treating all stream banks is not cost-effective or practical". The approach recommended by HRWA is to address the sites exhibiting the most erosion and supplement riparian vegetation where existing buffers are thin or sparse. CDM is in concurrence and would also recommend this approach for the main stem of the River and tributaries within the City.

The most cost effective remedies for this approach includes cattle exclusion, natural material revetments, and riparian plantings to protect and stabilize the banks and provide cover and appropriate organic inputs to the channel. These treatments are less destructive and more widely

applicable than natural channel design because they do not require the removal of existing trees or soil disturbance. While these methods may be sufficient for the less degraded channel banks, more intensive methods of bank shaping and channel modification may be warranted for more degraded channels.

Unit costs for stream restoration, bank stabilization, and riparian restoration depend on the method and workforce employed. HRWA developed unit costs based on proven local methods of cattle exclusion, bank stabilization, and riparian planting with volunteer labor. These unit costs were utilized to develop the cost estimates for the Five Mile Creek Watershed (HRWA, 2009) as shown in Table 2. A per linear foot cost estimate of $400 was used in the Sharps Branch Stormwater Master Plan for bank stabilization, which has already been included in the City's Capital Improvement Program (CIP) for future restoration along Sharps Branch. These estimates are consistent with regional stream restoration unit costs (NCEEP, 2011). For this study, $400 per linear foot (LF)is used for stream restoration and bank stabilization on the tributaries of the River and $60 per linear foot for riparian restoration of a 60 foot buffer on both sides of the stream. The $60 is a compromise between the low estimate from HRWA and the high estimate from NCEEP which includes extensive monitoring and other costs beyond the plantings. Costs derived from HRWA and other sources and applied to the identified areas for improvement are listed in Table 2. Estimated costs associated with the main stem of the River in the City were increased ($1,000/LF) to account for the size of the channel and all the estimated costs presented include some allowance for engineering, administration, permitting, and land acquisition.

6.0 Improvement Locations

Given the history, available assessment data, and current uses of the Harpeth River, areas for feasible improvement which would contribute to improvement of the systemic degradation were identified. Planned and potential improvement areas have been identified for cattle exclusion, stream restoration, bank stabilization, or riparian restoration. Figure 1 and Table 2 show the areas identified for improvement through various studies and methods.

Reaches in the Five Mile Creek basin have been specifically identified for stabilization, riparian planting, and cattle exclusion in the HRWA Five Mile Creek Watershed Plan (2009). One of the highest priority water quality problems in the River's watershed is livestock access and the associated bank degradation. Livestock exclusion fencing and alternative water supply provisions are being offered to cattle farmers and installed with HRWA support for the 7.7 miles of stream in the Five-Mile Creek Subbasin identified with this problem. No other cattle exclusion areas were identified in the visual assessment of sites or by the desktop analysis performed for this study.

Areas along the River's tributaries where erosion is common or occasional have been identified through visual assessment. For the purposes of this study, they have been assigned a corresponding need for stabilization. Candidate reach lengths with severe bank erosion along the main stem of the River were identified by CDM using aerial photography. Riparian planting areas

lacking a sufficient vegetated buffer were identified using aerial photography along the River and its tributaries, and are shown in **Figure 1**.

One location for full channel modification of the main stem of the River is recommended by this study. Aerial photography review revealed a channel avulsion towards the northwest border of the City where the channel bend appears to have been modified in the past. Flows are returning a functional radius of curvature to the bend by eroding the outside bank and beginning to form a new channel. Restoration of stream meanders to accelerate the return of the natural meander pattern is recommended to reduce the continuing deposition of sediment in the stream.

Planning level costs for improvements to the headwaters of the River and the low head dam removal and restoration project are not included in the overall estimate for potential enhancement in this study because they are beyond the geographic limits of this evaluation (i.e. outside the City limits) or have already been identified for funding by the City. Stabilization of Sharps Branch, as is included in the City's CIP is included since funds have not yet been spent. An estimated ten percent of the headwater streams are in need of restoration (HRWA, 2007). These are not included in the cost estimate herein due to the large cost of this effort and the lack of jurisdiction by the City to implement this restoration.

7.0 Cost and Benefit Correlation

Qualitative benefits of stream enhancement to the Harpeth River watershed include:

- Reduced bank erosion and subsequent channel sedimentation;
- Improved wildlife habitat;
- Improved aesthetics and accessibility for active and passive recreation;
- Filtering of runoff before it enters the stream; and
- Stream temperature reduction from tree shade.

These and other benefits of restoration and stabilization are difficult to quantify because their direct benefits are parts of many complex cumulative variables for which we do not have a standard valuation system. The most direct benefit of stream enhancement is reduction of sediment input into the stream and retention of nutrients contained in the sediment. This benefit can be estimated by applying an average erosion rate over a length and average height of banks and assuming a unit nutrient release amount for each volumetric unit of sediment. However, this method of estimation only provides an estimated sediment loading reduction which can then be converted to a cost per unit reduction. It does not quantify the ecological function improvements or the value of ecosystem services provided by those improvements.

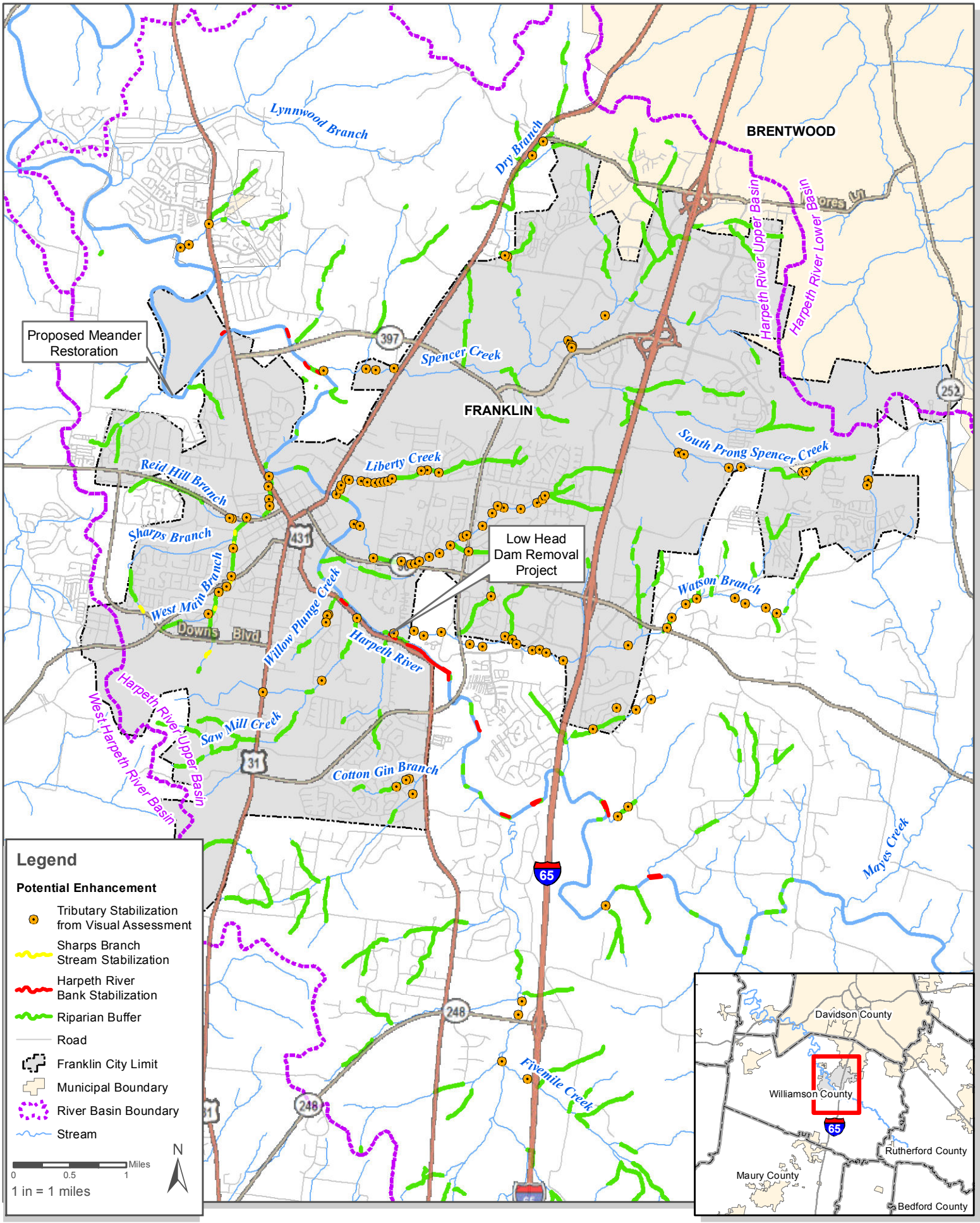

Figure 1- Potential Stream Enhancements
Franklin, Tennessee

Table 2 - Problem Areas and Estimated Improvement Costs

Location	Type	Source	Length /Area	Unit Cost	Estimated Budgetary Cost
Harpeth Main Stem	Low Head Dam Removal and Natural Channel Design	Design Presentation (Beaver Creek Hydrology, 2010)	~2,000 LF	-	Funded by USFWS
Five Mile Creek	Cattle Exclusion	HRWA Watershed Plan	7.7 Miles	$4/LF	$160,000
Five Mile Creek	Stabilization (Cedar Revetments and Mulch Socks)	HRWA Watershed Plan	8 Miles	$50/LF	$2,110,000
Five Mile Creek	Riparian Buffer Planting	HRWA Watershed Plan	20 Miles	$1,050 /acre	$305,000
Sharps Branch	Restoration/Stabilization	Sharps Branch Stormwater Master Plan (CDM, 2002)	1,700 LF	$400 /LF	$667,000 (Franklin CIP)
Harpeth Main Stem	Meander Restoration	Aerial Photography Review	750 LF	$1,000 /LF	$750,000
Harpeth Main Stem	Bank Stabilization	Aerial Photography Review	8,500 LF	$500 /LF	$4,250,000
Harpeth Main Stem	Riparian Buffer Planting	Aerial Photography Review	7,800 LF	$50 /LF	$390,000
Franklin Tributaries	Stream Restoration (common erosion)	Visual Assessment	11,000 LF	$400 /LF	$4,400,000
Franklin Tributaries	Bank Stabilization (occasional erosion)	Visual Assessment	4,100 LF	$400 /LF	$1,640,000
Franklin Tributaries	Riparian Buffer Planting	Aerial Photography Review	53 Miles	$50 /LF	$14,000,000
				Total:	**$28,000,000**

From the average unit cost estimates, planning level costs are developed for the potential projects identified in the previous section. Totals costs by area are $1.8 Million (M) for Five Mile Creek, $677,000 for Sharps Branch, $5.4 M for the main stem Harpeth River, and $19.9 M for the tributaries of the Harpeth River within and immediately upstream of the City.

To broadly quantify the benefits of stream enhancement on water quality, unit reduction efficiencies were adopted from the Chesapeake Bay Program (CBP). The total nitrogen (TN) loading reduction capacity of urban stream restoration as used in the Chesapeake Bay watershed model is 0.02 pounds/TN/year/foot (lb/TN/yr/ft). The pollutant reduction efficiencies for total phosphorus (TP) and total suspended sediment (TSS) used for this analysis are 0.0035 lb/TP/yr/ft and 2.55 lb/TSS/yr/ft , respectively (CBP, 2006). Grouping bank stabilization with urban stream restoration, CDM estimated the unit pollutant load reductions for the 26,000 linear feet of stream identified for stream enhancement within the study area. The following provides a summary of the unit costs:

- Cost per lb of TN removed: $63 per lb per day TN
- Cost per lb of TP removed: $364 per lb per day TP
- Cost per ton of Sediment removed: $0.50 per lb per day Sediment

In addition to preventative measures such as buffer protection and stormwater management, priority of the feasible restoration projects that provide the greatest benefit for the least cost and disturbance includes: cattle exclusion, followed by riparian restoration, bioengineered bank stabilization, and natural channel design methods of bank stabilization. Cattle exclusion should be the first priority because it carries the greatest positive impact and least cost to remedy. Riparian restoration can be performed without damaging established trees and provides very good localized habitat improvement and long term bank stability where banks are not extremely steep. Bioengineered bank stabilization including cedar revetments and mulch socks provide bank stability and vegetative habitat at a low cost where applicable. Implementation of the range of natural channel design techniques from simple bank shaping to full channel reconfiguration is necessary where conditions are severely degraded and trees will otherwise be lost to erosion if banks are not stabilized.

8.0 Conclusions

The total estimated planning level cost for stream corridor improvement projects in and immediately upstream of the City of Franklin is $28,000,000. This estimate is subject to many contingencies and costs could be compounded by permitting, land acquisition, etc. This cost is for anticipated channel modifications, bank stabilization, and riparian plantings and does not achieve the benefits of full stream restoration or watershed restoration. These treatment options have

the potential to reduce stream bank erosion and improve wildlife habitat conditions locally where implemented and have some cumulative positive impact on downstream conditions.

9.0 References

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