EXECUTIVE SUMMARY

COPPERMINE BROOK DRAINAGE EVALUATION

Bristol, Connecticut

August 28, 2008

MMI #2235-19

Prepared for:

City of Bristol
Department of Public Works
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INTRODUCTION

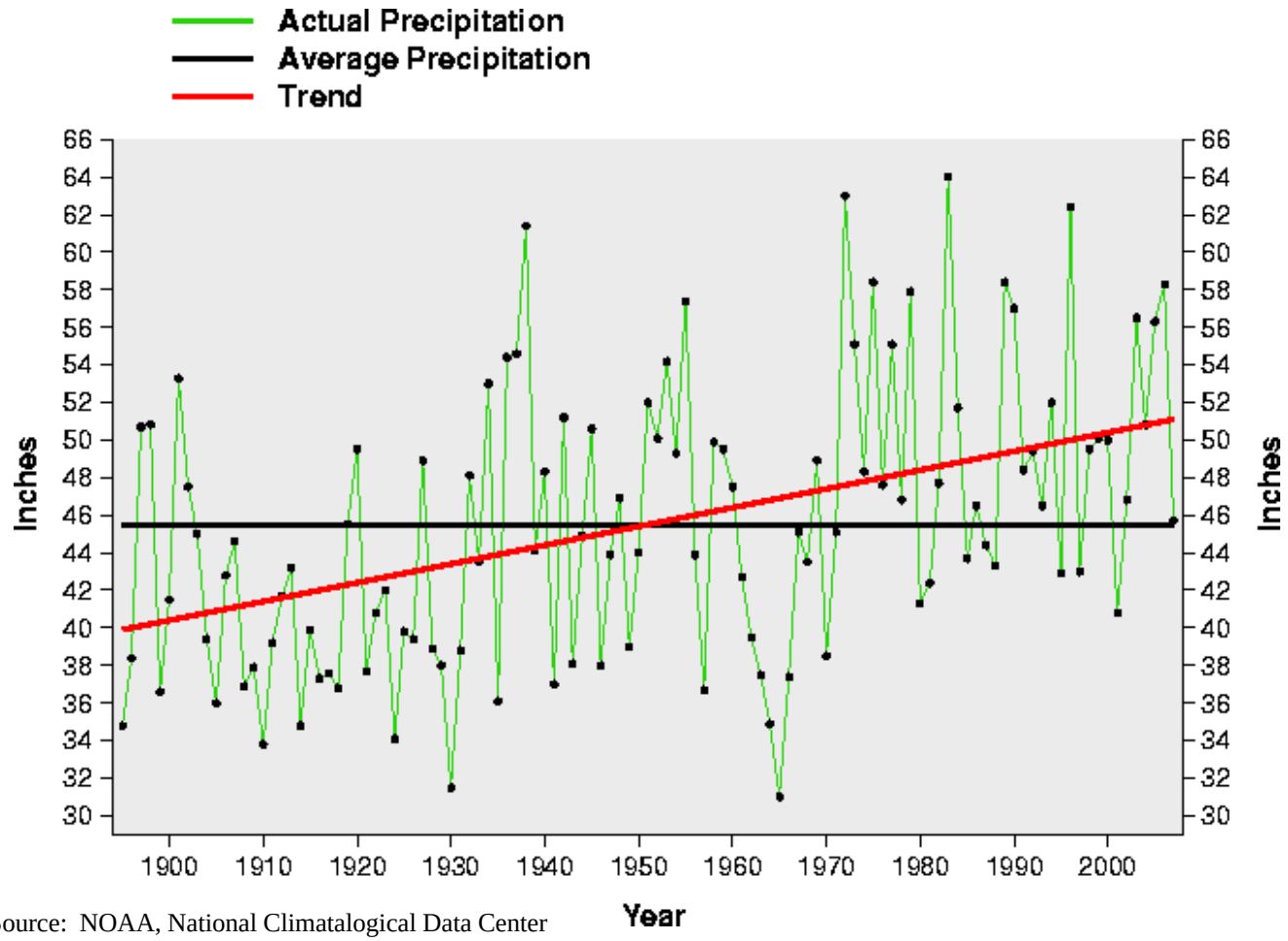
The City of Bristol contracted Milone & MacBroom, Inc. (MMI) to prepare a detailed evaluation of the Coppermine Brook watershed and stream channel. In recent years, residents along the Coppermine Brook channel have experienced repeated flooding of yards and residential structures. Many residents have expressed concern that the problem is becoming more severe as the frequency of events increases.

Flooding along streams and rivers is a normal, natural phenomenon that occurs due to excess surface runoff from precipitation or snow melt. Human activities and climate change can modify natural flooding patterns. Watershed topography, geology, and vegetation influence runoff rates which, in turn influence the shape, size, and slope of stream channels and floodplains. These factors then influence the presence, depth, and velocity of flood waters which may damage public and private property.

Erosion and deposition of sediments along alluvial channels often creates large, nearly level areas of land called floodplains. Floodplains help convey floodwaters to supplement the channel's capacity. Many floodplains have level, stone-free surfaces that are attractive locations for farms, roads, and communities. However, they remain prone to inundation and flood damages occur. Coppermine Brook has extensive floodplains that are now flood prone developed areas.

The purpose of this study was to evaluate current conditions in the watershed and along the channel corridor and identify potential strategies to alleviate the flooding problems. Three specific problem areas were identified based on discussions with residents and town staff alike: Richards Court/Stevens Street; Farmington Avenue; and Frederick Street. In completing this project, MMI developed a hydrologic model of the watershed, a hydraulic analysis of the channel corridor and an analysis of alternative improvements that may decrease the frequency of flooding.

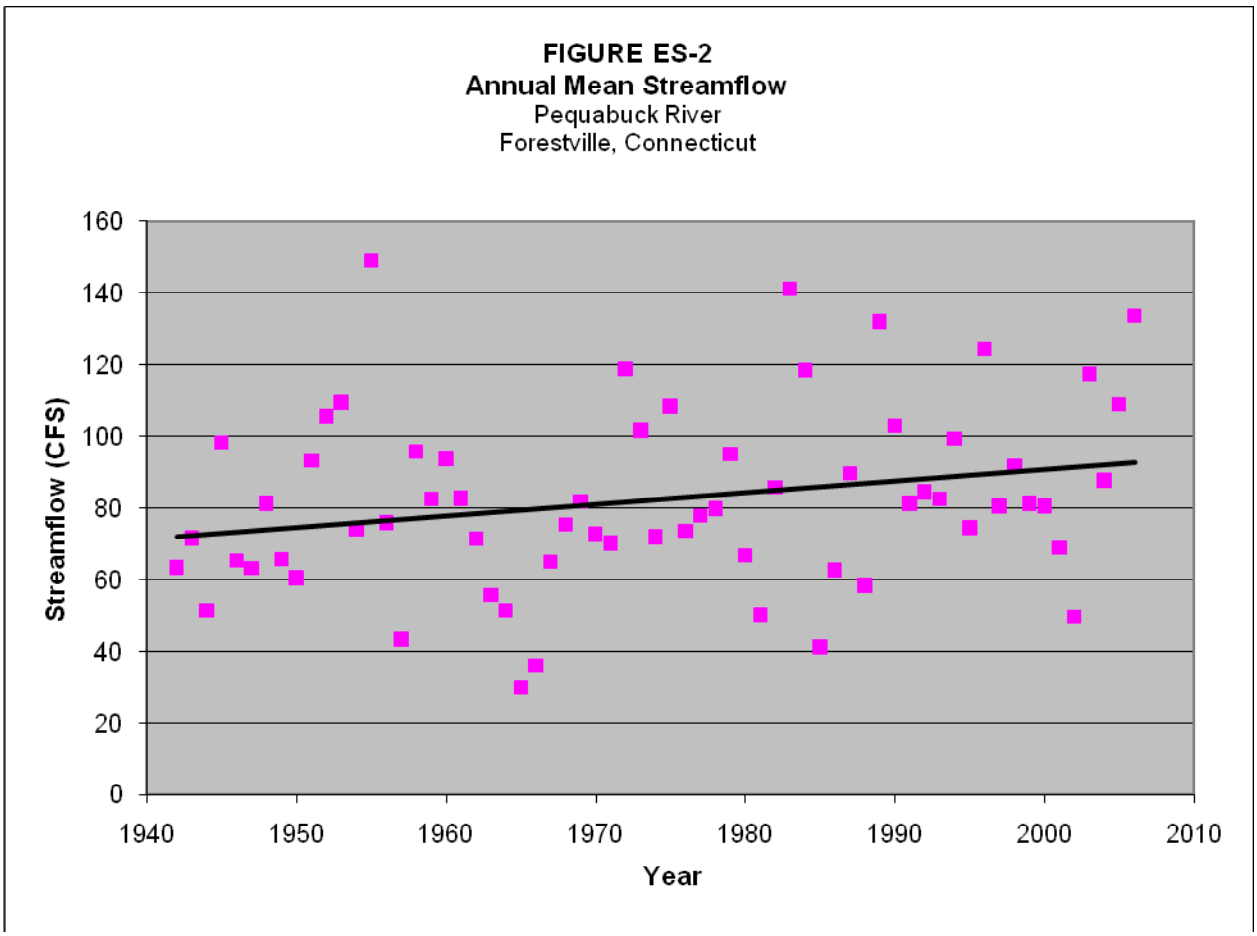
In evaluating and understanding drainage and flooding, it is imperative to understand rainfall trends and how these relate to changes in streamflow. In New England, the effects of urbanization are exacerbated by changes in rainfall patterns that have been observed. Connecticut's annual mean precipitation has consistently increased through the last century, with the increase generally measuring 0.96 inches per decade. This trend is depicted graphically in Figure ES-1.



Source: NOAA, National Climatalogical Data Center

FIGURE ES-1: Precipitation Trends in Connecticut 1895-2003

The combination of increased rainfall intensity and increased runoff rates (which can be attributed to a combination of increased rainfall and increased development) will invariably result in increases in annual streamflows. This trend is already evident when evaluating streamflow data in Connecticut. Figure ES-2 depicts the mean annual flow rates in the Pequabuck River from 1942 and 2006. In the 45.8 square mile watershed of Pequabuck River upstream of this gauge, annual stream flow has increased some 20 cubic feet per second over the 64 year period of record.



The impact of land use on runoff patterns is well documented. As part of this study, the land use regulations of both Burlington and Bristol were reviewed to identify requirements and standards that may be adversely impacting the Coppermine Brook channel. One general observation is that the regulations of the both communities should be updated to reference the 2004 Connecticut Stormwater Quality Manual. In addition, Bristol's regulations do not appear to currently have a floodplain overlay district. The zoning regulations must incorporate reference to requirements of the Federal Emergency Management Agency for development in flood prone areas. This will allow the City to have some control over the type of development that occurs within the mapped floodplains. The MMI report also identified specific stormwater management and "low impact development" standards that may be suitable for use on projects within the Coppermine Brook watershed.

HYDROLOGY OF COPPERMINE BROOK

Flow rates in a river channel are a function of the watershed size, land use characteristics, soil characteristics, vegetation and rainfall patterns. Hydrology is the science of using this information to determine streamflow rates. This streamflow data can then be used in conjunction with information on the river channel characteristics to predict the depth of water flow during various flood events.

As part of this study, the computer modeling program known as the Hydrologic Modeling System HEC-HMS 3.2 was used to estimate flow rates for the various storm events.

Existing Conditions

Table ES-1 presents the predicted channel flow rates at select areas within the watershed.

TABLE ES-1
Results of Existing Conditions Analysis

Description	Predicted Peak Flows (cfs)					
	2-Year	10-Year	25-Year	50-Year	100-Year	500-Year
Downstream of Stevens Street	454	1,382	2,033	2,687	3,388	5,579
Downstream of confluence with Polkville Brook	551	1,499	2,329	2,888	4,071	8,096
Upstream of Frederick Street	656	1,736	2,678	3,360	4,619	9,189
Confluence with Pequabuck River	656	1,737	2,679	3,362	4,606	9,181

The flows computed by MMI for this study are greater than the FEMA flows for the watershed area upstream of Negro Hill Brook, while at the Pequabuck River MMI predicted flow rates that were slightly lower than those used in the FEMA study. The reduction in flows is due to the extensive wetland storage between Stevens Street and Farmington Avenue, which MMI accounted for in the modeling for this study. Flood storage in wetlands and waterbodies serves to attenuate flood flows, allowing for a more controlled release of water downstream.

Potential Future Storage

MMI evaluated three areas in the Coppermine Brook watershed where it may be possible to increase flood storage. The purpose of developing such storage is to reduce the peak flow rates downstream of the storage area during large rainfall events. Generally, such decrease in peak flow translates to a decrease in flood heights. The three areas evaluated included: 1) A wetland area in Nassahegan State Forest in the Negro Hill Brook watershed; 2) a wetland area upstream of Whigville Reservoir; and 3) excavated upland area to increase storage between Stevens Street and Maltby Street. Table ES-2 depicts the results of this analysis assuming that all three storage locations are implemented.

TABLE ES-2
Comparison of Existing and Proposed Conditions Peak Flows
– Combined Storage at Three Locations

Storm Frequency	Downstream Negro Hill Brook			Confluence of Pequabuck River		
	Existing	Proposed	% Change	Existing	Proposed	% Change
10	1,606	1,253	-22.0	1,737	1,553	-10.6
25	2,411	1,954	-19.0	2,679	2,376	-11.3
50	3,396	2,562	-24.6	3,362	3,139	-6.6
100	4,380	3,083	-29.6	4,606	3,597	-21.9

Changes in Flow from Watershed Development

In the interest of understanding the potential changes in flow that may occur in Coppermine Brook as development continues in the watershed, the City requested that MMI run the hydrologic model assuming that all property in the watershed is developed to its maximum capacity given the current zoning regulations of Bristol and Burlington. Table ES-3 presents the results of this analysis. Not surprisingly, future development within this watershed has the potential to increase peak flows significantly.

TABLE ES-3
Comparison of Existing and Future Conditions Peak Flows

Storm Frequency	Downstream Negro Hill Brook			Confluence of Pequabuck River		
	Existing	Future	% Change	Existing	Future	% Change
10	1,606	1,897	+18.1	1,737	2,050	+18.0
25	2,411	2,860	+18.6	2,679	3,032	+13.2
50	3,396	3,875	+14.1	3,362	3,639	+8.2
100	4,380	4,865	+11.1	4,606	5,589	+21.3

Future Flows at Watershed Build Out with Proposed Storage

The future build out model was modified to reflect the impact of providing additional storage in the watershed as described previously. Table ES-4 compares future flows with and without increased storage.

TABLE ES-4
Comparison of Future Conditions Peak Flows
With and Without Proposed Storage

Storm Frequency	Downstream Negro Hill Brook			Confluence of Pequabuck River		
	Future	Future with Storage	% Change	Future	Future with Storage	% Change
10	1,897	1,482	-22	2,050	1,761	-14
25	2,860	2,213	-23	3,032	2,679	-12
50	3,875	2,778	-28	3,639	3,351	-8
100	4,865	3,355	-31	5,589	3,988	-29

HYDRAULIC ANALYSIS

The term "hydraulic analysis" refers to the computational prediction of the river's water elevations, depths, and velocities for specified water discharge rates. This analysis is used to predict the elevation that floodwaters will reach given different river flows.

Hydraulic analysis is commonly performed using the Army Corps of Engineers (ACOE) HEC-RAS (River Analysis System) software. The FEMA model, upon which the City's Flood Insurance Study is based, was used as the basis for this effort. MMI then verified bridge dimensions and performed field survey of additional cross sections in the channel corridor. Following development of a current existing conditions model, MMI evaluated strategies to alleviate flooding in the flood prone areas along Coppermine Brook.

Stevens Street / Richards Court

The following potential improvements were identified and evaluated at this area:

- Removal of sediment from beneath Stevens Street Bridge.
- Repair of the berm upstream of Stevens Street at its current elevation.
- Replacement of the berm upstream of Stevens Street at an elevation that fully contains the 100-year flood.
- Removal of the berm upstream of Stevens Street and creation of a compound channel.
- Relocation of the berm farther from the channel.
- Combination of modifying channel downstream of Stevens Street, lowering the channel at the bridge, and relocating the berm further from channel

Each of these alternatives was evaluated using the existing conditions HEC-RAS model. Results of each of these are presented as follows. For all alternatives, sealing the existing drain pipe

under the earth berm at #72 Richards Court is essential. A flap gate could be used, but a pump station may be the ultimate solution.

Farmington Avenue

Based on input from residents and city staff, the area around Farmington Avenue was identified for evaluation. Farmington Avenue is a state highway with densely developed commercial properties surrounding the bridge. This structure was replaced by the Connecticut Department of Transportation in 2005. The existing conditions hydraulic analysis indicates that Farmington Avenue passes up to a 10-year storm event without overtopping. Under existing conditions, the model predicts that Farmington Avenue overtops by two to four feet for the storm events ranging from a 25-year to 100-year event. This cannot be corrected just by using a longer bridge.

Also affecting flooding in this area is a narrow private bridge that connects the Staples parking lot with the commercial property on the east bank of the river. This structure appears quite old and is narrow when compared to the upstream channel. Compounding the problem in this area is the fact that the channel is narrowing downstream of the large wetland floodplain area that exists at Maltby Road.

Further creating hydraulic restrictions here is the downstream channel. Recall from Section 2.3 that the channel downstream of this bridge is incising, which separates the channel from its floodplain. While incision is part of the natural progression of channel evolution, it does restrict the capacity of the channel.

The following alternatives were evaluated for this area:

- Removal of the Farmington Avenue Bridge.
- Removal of the undersized private bridge.
- Removal of Farmington Avenue and undersized private bridge.

It should be noted that numerous reports were provided by residents and city staff that flooding at Farmington Avenue is not solely the result of these structures. Many reports were provided that indicated water enters Mix Street north of Staples and then flows down Mix Street to the intersection at Farmington Avenue. This condition may occur because the channel constricts from the broad floodplain at the confluence of Polkville Brook to the narrow channel that is observed near Farmington Avenue. This constriction limits the amount of flow in the channel. The elevation of Mix Street is only slightly higher than the floodplain wetland in this area, allowing water to readily enter the street. Correcting this condition cannot be easily accomplished due to floodplain development.

Frederick Street

Frederick Street is located approximately 450 feet upstream of the confluence of Coppermine Brook with Pequabuck River. The existing bridge has a waterway opening width of 33 feet. Concrete parapet walls approximately 3.25 feet higher than the roadway elevation are located on

the upstream and downstream face of the crossing. There is a maximum of nine feet of clearance between the channel bed and the low chord of the structure at its upstream face, but part of the waterway is filled with sediment.

Upstream of the bridge Coppermine Brook is contained within an earthen berm on the right bank. On the left bank a vegetated sediment bar has developed and the channel makes two approximately 90 degree bends immediately before entry to the bridge. The earth channel below the Frederick Street crossing is trapezoidal in shape, and appears to have been significantly manipulated over time.

Critical elevations in the vicinity of this crossing are as follows:

- Low point of Frederick Street: 215.31 feet (NDVD 29).
- Roadway elevation at bridge: 217.98 feet (NGVD 29).
- Finished floor elevation at the house located on the right bank upstream of Frederick Street: 219.95 feet (NGVD29)
- Bottom of bridge beam: 214.48 feet (NGVD29)
- Dike Elevation: 217.00 to 217.98 feet (NGVD29)
- Pequabuck River 10-year: 212.20 feet (NGVD29)
- Pequabuck River 50year: 216.00 feet (NGVD29)
- Pequabuck River 100year: 216.40 feet (NGVD29)

The key elevations indicate that the yard at the house located on the right bank upstream of Frederick Street will be flooded from the Pequabuck River if Coppermine Brook was not present. It has been reported that Frederick Street crossing overtops during flood events due to inadequate hydraulic capacity of the bridge. This is the result of both tailwater flooding from the Pequabuck River as well as Coppermine Brook flows. Nuisance flooding occurs with water flowing across Frederick Street at its low point. Flooding has also occurred upstream of bridge, when the channel overtops behind Black Bear Auto and flows through the parking lot of that property and into Frederick Street, re-entering Coppermine Brook downstream of Frederick Street. The houses located on the right bank upstream of the crossing also reportedly experience flooding due to water overtopping the berm that bounds the brook.

The following alternatives were evaluated to relieve flooding at this location:

- Removal of Frederick Street crossing.
- Replacement of Frederick Street crossing with a structure capable of passing the 25-, 50- and 100-year storm events.
- Construction of a high overflow culvert on the right bank through the existing parking lot.
- Construction of a formal compound channel upstream of Frederick Street behind Black Bear Auto.
- Relocation of the channel behind Black Bear Auto to eliminate the meander.

Each of these alternatives was evaluated by modifying the existing conditions HEC-RAS model to reflect proposed changes discussed above. There has been much public comment about the influence of the Pequabuck River on flooding in this reach of Coppermine Brook. In order to more fully understand that influence, MMI performed one model run assuming the Pequabuck River had no influence on Coppermine Brook and compared it to runs that assumed the Pequabuck River had some influence. Based on this we believe that the Pequabuck River has some influence up the Frederick Street crossing, but limited influence upstream of it.

CONCLUSIONS AND RECOMMENDATIONS

The study completed by MMI included a comprehensive evaluation of watershed and stream corridor conditions along Coppermine Brook. The result of the analyses is recommendations that may reduce the severity of flooding in some locations; however, even if these improvements are made the fact remains that a number of issues contribute to the flooding problems that residents have been experiencing. These have been described in detail in the report but are summarized here:

1. Rainfall patterns in the northeast are changing, resulting in increasing streamflows. There has been widespread flooding in central Connecticut in recent years, including 1999, 2005 and 2006. These events were not unique to Coppermine Brook. Federal records also confirm a long term increase in stream flow throughout Connecticut.

2. Historic development has resulted in floodplain encroachment that cannot be easily mitigated. Much of this development pre-dates FEMA's Flood Insurance Program and certainly pre-dates the increasing rainfall patterns and stream flows discussed above.

3. The FEMA study is outdated and based on our analysis some properties should be identified within the floodplain that are currently not. These properties will not be eligible for federal flood insurance unless FEMA approves a floodplain modification.

4. Future land use build-out could theoretically increase peak flows by 10 to 20 percent, if unmitigated.

5. New Britain's Whigville Reservoir does not have any facilities that could be operated so as to suddenly cause a significant increase in stream flow rates. The source of the flood flow that was reported by residents could not be identified with certainty, but it is possible that the failure of weir boards in one or more of the three dams located upstream of Jerome Avenue contributed to this.

6. Some bridges along the channel corridor are undersized resulting in overtopping during some storm events. In some instances this is due to floodplain encroachment as much as it is undersized structures. For example, even if the Farmington Avenue bridge were removed, the roadway would still be flooded. The only solution evaluated that could correct this problem is increasing the size of this structure slightly in conjunction with

widening the channel upstream. Such widening would impact the existing land uses in the floodplain such as Staples.

It is absolutely critical that residents and town officials alike recognize that it will not be possible to stop all flooding of structures along Coppermine Brook. The recommendations herein are expected, however, to decrease the severity and frequency of flooding.

Based on the work completed we recommend the following:

1. **Pursue the construction of watershed storage areas.** The hydrologic analysis indicated that upstream storage could be very effective at reducing downstream flow rates. We recommend that the area identified between Maltby Street and Stevens Street be pursued first. This is because the area appears generally to be upland and state and federal regulators frown on the use of existing wetlands for flood storage. In other words, we think this will be the easiest area to obtain permits for construction. Design and permitting of this basin is expected to be on the order of $50,000 to $75,000 depending on the level of permitting required.

2. **Manage flooding at Richards Court through dike improvements, sealing the existing storm drain through the dike, and channel improvements downstream of Stevens Street Bridge**. The problems at Richards Court are caused by a number of issues. Regardless of the improvements that are made as a result of this study, the fact remains that this neighborhood sits atop what was once mapped as floodplain soils. The issues here are compounded by the fact that much of the improvements suggested are on private property. The exception is the downstream channel improvements, which would occur on property we believe to be owned by the City of New Britain. It is not clear what obligation the City has to repair to former dike, which is located on private property. Design and permitting of this work is expected to be on the order of $70,000 to $100,000 depending on the level of permitting required and the final solution selected for the drainage pipe at 72 Richards Court.

3. **Make improvements near Farmington Avenue.** Flooding at and upstream of Farmington Avenue is occurring because of floodplain construction and development, and high tailwater along the low gradient channel. Bridge improvements alone cannot solve flood hazards, but the combination of removing the private driveway bridge supplemented by channel improvements may provide some benefit. As with the improvements at Richards Court, both of these recommendations involve work on private property. Modification of the Farmington Avenue bridge is not suggested at this time as this is clearly not the responsibility of the City. That being said, once the upstream channel improvements suggested herein are completed, the City may choose to discuss Farmington Avenue with the DOT. Design and permitting of this work is expected to be on the order of $35,000 to $45,000 depending on the level of permitting required.

4. **Make improvements at Frederick Street**. The Frederick Street area is subject to flooding and erosion due to riverine sources, bridge construction, and Pequabuck River

backwater. Bridge and channel improvements could reduce the frequency of flooding, but long term hazards remain. At this point, given the age of this structure the most prudent alternative would be replacement of this bridge. It needs to be clear that this will not fully alleviate flooding at Frederick Street as the nearby residences are within the floodplain. Design and permitting of this work is expected to be on the order of $80,000 to $90,000 depending on the level of permitting required.